

MISSOURI

LIVESTOCK WATERING SYSTEM HANDBOOK

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MISSOURI LIVESTOCK WATERING SYSTEMS HANDBOOK

TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION

PART 1.1	PURPOSE AND OBJECTIVES	1-1
PART 1.2	GENERAL	1-1
PART 1.3	GLOSSARY	1-2
PART 1.4	CONVERSIONS AND ABBREVIATIONS	1-15

CHAPTER 2 PLANNING CONSIDERATIONS

PART 2.1	GENERAL	2-1
PART 2.2	PLANNING PROCEDURE	2-3
	2.2.1 Objectives	2-3
	2.2.2 Resource Inventory	2-3
	2.2.3 System Alternative	2-3
	2.2.5 Implementation	2-4
	2.2.6 Follow-up	2-4
PART 2.3	WATER QUANTITY REQUIREMENTS	2-4
PART 2.4	PIPELINE DELIVERY RATES	2-4
PART 2.5	WATER STORAGE REQUIREMENTS	2-5
PART 2.6	SOURCE OF WATER	2-6
	2.6.1 Springs	2-6
	2.6.2 Surface Source	2-7
	2.6.3 Well	2-7
	2.6.4 Rural Water	2-7
	2.6.5 Water Quality	2-7

CHAPTER 3 PIPELINE SYSTEM TYPES

PART 3.1	GENERAL	3-1
PART 3.2	GRAVITY SYSTEM	3-1
	3.2.1 Low Pressure Gravity System	3-1
	3.2.2 High Pressure Gravity System	3-3
PART 3.3	AUTOMATIC PRESSURE SYSTEM	3-3
PART 3.4	TIMED OR MANUAL PRESSURE SYSTEM	3-3
PART 3.5	FLOAT SWITCH OPERATED PRESSURE SYSTEM	3-3
PART 3.6	ALL YEAR VERSUS SUMMER PIPELINES	3-9
	3.6.1 Summer Pipeline	3-9
	3.6.2 All Year Pipeline	3-9

CHAPTER 4 PIPELINE ROUTE SELECTION AND SURVEYS

PART 4.1	ROUTE CONSIDERATIONS	4-1
PART 4.2	ROUTE SURVEYS--GENERAL	4-2
PART 4.3	ENGINEERING INSTRUMENT SURVEY	4-2
PART 4.4	USE OF USGS QUAD MAPS	4-2

MISSOURI LIVESTOCK WATERING SYSTEMS HANDBOOK

TABLE OF CONTENTS (continued)

CHAPTER 5 PIPE DESIGN

PART 5.1	GENERAL	5-1
PART 5.2	PLASTIC PIPE CHARACTERISTICS	5-1
	5.2.1 Pressure Rating Pipe	5-1
	5.2.2 How Temperature Affects Pressure Rating	5-2
	5.2.3 Freezing of Water In Pipe	5-3
PART 5.3	POLYVINYL CHLORIDE (PVC) PLASTIC PIPE	5-3
PART 5.4	POLYETHYLENE (PE) PLASTIC PIPE	5-4
PART 5.5	ACRYLONITRILE-BUTADINE-STYRENE (ABS) PLASTIC PIPE	5-5
PART 5.6	POLYBUTYLENE (PB) PLASTIC PIPE	5-5
PART 5.7	STEEL PIPE	5-5
PART 5.8	FRICITION LOSS IN PIPING SYSTEM AT THE PUMP	5-6
PART 5.9	PIPE FRICTION LOSS TABLES	5-9
PART 5.10	PCV PIPE FITTINGS	5-16

CHAPTER 6 PRESSURE AND SURGE CONTROL

PART 6.1	PIPELINE PRESSURE CONTROL	6-1
	6.1.1 Need for Pressure Control	6-1
	6.1.2 Pressure Reducing Valves	6-1
	6.1.3 Grade Break at Tank	6-4
PART 6.2	SURGE CONTROL	6-6
	6.2.1 Pressure Tank as Surge Chamber	6-6
	6.2.2 Minimize Frequency of Pump Cycle	6-7
	Flow Control Valve	6-9
	Flow Controlled Pressure Switch	6-9
	Pump Cycle Timer	6-9
	6.2.3 Install Air Valves	6-11
	6.2.4 Use Slow Closing Valves	6-11
	6.2.5 Control Flow Rate at Float Valve	6-11
	6.2.6 Operation Plan	6-11

CHAPTER 7 AIR CONTROL

PART 7.1	GENERAL	7-1
PART 7.2	AIR GAS/PROBLEMS	7-1
PART 7.3	AIR IN LOW HEAD GRAVITY PIPELINES	7-3
PART 7.4	AIR CONTROL IN HIGH HEAD, LONG PIPELINES	7-3
PART 7.5	HOW AIR VALVES WORK	7-8
PART 7.6	AIR VALVE INSTALLATION	7-12

MISSOURI LIVESTOCK WATERING SYSTEMS HANDBOOK

TABLE OF CONTENTS (continued)

CHAPTER 8 PIPELINE SYSTEM ACCESSORIES

PART	8.1	SPRING FED PIPELINE ENTRANCE	8-1
PART	8.2	WELLS AND SUMPS	8-5
PART	8.3	PUMPS	8-5
	8.3.1	Submersible Electric Pump, Jet, Turbine and Piston Pump. For Details see MWPS-14.	8-5
	8.3.2	Windmill	18-5
	8.3.3	Wind Generator Powered Pump	8-10
	8.3.4	Solar Powered Pump System	8-11
	8.3.5	Internal Combustion Engine Powered Pumps	8-14
	8.3.6	Hydraulic Rams	8-15
PART	8.4	PRESSURE TANKS	8-18
	8.4.1	Plain Pressure Tank	8-19
	8.4.2	Diaphragm-Type Tank	8-21
	8.4.3	Tank Pressure Rating	8-21
	8.4.4	For additional details for Pressure Tanks See MWPS-14.	8-21
PART	8.5	PRESSURE SWITCHES	8-32
	8.5.1	Switch Characteristics	8-32
	8.5.2	Pressure Gauges	8-32
PART	8.6	ELETRICAL PUMP CONTROL EQUIPMENT	8-33
	8.6.1	Automatic Water Level Control	8-33
	8.6.2	Remote Control Pump Float Switch	8-35
PART	8.7	STOCKWATER TANKS	8-37
	8.7.1	Tank Materials	8-37
		Concrete Tanks	8-37
		Fiberglass Tanks	8-43
		Plastic Tanks	8-43
		Galvanized Steel Tanks	8-45
	8.7.2	Water Inlet Protection including Float Valve	8-49
	8.7.3	Protection Around Tanks	8-53
	8.7.4	Tank Overflows	8-53
	8.7.5	Inlet to Pipeline from Tank	8-55
PART	8.8	STORAGE TANKS	8-56
PART	8.9	PIPELINE DRAINS	8-62

CHAPTER 9 SYSTEM DESIGN PROCEDURES

PART	9.1	GENERAL	9-1
PART	9.2	EXAMPLE 1, LOW PRESSURE GRAVITY SYSTEM	9-1
PART	9.3	EXAMPLE 2, PUMPED AUTOMATIC PRESSURE PIPELINE	9-5
	9.3.1	Pumped Automatic Pressure System Computations	9-5
	9.3.2	Lateral Computations	9-6
PART	9.4	EXAMPLE 3, TIMER OR MANUALLY OPERATED PRESSURE SYSTEM	9-11
	9.4.1	Timer or Manually Operated Pumped System Computations	9-11
	9.4.2	Gravity Line Computations	9-15
	9.4.3	Lateral Computations	9-16
PART	9.5	EXAMPLE 4, PRESSURE REDUCER	9-18

MISSOURI LIVESTOCK WATERING SYSTEMS HANDBOOK

TABLE OF CONTENTS (continued)

CHAPTER 10 PIPELINE INSTALLATION

PART 10.1 TRENCHING	10-1
10.1.1 Backhoe Constructed Trench	10-1
10.1.2 Trencher Constructed Trench	10-1
10.1.3 Backfilling and Maintenance	10-1
10.1.4 Road Crossings	10-2
10.1.5 Safety	10-2
PART 10.2 PIPE JOINTS	10-4
PART 10.3 INSPECTION DURING CONSTRUCTION	10-4
PART 10.4 MEASUREMENT FOR PAYMENT	10-4

CHAPTER 11 OPERATION, MAINTENANCE AND REPLACEMENT

PART 11.1 GENERAL	11-1
PART 11.2 WINTERIZING	11-1
PART 11.3 OPERATION AND MAINTENANCE PLAN	11-1
PART 11.4 REPLACEMENT	11-1

APPENDIX A WORKSHEETS

APPENDIX B COMPUTER PROGRAMS

APPENDIX C MATERIALS SOURCES

APPENDIX D PLANNING AND DESIGN GUIDE

APPENDIX E REFERENCES

Chapter 1

Introduction

CHAPTER 1 INTRODUCTION

TABLE OF CONTENTS

PART 1.1	PURPOSE AND OBJECTIVES	1-1
PART 1.2	GENERAL	1-1
PART 1.3	GLOSSARY	1-2
PART 1.4	CONVERSIONS AND ABBREVIATIONS	1-15

CHAPTER 1

INTRODUCTION

1.1 PURPOSE AND OBJECTIVES

The purpose of the Missouri Livestock Watering Systems Handbook is to provide Natural Resources Conservation Service (NRCS) personnel, and others where appropriate, with detailed technical information and procedures for planning, designing and managing of livestock watering systems.

Livestock watering systems are installed to (1) provide improvement in the beneficial use of pasture and rangeland by providing better distribution of livestock, (2) prevent loss of water by evaporation and seepage, (3) maintain and improve the plant growth and cover; and (4) prevent erosion resulting from overgrazing near water sources.

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

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

1.2 GENERAL

Livestock watering systems come in many configurations and sizes. They may vary from a short piece of pipe between a spring and stockwater tank, to many miles of pipeline with pressures at the low point as high as 500 psi. The design should ensure that the maximum pressure does not exceed the strength of the pipeline. A design may be as critical for a short pipeline as for a long one.

Consider what can happen if a pipeline fails. If there is little or no backup water available in a field and the problem is not discovered promptly, livestock will perish. During hot, dry weather a cow can only survive three or four days without water. Thirsty cows present a danger to people and property.

A livestock water system can be a great improvement over previously used watering systems. Stockwater ponds tend to dry up at the worst times and livestock become mired down in the mud. Windmills often do not work when they are needed and hauling water is a expensive, difficult, inefficient way of watering livestock. On the other hand, a livestock watering system 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 serve healthy animals.

Planning and design of a livestock watering system may be complex. These systems can be a significant investment. It is very important that they be correctly planned, designed and installed to be economical, functional and last for the planned life of the project. This handbook is dedicated to providing some of the information and tools needed to accomplish this job.

1.3 GLOSSARY

Acidity	A condition of water when the pH is below 7. See pH.
Alkalinity	A condition of water when the pH is above 7. See pH.
Air Gap	Separation of one water source from another by air to eliminate any chance of backflow.
Air lock	A blockage of water flow caused by trapped air.
Air Release Valve	A device in pipeline to release collected air.
Air-Vac-Air Release Valve (3 way)	Valve which releases air as well as allows air to enter a pipeline.
Aquifer	A water-saturated geologic unit or system that yields water to wells or springs at a sufficient rate that the wells or springs can serve as practical sources of water.
Artesian Well	(flowing and non-flowing) A well where the water rises above the surface of the water in the aquifer. It is a flowing artesian well if the water rises above the surface of the earth.
Automatic Pressure System	A system controlled by a pressure switch. A pressurized tank stores water between cut-in and cut-out pressure settings.
Back Pressure	A pressure that can cause water to backflow into the water supply when a user's water system is at a higher pressure than the source
Barometric Variations	Atmospheric pressure changes due to changes in weather and high or gusty winds.
Check Valve	A special valve with a hinged disc or flap that opens in the direction of normal flow and is forced shut when flows attempt to go in the reverse or opposite direction of normal flows.
Cistern	A non-pressurized tank (usually underground) for storing water.
Clearance Head	Certain vertical distance above the natural ground at which the hydraulic grade line passes.
Contamination	The introduction into water of microorganisms, chemicals, toxic substances, wastes, or wastewater in a concentration that makes the water unfit for its next intended use.

Coliform Bacteria	A group of bacteria present in fecal waste. If found in water, the water is likely unsafe to drink because of the possible presence of disease-causing bacteria.
Cone of Depression	As water approaches a well that is being pumped, the slope of the water table increases. As distance from the well increases, the slope becomes flatter until it merges with the water table level beyond the influence of the well. The water surface within the influence of a pumped well is an inverted cone with its apex in the well and its base in the static water table. This is known as the cone of depression.
Consolidation Formation	A naturally occurring geologic formation that has been lithified (turned to stone). The term is sometimes used interchangeably with the word "bedrock." It includes rocks such as basalt, rhyolite, sandstone, limestone, and shale. Commonly, this type of formation will stand at the edges of a bore hole without caving in.
Contamination	Introduction of any chemical, organic material, live organism, or radioactive material that will lower the quality of the natural ground water. Also included is the introduction of heated or cooled water into the ground water if the changing of the water temperature renders the water less usable.
Contaminated Water	Water that contains a disease-causing toxic substance.
Cross Connection	A link or channel between pipes carrying contaminated water and pipes carrying potable water. Contaminated water, if at higher pressure, enters the potable water system.
Design Factor (DF)	The multiplier that is used to reduce the hydrostatic design basis to arrive at the hydrostatic design stress, from which the pressure class is calculated. Unless otherwise noted, the design factor used in this standard is 0.5. NOTE: Because the strength of PE materials depends on the duration of loading, the effective safety factor based on a design factor of 0.5 will vary with end-use conditions. For the PE materials covered in this standard, when subjected to loading at maximum system working pressure and service temperature, the effective safety factor ranges from 3 or more for short-term loading to 2 for long-term loading.
Dimension Ratio (DR)	The ratio of the specified average inside diameter to the specified minimum wall thickness.
Drawdown	The vertical distance the water level drops in a well pumped at a given rate.
Delivery Rate	The rate at which a quantity of water is delivered in a certain time period to a given location.

Design Water Surface Elevation (hydraulic grade line)	The line showing the pressure head, or piezometric head, at any point in the pipe.
Diaphragm-Type Tank	A flexible diaphragm separating air and water in the tank. This type of tank may be buried.
Elongation	Extension or lengthening of a pipe.
Encrustation	A mineral scale chemically or physically deposited on wetted surfaces, such as well screens, gravel packs, and in tea kettles.
Energy Grade Line (EGL)	A line that represents the elevation of energy head (in feet) of water flowing in a pipe, conduit, or channel. The line is drawn above the hydraulic grade line (gradient) a distance equal to the velocity head ($V^2/2g$) of the water flowing at each section or point along the pipe or channel. Also see HYDRAULIC GRADE LINE.
Evaporation	The loss of water from an area into the atmosphere.
Flexible Plastic Pipeline	Material, which comes in coils, is used for most “pull-in” type systems. Polyethylene (PE) pipe is a commonly used material.
Float Switch Operated System	A pumped pipeline system in which the pump is turned on or off with a float switch located at the highest tank in the system.
Float Valve Box	A small tank with a float valve strictly used for pressure regulation.
Flow Rate	The quantity of water available and/or needed per minute, per hour, or per day to satisfy the requirements of people, livestock, and water fixtures.
Flushing	A method used to clean water distribution lines. Hydrants are opened and water with a high velocity flows through the pipes, removes deposits from the pipe, and flows out the hydrants.
Friction Losses	The head, pressure or energy (they are the same) lost by water flowing in a pipe or channel as a result of turbulence caused by the velocity of the flowing water and the roughness of the pipe, channel walls, and restrictions caused by fittings. Water flowing in a pipe loses pressure or energy as a result of friction losses. Also see HEAD LOSS.
Frost Depth	The maximum depth at which soil material will freeze.

Frost Proof Concrete Tank	A tank that is predominantly buried with insulating earth cover and stores livestock water that seldom freezes.
Gage Pressure	The pressure within a closed container or pipe as measured by a gage. In contrast, absolute pressure is the sum of atmospheric pressure (14.7 lbs/sq in) PLUS pressure within a vessel (as measured by a gage). Most pressure gages read in “gage pressure” or psig (p ounds per square inch g age pressure).
Grains Per Gallon	The weight of a substance, in grains, in a gallon. Commonly, grains of minerals per gallon of water as a measure of water hardness.
Gravel Pack or Filter	A gravel envelope surrounding the well screen, designed to prevent sand from entering the well.
Gravity Pipeline System	A watering system in which the water supply is higher than all points in the pipeline and no pump is required.
Ground Water	Water that has filtered down to a saturated geologic formation beneath the earth’s surface.
Hardness Minerals	Minerals dissolved in water that increase the scaling properties and decrease cleansing action--usually calcium, iron, and magnesium.
Hazen - Williams Formula	A formula widely used for computing pipe flow in waterworks design. It is an empirical equation based in laboratory and field observations.
HDPE - High Density Polyethylene Pipe	Tougher high density polyethylene plastic material, able to be used for above ground installations.
Head	The vertical distance (in feet) equal to the pressure (in psi) at a specific point. The pressure head is equal to the pressure in psi times 2.31 ft/psi.
Head	A measure of water pressure, in feet of water or pounds per square inch (psi). 1 psi = 2.31 ft of water.
Head Loss	The head, pressure or energy (they are the same) lost by water flowing in a pipe or channel as a result of turbulence caused by the velocity of the flowing water and the roughness of the pipe, channel walls, or restrictions caused by fittings. Water flowing in a pipe loses head, pressure, or energy as a result of friction losses. Also see FRICTION LOSSES.
High Head Gravity System	This system is often located at the end of a pumped pipeline, starting at a storage tank at the top of the hill. for drawing water from a water source.

Hydraulic Grade Line (HGL)	The surface or profile of water flowing in an open channel or a pipe flowing partially full. If a pipe is under pressure, the hydraulic grade line is at the level water would rise to in a small vertical tube connected to the pipe. Also see ENERGY GRADE LINE.
Hydraulic Gradient	The slope of the hydraulic grade line. This is the slope of the water surface in an open channel, the slope of the water surface on the groundwater table, or the slope of the water pressure for pipes under pressure.
Hydraulic Ram	A water pump in which the downward flow of naturally running water is intermittently stopped by a valve so that the flow is forced upward through an open pipe into a reservoir.
Hydrostatic Design Basis (HDB)	The categorized long-term hydrostatic strength in the circumferential or hoop direction as established from long-term pressure tests performed in accordance with ASTM D2837.
Hydrostatic Design Stress (HDS)	The maximum allowable working hoop stress in the pipe wall when the pipe is subjected to sustained long-term hydrostatic pressure. For use in this standard, the hydrostatic design stress is determined by multiplying the hydrostatic design basis by a design factor.
Hydrostatic Pressure	(1) The pressure at a specific elevation exerted by a body of water at rest, or (2) In the case of groundwater, the pressure at a specific elevation due to the weight of water at higher levels in the same zone of saturation.
Inside Dimension Ratio (IDR)	The ratio of the specified average inside diameter to the minimum wall thickness. The ratio shall be rounded off, when necessary, to the nearest 0.5 or 0.1, whichever is applicable.
Inspection Riser	A vertical pipe through which observations can be made, as to the condition and functioning of a closed conduit.
Inspector	The authorized representative of the purchaser, who is entrusted with the inspection of products and production records, and the observance of production operations and quality-control tests to ensure that products comply with the requirements of this standard and the purchaser.
Intermediate Storage	A holding tank included in a water system when the water source does not supply the peak use rate.
Internal Combustion Engine Powered Pump	A pump that employs a piston-type engine that uses a combustion process occurring at constant volume, at constant pressure, or by a combination of both.
Internal Friction	Friction within a fluid (water) due to cohesive forces.

Jet (or ejector) Pump	A pump, usually centrifugal type, with a jet or ejector assembly. It has few moving parts and both shallow-well and deep-well jets can be offset from the well. It can provide high capacity at low heads.
Kinetic Energy	Energy possessed by a moving body of matter, such as water, as a result of its motion.
Langelier Index	An index reflecting the equilibrium pH of a water with respect to calcium and alkalinity. This index is used in stabilizing water to control both corrosion and the deposition scale. Langelier Index = $\text{pH} - \text{pH}_s$.
License	A certification, required by the State government, of a person or firm engaged in well drilling.
Lift (L)	The vertical distance from the water level in the well during pumping to the ground surface or some other specified point such as the center of the discharge pipe.
Low Pressure Gravity System	A system designed with line pressure below 15 psi at all points in the line. The flow rate is usually whatever the water source will provide.
Manning's Roughness Coefficient	A roughness factor along a flow path. It is a function of Reynolds number, Weber number, and relative roughness.
Manual or Timer Operated System	System where high pressures make it impractical to use an automatic pressure system.
Measuring Wheel	A device having a circular wheel and a counter, used to determine distances between points.
Milligrams Per Liter (mg/l)	The weight of a substance, in milligrams in a liter. 1 mg/l = 1 oz. per 7500 gallons. It is equivalent to ppm; see Parts per Million.
Mineralized Water	Any naturally occurring ground water that has a high chemical content.
Neutrality	A condition of water when the pH is at 7. See pH.
Operation, Maintenance, and Replacement (O,M, &R)	The processes of properly using, maintaining, and replacing components of conservation practices.
Orifice	An opening (hole) in a plate, wall, or partition. An orifice flange or plate placed in a pipe consists of a slot or a calibrated circular hole smaller than the pipe diameter. The difference in pressure in the pipe above and at the orifice may be used to determine the flow in the pipe.
Oxidation	A chemical reaction between a substance and oxygen.

Palatable Water	Water of acceptable taste. May also include non-offensive appearance and odor.
Parts Per Million (ppm)	A measure of concentration; one unit of weight or volume of one material dispersed in one million units of another; e.g., chlorine in water, carbon monoxide in air. Equivalents to indicate small size of this unit: 1 ppm = 1 oz. per 7500 gallons; 1 kernel of corn in 13 bushels; 6 1/4 sq. in. in an acre.
Peak Use Rate	The flow rate necessary to meet the expected maximum water demand in the system.
PE Pipe	Plastic pipe based on polymers made with ethylene as essentially the sole monomer.
pH	Actual measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity.
pH	A measure of the acidity or alkalinity of water. Below 7 is acid, above 7 is alkaline.
pHs	pH at which water having the same alkalinity and calcium content is just saturated with calcium carbonate.
Pipe Friction Loss	The loss of energy or head resulting from turbulence created at the boundary between the sides of the conduit and flowing water.
Pipe Joints	The fabricated connection between pipe lengths; this is a watertight junction.
Pipeline	A conduit or pipe used for conveying water.
Pipeline Drains	A controlled outlet at all low spots in pipelines that are subject to freezing.
Piston Pump well	A double-acting piston pump that sucks water from the [water source] during both strokes and forces the water out the pressure side.
Plain Pressure Tank	In a plain pressure tank, air can be lost over time. There is no diaphragm or barrier between compressed air and water.
Plastic Pipe	A hollow cylinder of a plastic material in which the wall thickness are usually small when compared to the diameter and in which the inside and outside walls are essentially concentric.
Polluted Water	Water containing a natural or man-made impurity.

Pollution	The impairment (reduction) of water quality by agricultural, domestic, or industrial wastes (including thermal and radioactive wastes), to a degree that has an adverse effect on any beneficial use of water.
Polyethylene Plastic	Thermoplastic extrusion material prepared by polymerization of no less than 85 percent ethylene and no less than 95 percent of the total olefins by weight, plus the addition of compounding ingredients.
Potable Water	Water safe for drinking.
Pressure Class (PC)	The design capacity to resist working pressure at 73.4 degrees Fahrenheit (23 degree Celsius) maximum service temperature with an allowance for surge pressure. The following expressions, commonly known as the ISO equations, * are used to calculate pressure class: For OD-based pipe or tubing: $PC = \frac{2}{DR-1} \times HDB \times DF$
Pressure Control	A method of influencing or stabilizing the pressure at a certain point in a system.
Pressure Head	The vertical distance (in feet) equal to the pressure (in psi) at a specific point. The pressure head is equal to the pressure in psi times 2.31 ft/psi.
Pressure Gauge	A device for measuring fluid pressure.
Pressure Rating	The maximum rating at which a component is able to perform in a system.
Pressure Switches	They are designed for certain pressure ranges and electrical services.
Pressure System	Systems in which pressure is in excess of atmospheric pressure.
Pressure Tank	An enclosed pneumatic tank in which air can be compressed but water cannot.
Pressure Test	A test in which current pressure can be estimated anywhere in a system.
PSIG	Pounds per Square Inch Gage pressure. The pressure with a closed container or pipe measured with a gage in pounds per square inch. See GAGE PRESSURE.
Pump Cycle	Period of time, between switch-on and switch-off controls, that a pump operates.
Pump Cycle Timer	A device used to control the pump cycle.

Pumping Level (h)	Static head or depth of water in well while pumping
Pumping Water Level	The vertical distance in feet from the centerline of the pump discharge to the level of the free pool while water is being drawn from the pool.
PVC pipe	Polyvinyl chloride is a commonly used type of pipe used for stockwater pipelines. This is a rigid plastic pipe which usually comes in 20-foot lengths.
Quadrangle Map	The land area shown on one atlas sheet charted by the U. S. Geological Survey.
Reserve Storage	A volume of reserve water used in the system in the event of a water shortage.
Route Survey	A topographic measurement to determine relative differences in elevation between points, some distance apart.
Rubber Gasket Joint	A joint connection with a circular rubber liner, to aid in maintaining watertightness.
Saline Water	Water containing mineral salt.
Salinity	(1) The relative concentration of dissolved salts, usually sodium chloride, in a given water. (2) A measure of the concentration of dissolved mineral substances in water.
Saturation	The condition of water when if it has taken into solution the maximum possible quantity of a given substance at a given temperature and pressure.
Schedule (Pipe) SDR-PR	Standard Dimension Ratio - Pressure Rated pipe. It is a PVC pipe material.
Seepage	The process of a fluid slowly passing through small openings or pores.
Shut Off Valve	A pipeline valve with which flow can be interrupted.
Solar Powered Pump System	A pumping system employing solar panels containing photovoltaic cells to convert sunshine into electrical energy to power 12, 24, or 36 volt water pumps.
Softening	The process of removing hardness caused by calcium and magnesium minerals
Spring	A place on the earth's surface where ground water emerges naturally.
Spring Box	A formed box located near a naturally occurring spring. Box is used to control outflow for desired use.

Standard Dimension Ratio (SDR)	The ratio of the specified average outside diameter to the specified minimum wall thickness. This ratio is common to all pipe sizes of a specific standard dimension ratio series.
Static Water Table	The surface level of the ground water at the top of the saturated zone in a water-bearing formation.
Steel Pipe	An enclosed conduit made of strong durable material.
Stockwater Tank	An enclosed container used to store water for livestock consumption.
Static Head	When water is not moving, the vertical distance (in feet) from a specific point to the water surface is the static head. (The static pressure in psi is the static head in feet times 0.433 psi/ft.) Also see DYNAMIC PRESSURE and STATIC PRESSURE.
Static Pressure	When water is not moving, the vertical distance (in feet) from a specific point to the water surface is the static head. The static pressure in psi is the static head in feet times 0.433 psi/ft. Also see DYNAMIC PRESSURE and STATIC HEAD.
Static Water Depth pump	The vertical distance in feet from the centerline of the discharge down to the surface level of the free pool while no water is being drawn from the pool or water table.
Static Water Level	(1) The elevation or level of the water table in a well when the pump is not operating. (2) The level or elevation to which water rises in a tube connected to an artesian aquifer, or basin, or conduit under pressure.
Submersible Electric Pump	A electric powered pump that operates below the waterlevel. It produces a smooth, even flow.
Suction Lift	The NEGATIVE pressure (in feet of water or inches of mercury vacuum) on the suction side of the pump. The pressure can be measured from the centerline of the pump DOWN TO (lift) the elevation of the hydraulic grade line on the suction side of the pump.
Sump	A hole at the lowest point of an appurtenance in a pipeline into which water is drained in order to be pumped out.
Sun Exposure	Radiation energy that may affect the characteristics of processed material, i.e. plastic, fiberglass, other materials.
Sure Pressure	The maximum positive transient pressure increase (commonly called water hammer) that is anticipated in the system as the result of a change in velocity of the water column.

Surge Chamber (control tank)	A chamber or tank connected to a pipe and located at or near a valve that may quickly open or close or a pump that may suddenly start or stop. When the flow of water in a pipe starts or stops quickly, the surge chamber allows water to flow into or out of the pipe and minimize any sudden positive or negative pressure waves or surges in the pipe.
Surging	Forcing water back and forth rapidly and with more than normal force in a well or other part of the water system.
Tank Pressure Rating	Maximum pressure that a tank will safely hold.
Timed or Manual Pressure System used	A pipeline system in which a pump is used to pressurize the system and a timer to turn the pump on or off. It is where high pressures make it impractical to use an automatic pressure system.
Total Dynamic Head line	When a pump is lifting or pumping water, the vertical distance (in feet) from the elevation of the energy grade line on the suction side of the pump to the elevation of the energy grade line on the discharge side of the pump.
Trenching	The process of excavating a long, narrow ditch embanked with its own soil and used for protecting an encased pipeline.
Trough	A long, narrow, generally shallow receptacle, especially one for holding water for animals.
Turbine Booster Pump	Pump with internal parts similar to a submersible pump. It can be used to boost pressure from sources such as domestic water supplies and storage tanks.
Ultraviolet Radiation	Of or relating to the range of radiation wavelengths from approximately 4,000 angstroms, just beyond the violet in the visible spectrum, to approximately 40 angstroms, on the border of the x-ray region.
Vacuum Relief	The ability to allow air to enter a pipeline, thus eliminating a vacuum situation.
Velocity Head	The energy in flowing water as determined by a vertical height (in feet) equal to the square of the velocity of flowing water divided by twice the acceleration due to gravity ($V^2/2g$).
Vented Cap	Cap is assembled with capability to allow air release.
Water Bars	A small diversion dike constructed across the trench locations where the trench is traveling up or down the slope. Normally 1 to 3 feet high from bottom of channel to top of ridge.

Water Bearing Zone	A depth of ground below surface that has the potential to provide water.
Water Distribution System	The distribution of water from a source to the locations where it can be used (includes pipeline, valves, vents, and other related appurtenances).
Water Hammer	The sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can cause serious damage to the system.
Water Storage	A contained area used to store a volume of water for later use.
Water Table Well	A well where the water level is at the surface of the aquifer.
Water Treatment	A process to improve the quality of water.
Water Well	A man-made hole in the earth from which ground water is removed.
Weber Number	A dimensional ratio of the internal force to the surface tension force.
Wind Generator Powered Pump	Wind generators can be used to power low volume pumps. The generators may be more reliable than windmills because there are less mechanical components.
Windmill	A mill or other machine powered by a wheel of adjustable blades or slats rotated by the wind.
Winterizing	To equip or prepare for cold freezing weather.
.Well Casing	A rigid pipe installed in the well to prevent the walls from sloughing into the well.
Well Development	A process to increase or maintain the yield of a well.
Well Driller	Any person who excavates, develops, or opens a well.
Well Drilling	The act of constructing a new well or deepening or modifying an existing well.
Well Drilling Report	A written report concerning the log of a well.
Well Rig	Any power-driven percussion, rotary, boring, digging, jetting, or auguring machine used in the construction and development of a well.
Well Screen	A perforated or slotted section of pipe or screen used to separate the well water from the surrounding aquifer.

Well Stabilizer

Material or grout placed around the outside of the well casing to hold it in place.

Working Pressure

The maximum anticipated sustained operating pressure, in pounds per square inch gauge, applied to the pipe, exclusive of surge pressures.

1.4 CONVERSIONS AND ABBREVIATIONS**CONVERSIONS**

<u>To Convert From</u>	<u>To</u>	<u>Multiply By</u>
Acres	Square Feet	43,560
Acres	Square yards	4,840
Acre Feet	Gallons	325,851
Cubic Feet	Gallons	7.48
Cubic Feet	Cubic Inches	1,728
Head (Feet of Water)	Pressure	0.434
Gallons	Cubic Inches	231
Gallons	Cubic Feet	0.133
Gallons	Pounds of Water	8.33
Gallons	Liters	3.785
Gallons Per Minute	Gallons Per Hour	60
Milligrams Per Liter	Parts Per Million	1
Milligrams Per Liter	Grains Per Gallon	17.1
Parts Per Million	Pounds Per Gallon	8.35×10^{-6}
Pressure (Pounds Per Square Inch)	Head (Feet of Water)	2.31

ABBREVIATIONS

ac-ft	acre-feet
in	inches
ft	feet
gal	gallons
gpm	gallons per minute
gpd	gallons per day
gph	gallons per hour
gpg	grains per gallon
mg/l	milligrams per liter
ppm	parts per million
psi	pound per square inch

Chapter 2

Planning Considerations

CHAPTER 2 PLANNING CONSIDERATIONS

TABLE OF CONTENTS

PART	2.1 GENERAL	2-1
PART	2.2 PLANNING PROCEDURE	2-3
	2.2.1 Objectives	2-3
	2.2.2 Resource Inventory	2-3
	2.2.3 System Alternative	2-3
	2.2.4 Landuser decisions	2-4
	2.2.5 Implementation	2-4
	2.2.6 Follow-up	2-4
PART	2.3 WATER QUANTITY REQUIREMENTS	2-4
PART	2.4 PIPELINE DELIVERY RATES	2-4
PART	2.5 WATER STORAGE REQUIREMENTS	2-5
PART	2.6 SOURCE OF WATER	2-6
	2.6.1 Springs	2-6
	2.6.2 Surface Source	2-7
	2.6.3 Well	2-7
	2.6.4 Rural Water	2-7
	2.6.5 Water Quality	2-7

FIGURES

Figure	2.1 Stockwater Pipeline Planning Procedure	2-2
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TABLES

Table	2.1 Use of Saline Water for Livestock	2-8
Table	2.2 Effects of Nitrates on Livestock	2-8

CHAPTER 2

PLANNING CONSIDERATIONS

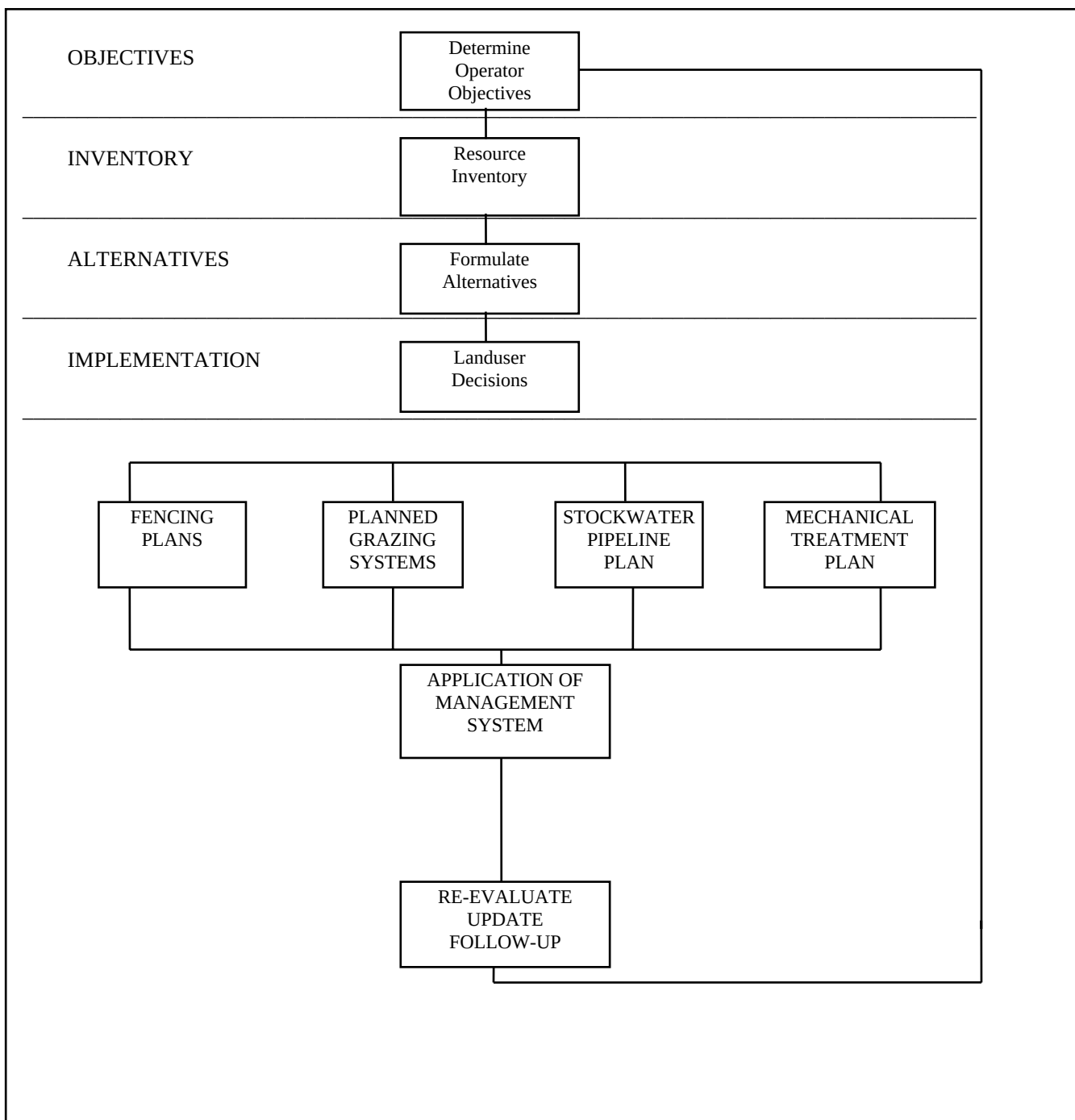
2.1 GENERAL

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 livestock watering systems. The planning processes must be followed, even when NRCS is involved with a system where the landowner knows exactly what is wanted and NRCS is 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 needs of the cooperator
- System that cannot later be expanded
- System that requires excess maintenance
- 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. Do they want a more dependable supply of water, better grazing distribution, better water, or what? NRCS needs to remember the involvement and objectives. These are to maintain the resource base, to maintain quality in the standard of living and to maintain or enhance the environment. This is accomplished by aiding the landuser in the development of a Resource Management System (RMS). These objectives should be clearly in mind before starting 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 pasture use patterns, pasture 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.

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 and

spring developments 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

It is important 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 time and money.

2.2.5 Implementation

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

2.2.6 Follow-up

Stockwater systems can be complex and may sometimes experience problems. NRCS must be constantly alert for problems such as water hammer, freezing pipes, erosion, low flows and improperly functioning valves so that the problem can be corrected and avoided in future jobs. This means that NRCS must maintain contact with the landowner and re-visit at least some of the systems after being operated for a period of time.

2.3 WATER QUANTITY REQUIREMENTS

Design the system to deliver and or store enough water to meet peak demand i.e. summer time drinking for the projected numbers of animals. Peak demand is defined as 30 gallons per day (at 90 degrees F) per 1000 lbs. liveweight. Exceptions to this design criterion are pipelines feeding limited access tanks where gallons per minute becomes the design criterion of choice (see section 2.4) and pasture (animal operated) pumps where the animal access (number of head per appliance) becomes the limiting parameter (see section 2.5)

Animal consumption rate figures vary widely among the information resources available on the subject. The above figure volume will adequately water dairy cows to chickens; animals in confinement, to intensively managed grazing systems to open range foraging.

2.4 Pipeline Delivery Rates

Water delivery requirements will vary depending on the water source available, how it is conveyed to a tank from which the animal will access the water, and how much storage capacity is designed into the system. The previous information will address the following situations:

1. Pumped pressure systems and gravity forced systems from ponds and high flow springs with delivery to open tanks.
2. Pumped pressure systems and gravity forced systems from ponds and high flow springs delivering water to limited access waterers, e.g. barrel tanks, "freeze proof" tanks.

Pipelines under pressure from a pump or gravity forced lines from a pond or high flow springs feeding open water tanks should be sized to provide the peak demand for the herd in 12 hours.

Pipeline in pumped pressure systems and gravity forced systems from ponds and high flow springs delivering water to limited access waterers should be sized for rapid recharge due to the limited reservoir capacity. Multiply the number of the herd that can access the tank times 2 gallons per minute. Future expansion of herd size should be considered in designing the system. Reference the University of Missouri, “Missouri Grazing Manual” which states that cattle will drink at a rate of 2 gallons per minute for 4 minutes per drink and will come to water 5-7 times per day depending on the distance traveled to water.

2.5 WATER STORAGE REQUIREMENTS

Where source flow volume or the delivery system is too low to meet criteria noted in the preceding two sections storage must be designed into the system to provide for peak herd demand. The following situation(s) are addressed in this section:

1. Low source flow volume or low delivery flow systems such as low flow springs, hydraulic rams, and windmills.
2. Pasture pumps
3. Sizing water tanks for animal access and water storage volume
4. Backup storage

In low source flow volume or low delivery flow systems such as low flow springs, hydraulic rams, and windmills the water tanks should be sized to store 30 gallons per 1000 pounds live weight minus the flow or delivery volume in the system (gallons per day) times the average grazing period (number of days). These systems will only water a limited number of animal units.

Backup storage volume of 1-3 days of the herd requirement should be considered in the event water supply, power, pump, or pipeline failure where ponds, springs, creeks, or hauled water are not available or not feasible.

There are several considerations for sizing water tanks where delivery or flow are not limited by the water source or delivery system. These are: distance animals must travel to water, access space at the tank, time of year the tank will be in service, and animal traffic patterns to get to tank and loitering time (animal traffic damage) at the watering point.

Generally animals won't die if a tank is not sized according to the following suggestions but time to water the herd, hoof damage and loitering time (manure deposition) at the watering point will be affected. Both access space (tank perimeter) and storage volume should be considered.

Distance animals have to travel to get to water affects herd behavior as related to the social event of going to the water hole and the amount of water consumed. According to cow psychologists, cattle go to water less frequently and go as a herd or large grazing groups if water is farther than 800 feet from the pasture. If water is closer animals tend to go to water more often and as singles, pairs, or small groups (especially in flat or gently rolling terrain

where they can keep sight of their buddies. The exception to this rule is yearling cattle new to the farm. Producers receiving new lots of cattle frequently should size the tanks as if water was far from the pastures. These young cattle will graze and water as a herd or large grazing groups despite the proximity to water.

If distance to water is greater than 800 feet, size the tank volume for $\frac{1}{3}$ of the daily herd requirement. The thought process is that the herd will go to water in small groups (herd number divided by 10) and will water more frequently (5 times per day).

If water is close, size the tank for $\frac{1}{50}$ of the herd requirement. The thought process is that cattle will make 5 trips to water in small groups.

Estimate access space by multiplying $\frac{1}{3}$ or $\frac{1}{10}$ of the herd number, depending on proximity of water to the pastures, by 15 inches. Then check to see that the circumference or perimeter of the tank needed to provide the volume of water also has enough access space. Usually it does, but in some cases where high numbers of stockier cattle were being grazed access space became the determining factor in sizing the tank.

The design delivery rate should be the maximum available or maximum required whichever is less. The tank size should be made bigger for low delivery systems. History has shown that oversized tanks work well with few problems.

Livestock tank capacities are shown in Chapter 8 and Appendix C. Access makes the energy free, freeze proof, (including concrete bunkers often embedded in the backslope of ponds), limited access tanks less desirable if they are used in grazing cells that will be used in the summer.

Pasture pumps can be a very effective method for watering livestock. If this system is used the design criteria is to divide the number of head by 30 to determine the number of appliance needed. Claims of number of animals served per unit varies from manufacturer to manufacturer.

2.6 SOURCE OF WATER

Water should be tested for adequate quality. Contaminates such as iron or sand will clog pipelines. Sulfur waters are corrosive and have a bad odor.

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 Rural Water

Rural water is a reliable source of water with which to supply livestock. Pipeline flow rates for systems fed by rural water pressure should be designed using the criteria described in Section 2.4. Backflow valves shall be used to prevent contamination of the rural water supply. In most cases rural water districts require an air gap because backflow valves are not safe enough.

2.6.5 Water Quality

The most common factors to consider are salinity and nitrates. Tables 2.1 and 2.2 describe tolerable levels of these elements..

Table 2.1
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 2.2
EFFECTS OF NITRATES ON LIVESTOCK

Nitrate Concentration (mg/l NO ₃ 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 losses, secondary diseases
195 up	Acute losses.

Chapter 3

Pipeline System Types

CHAPTER 3 PIPELINE SYSTEM TYPES

TABLE OF CONTENTS

PART	3.1	GENERAL	3-1
PART	3.2	GRAVITY SYSTEM	3-1
	3.2.1	Low Pressure Gravity System	3-1
	3.2.2	High Pressure Gravity System	3-3
PART	3.3	AUTOMATIC PRESSURE SYSTEM	3-3
PART	3.4	TIMED OR MANUAL PRESSURE SYSTEM	3-3
PART	3.5	FLOAT SWITCH OPERATED PRESSURE SYSTEM	3-3
PART	3.6	ALL YEAR VERSUS SUMMER PIPELINES	3-8
	3.6.1	Summer Pipeline	3-8
	3.6.2	All Year Pipeline	3-8

FIGURES

Figure	3.1	Typical Pressure Head Gravity System	3-2
Figure	3.2	Typical Pressure Head Gravity System	3-4
Figure	3.3	Typical Automatic Pressure System	3-5
Figure	3.4	Typical Manual or Timer Operated System	3-6
Figure	3.5	Typical Float Switch Operated System	3-7
Figure	3.6	Frost Depths in Missouri	3-10

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 SYSTEM

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 pressure gravity system and (2) the high pressure gravity system.

3.2.1 Low Pressure Gravity System

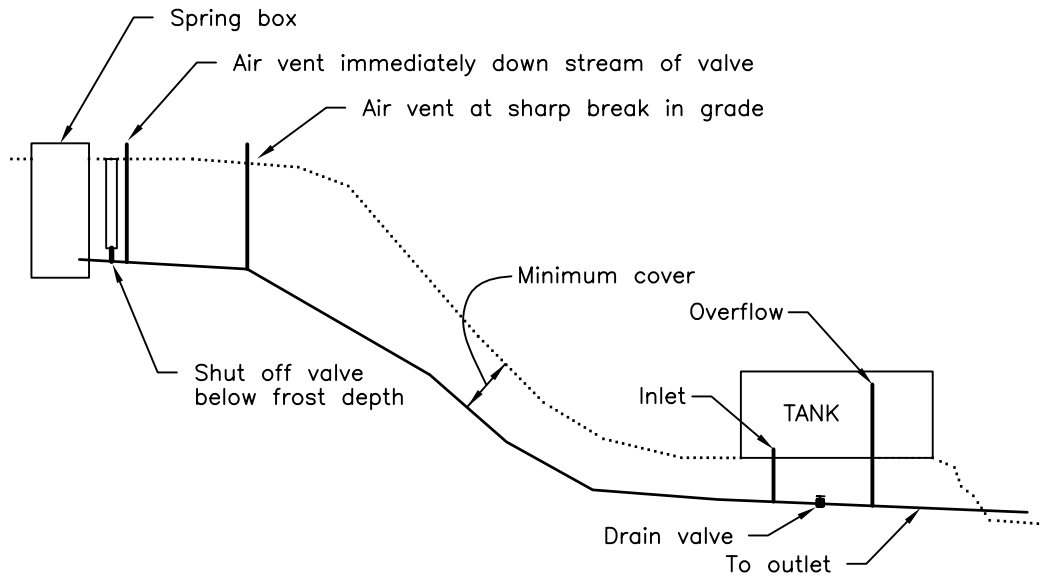
Low pressure is loosely defined as below 15 psi at all points in the line. An example of a typical low head gravity pipeline is shown in Figure 3.1. In this type of system the flow rate is usually whatever the spring or other water supply will provide.

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 pressure 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 pipe vents may be used.**

3.2.2 High Pressure Gravity System

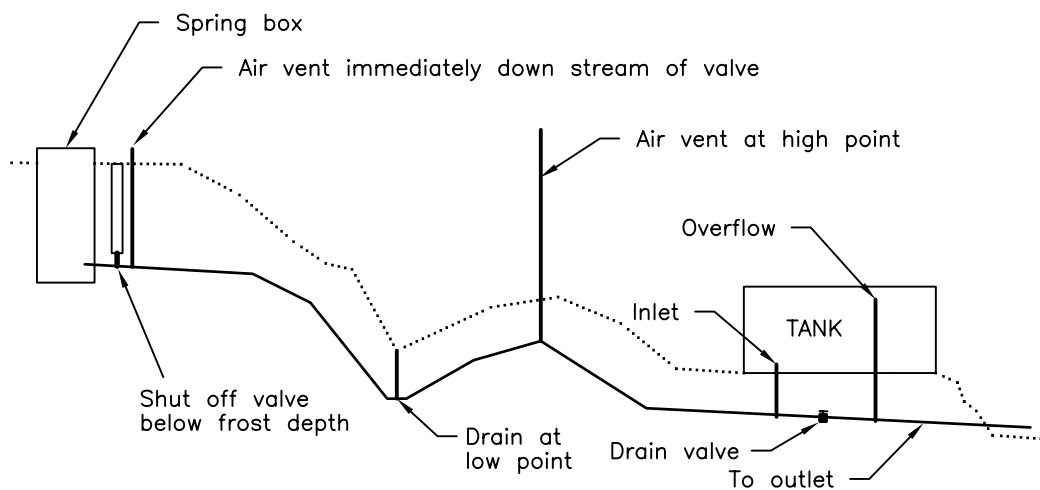
Figure 3.2 illustrates a typical high pressure gravity system. This type of system is often located at the end of a pumped pipeline, starting at a storage tank at the top of a hill. Float valves are used on all tanks to control flow. Air locks at significant high points in the pipeline are prevented by installing air valves or vents. Air valves will not work if pressure is too low.

Figure 3.1
TYPICAL LOW PRESSURE GRAVITY SYSTEM



System With Downhill Grade in Direction of Flow

Note:
There is not enough pressure to operate an air valve so air vent standpipes are used.



System With Undulating Grade

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 pressures. Chapter 8 shows this in more detail. 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 PRESSURE GRAVITY SYSTEM

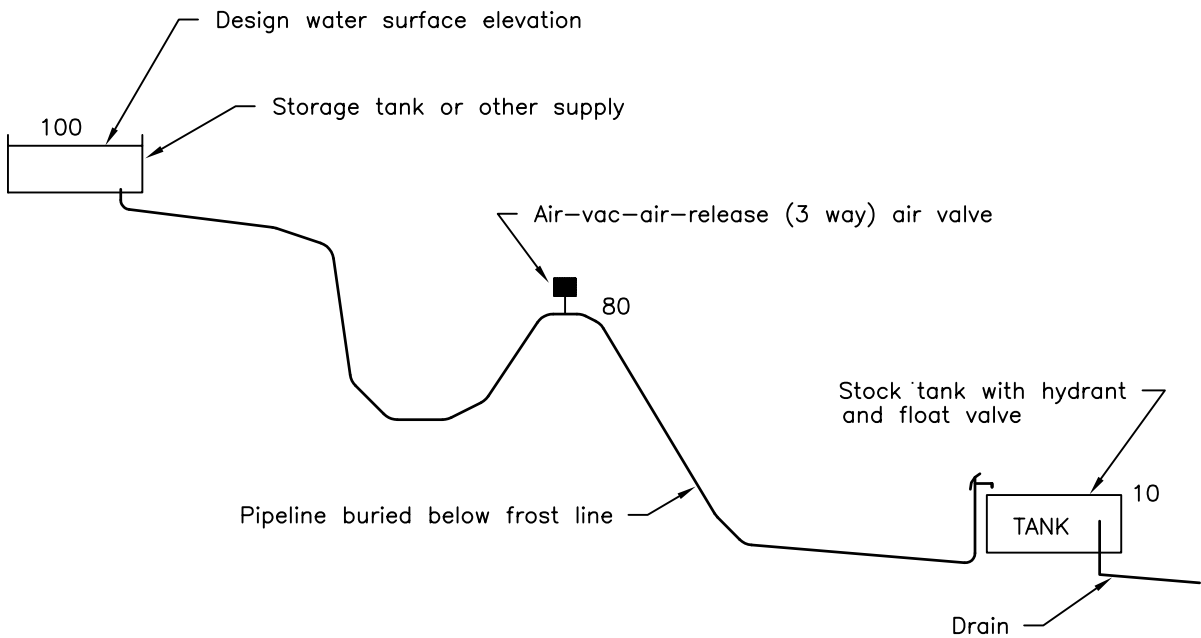


Figure 3.3
TYPICAL AUTOMATIC PRESSURE SYSTEM

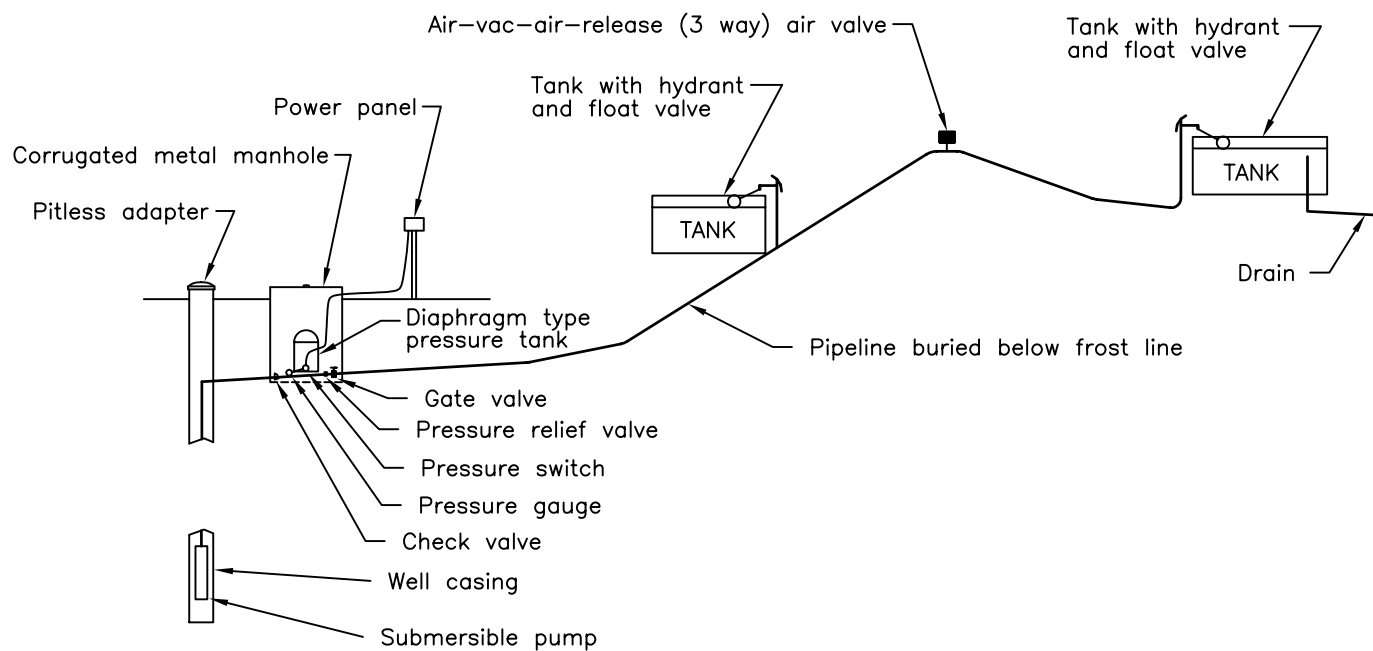


Figure 3.4
TYPICAL MANUAL OR TIMER OPERATED SYSTEM

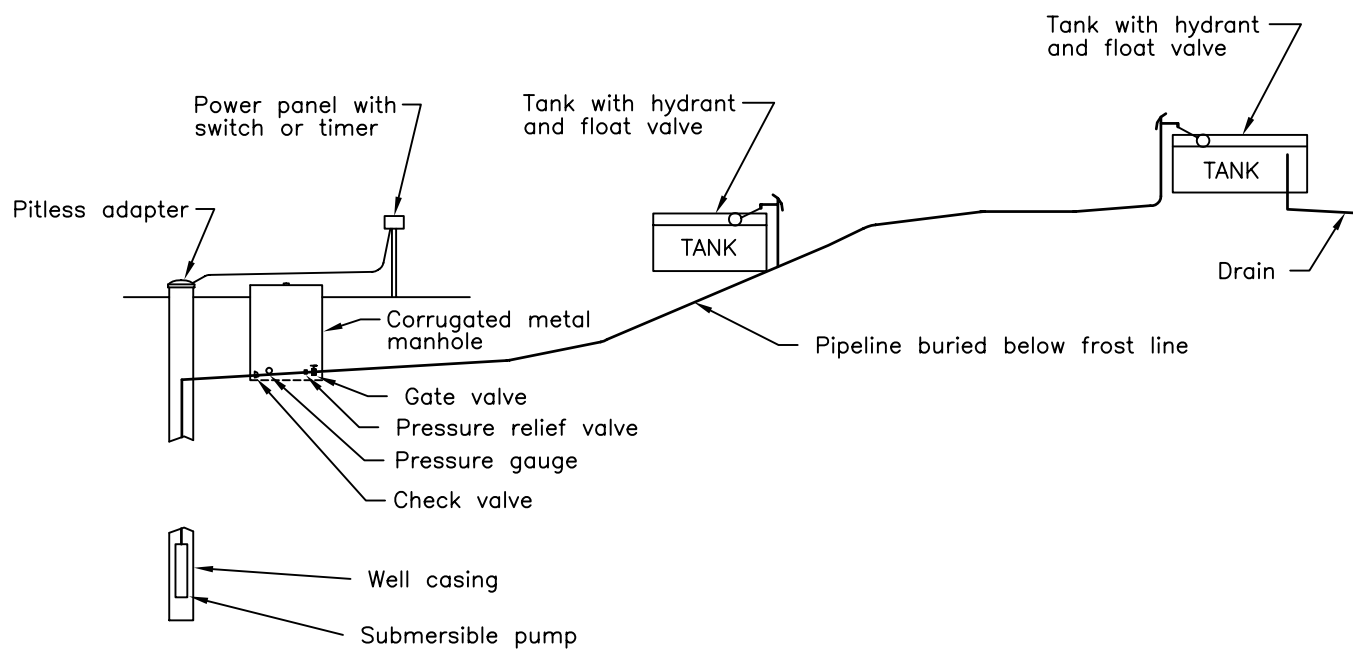
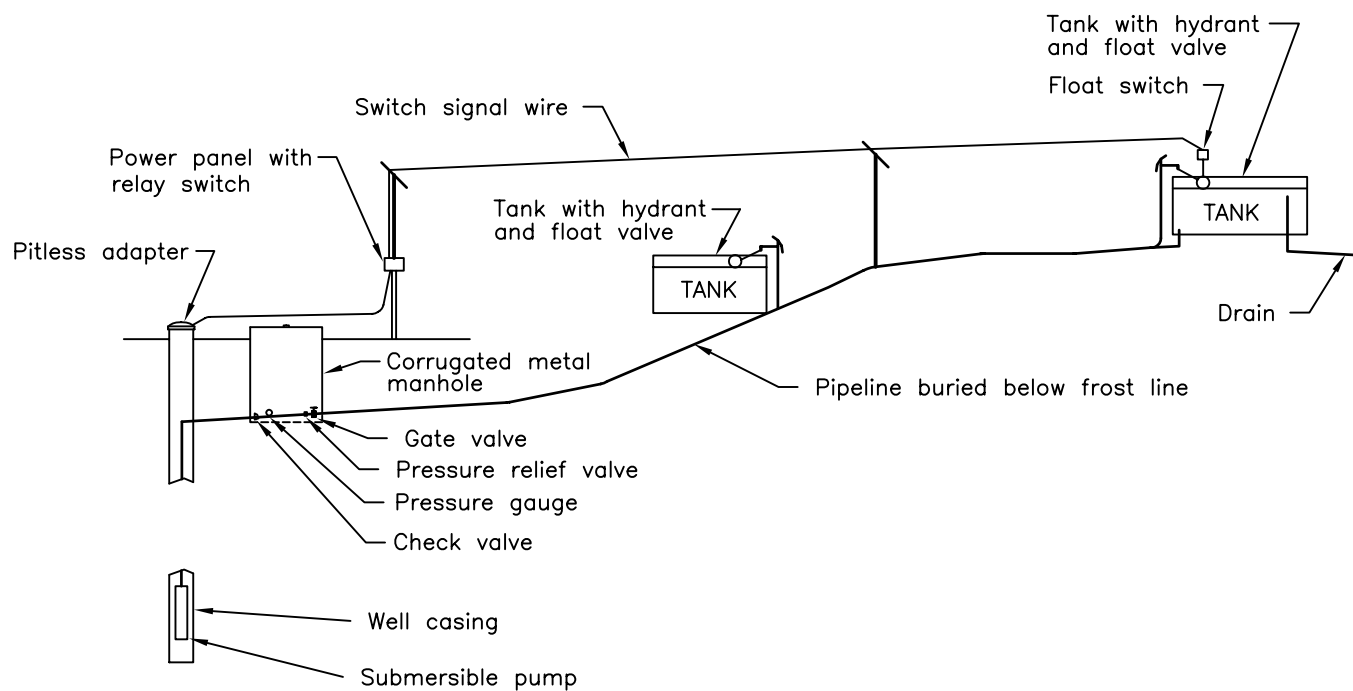


Figure 3.5
TYPICAL FLOAT SWITCH OPERATED SYSTEM



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 12 to 30 inches deep. By contrast, all year pipelines are buried below frost depth as shown in Figure 3.6.

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 or 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.

Above ground installations are permissible if high density polyethylene pipe (HDPE) is used. For additional details see Chapter 5 Section 5.4

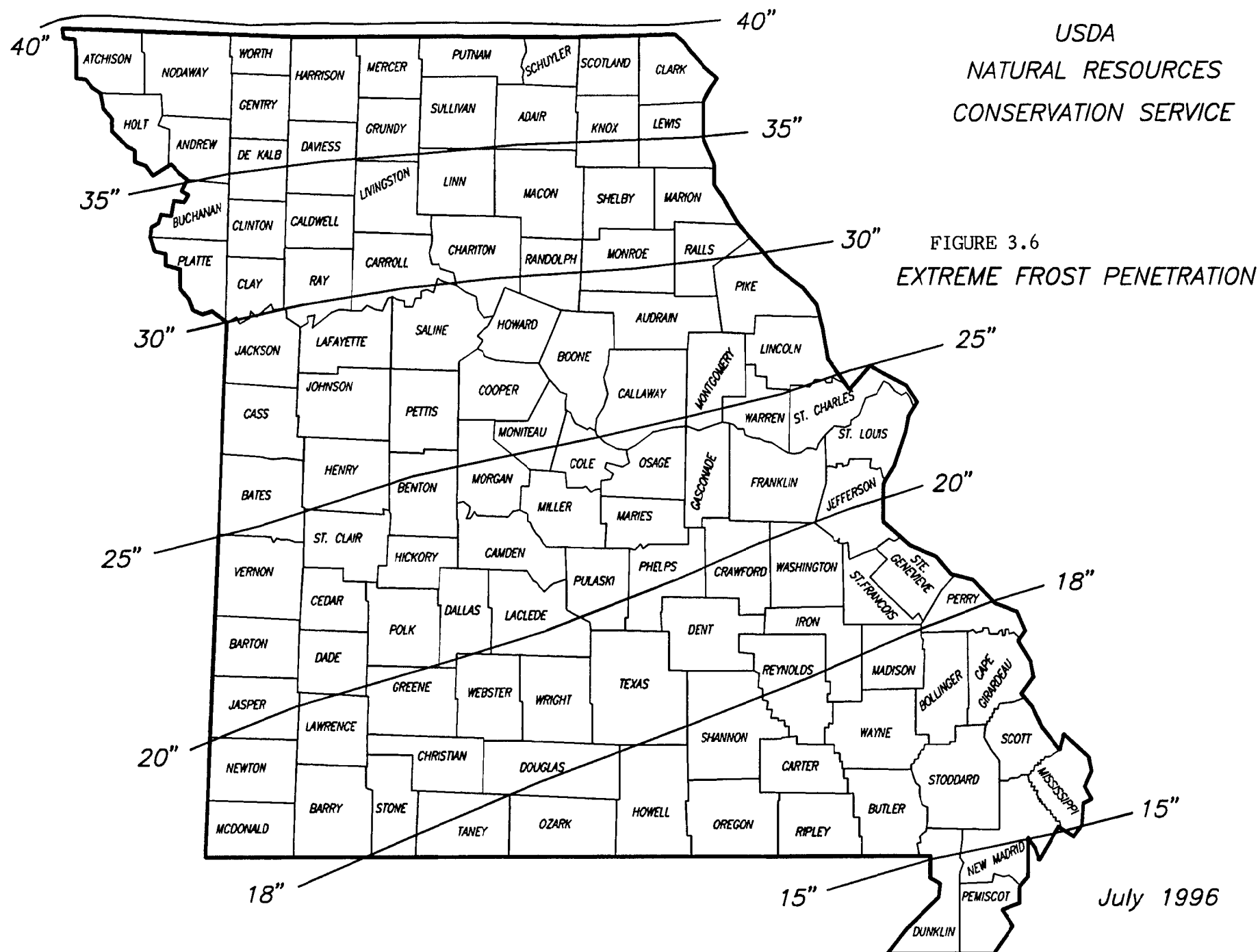
3.6.2 All Year Pipeline

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 below frost depth. North slope exposure, 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.

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

PART 4.1	ROUTE CONSIDERATIONS	4-1
PART 4.2	ROUTE SURVEYS--GENERAL	4-1
PART 4.3	ENGINEERING INSTRUMENT SURVEY	4-2
PART 4.4	USE OF USGS QUAD MAPS	4-2

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 may 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 property lines where possible. An easement should be obtained for right-of-way and maintenance of the pipeline if it crosses a property line. Obtaining an easement 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.
- Identify buried utilities and contact the utility company for technical guidance if the route must be located where it will intersect the utility route. Missouri One Call System, Inc. should aid in locating the buried utility (1-800-344-7484)

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.

If a survey is needed, a good set of survey notes could become a valuable reference for you, for someone who may need to finish the job, for the landowner or for the contractor at a later date. Make sure the notes are complete and the circuit is closed to ensure accuracy.

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 series USGS quadrangle maps. Contour interval on most quad sheets of interest in Missouri is either 10 or 20 feet. Fairly accurate interpolations can be made to an elevation of 5 or 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. Remember, the actual pipeline length will be longer than horizontal distances measured from the map.

Pipeline length guesswork can be reduced by physically measuring the route distance. Depending on the accuracy needed, pipeline length can be measured by pacing, using a tape, string measurer or measuring wheel.

Chapter 5

Pipe Design

CHAPTER 5 PIPE DESIGN

TABLE OF CONTENTS

PART	5.1	GENERAL	5-1
PART	5.2	PLASTIC PIPE CHARACTERISTICS	5-1
	5.2.1	Pressure Rating Pipe	5-1
	5.2.2	How Temperature Affects Pressure Rating	5-2
	5.2.3	Freezing of Water in Pipe	5-3
PART	5.3	POLYVINYL CHLORIDE (PVC) PLASTIC PIPE	5-3
PART	5.4	POLYETHYLENE (PE) PLASTIC PIPE	5-4
PART	5.5	ACRYLONITRILE-BUTADIENE-STYRENE(ABS) PLASTIC PIPE	5-5
PART	5.6	POLYBUTYLENE (PB) PLASTIC PIPE	5-5
PART	5.7	STEEL PIPE	5-5
PART	5.8	FRICITION LOSS IN PIPING SYSTEM AT THE PUMP	5-6
PART	5.9	PIPE FRICTION LOSS TABLES	5-9
PART	5.10	PVC PIPE FITTINGS	5-16

FIGURES

Figure	5.1	Estimate Friction Loss at Well	5-7
--------	-----	--------------------------------	-----

TABLES

Table	5.1	Plastic Pipe Working Pressure for PVC	5-2
Table	5.2	Plastic Pipe Working Pressure for PE	5-2
Table	5.3	PVC Plastic Pipe Reduction Due to Temperature	5-3
Table	5.4	Friction Loss PVC-SDR 26 Pipe 160 psi	5-9
Table	5.5	Friction Loss PVC-SDR 21 Pipe 200 psi	5-10
Table	5.6	Friction Loss PVC SDR 17 Pipe 250 psi	5-11
Table	5.7	Friction Loss PVC SDR 13.5 Pipe 315 psi	5-12
Table	5.8	Friction Loss PVC-IPS Pipe Schedule 40	5-13
Table	5.9	Friction Loss PVC-IPS Pipe Schedule 80	5-14
Table	5.10	Friction Loss Polyethylene (PE) Pipe	5-15
Table	5.11	Est. Limit of Working Pressure for Sch 40 & 80 PVC Fittings	5-16

CHAPTER 5

PIPE DESIGN

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.

Many plastic pipes are specified as having an SDR (Size Dimension Ratio) or DR (Dimension Ratio). For these pipes, as SDR or DR increases, the pipe's wall thickness decreases. For Outside Diameter (OD) controlled pipes, $SDR = \text{average OD} / \text{minimum wall thickness}$. For inside diameter (ID) controlled pipes, $DR = \text{average ID} / \text{minimum wall thickness}$.

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. If the surge pressure is not calculated, which is usually the case in Missouri, limit the maximum pressure on the pipe to 72% of its pressure rating (PR). This is an industry accepted method (ASAE S376.1). See tables 5.1, and 5.2 for maximum allowable pressure for PVC and PE.

$$PR = \frac{2f}{SDR-1} \text{ (Outside Diameter Controlled)}$$

$$PR = \frac{2f}{DR+1} \text{ (Inside Diameter Controlled)}$$

$$PR = \text{Pressure Rating}$$
$$f = \text{Hydrostatic Design Stress (See TR-77)}$$

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.

Table 5.1
**MAXIMUM ALLOWABLE PRESSURE (psi) FOR NONTHREADED PVC
 WHEN SURGE PRESSURES ARE NOT KNOWN
 ASTM-D-2241 SDR-PR, OD BASED**

SDR	PVC Material (OD based)			
	PVC 1120	PVC 2116	PVC 2112	PVC 2110
	PVC 1220			
	PVC 2120			
13.5	227	180	144	115
17.0	180	144	115	90
21.0	144	115	90	72
26.0	115	90	72	58
32.5	90	72	58	45

Maximum allowable pressure = 72% of the PR for SDR and DR pipe @ 73.4 degrees F.

Table 5.2
**MAXIMUM ALLOWABLE PRESSURE (psi) FOR NONTHREADED PE
 WHEN SURGE PRESSURES ARE NOT KNOWN**

SDR		PE Material (OD & ID based)		
		PE 3408	PE 3406	PE 2305
			PE 3306	
			PE 2306	
OD based	ID based		PE 2406	
	5.3	180	144	115
	7.0	144	115	90
11.0	9.0	115	90	72
13.5	11.5	90	72	58
17.0	15.0	72	58	45
21.0		58	45	
26.0		45	36	
32.5		36	29	

Maximum allowable pressure = 72% of the PR for SDR and DR pipe @ 73.4 degrees F.

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 5.3 lists the temperature reduction factors for PVC pipe.

Table 5.3
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-butyrates, acrylonitrile-butadiene-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 used in pressure pipelines. Standard Dimension Ratio-Pressure Rated pipe (SDR-PR) is manufactured under specification ASTM D2241. PVC Iron Pipe Size (PVC-IPS) pipe (eg. Schedule 40) is manufactured under specification ASTM D1785.

SDR-PR rated pipe is rated using standard dimension ratio (SDR) and pressure as factors. SDR equals average outside diameter divided by minimum wall thickness. Wall thickness increases as SDR value decreases. Tables 5.4, 5.5, 5.6 and 5.7 list available sizes, pressure ratings and friction loss factors.

PVC-IPS has the same outside diameter as iron pipe. It has various pressure ratings depending on nominal diameter, schedule and material (eg. PVC 1120) designations. Schedule 40, 80, and 120 pipe are available. Out of the three schedules, Schedule 40 is most commonly used in Missouri. Tables 5.8 and 5.9 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.

Both PVC-PR and PVC-IPS are available in different pressure ratings (PVC material). Type I, Grades 1 and 2 are designated PVC1120 and PVC1220, respectively. The following materials are designated for Type II, Grade 1; PVC2120, PVC2116, PVC2112 and PVC2110. Check with your local supplier for availability of the material designation (eg. PVC2120), ASTM specification (eg. ASTM-D-2241) as well as the SDR or schedule for pipe sizes needed. These variables are important to know before friction loss can be accurately calculated.

Three specifications cover low pressure PVC pipe that can be used in gravity systems: ASTM-D-2665 (PVC, 1-1/4" to 12"), ASTM-D-2729 (PVC Sewer Pipe, 2" to 6") and ASTM-D-3034 (PVC Type PSM, 4" to 15").

5.4 POLYETHYLENE (PE) PLASTIC PIPE

Polyethylene (PE) pipe is another commonly used pipe 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 and is recommended in Missouri.

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 ID Controlled) and is manufactured under specification ASTM D2239. SIDR 15, 100 psi pipe is usually the most available polyethylene pipe. Less common types include; ASTM-D-2104 (PE, Schedule 40), ASTM-D-3035 (PE, SDR-PR, OD Controlled), ASTM-D-2447 (PE Schedules 40 and 80, OD Controlled), ASTM-D-2737 (PE) and ASTM-F-771 (PE). Polyethylene (PE) pipe conforming to AWWA C901 is readily available.

Table 5.10 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 available in sizes 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.

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. Types of ABS include; ASTM-D-1527 (ABS Schedules 40 and 80), ASTM-D-2282 (ABS, SDR-PR). However, ABS pipe and their fittings may not be available in Missouri.

5.6 POLYBUTYLENE (PB) PLASTIC PIPE

Polybutylene pipe, is sometimes used in household plumbing and underground water service. However, it is no longer available in Missouri.

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.

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. If corrosion is a problem heavier threaded PVC pipe, schedule 80 or 120 may be beneficial.

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.

Some water in Missouri 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 Langelier 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 Langelier Index is beyond the scope of this manual and should be referred to State or

Area Engineering staff with knowledge of its use. Steel pipe connected to brass or bronze fittings will corrode at a faster rate.

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 bursting pressure.

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.

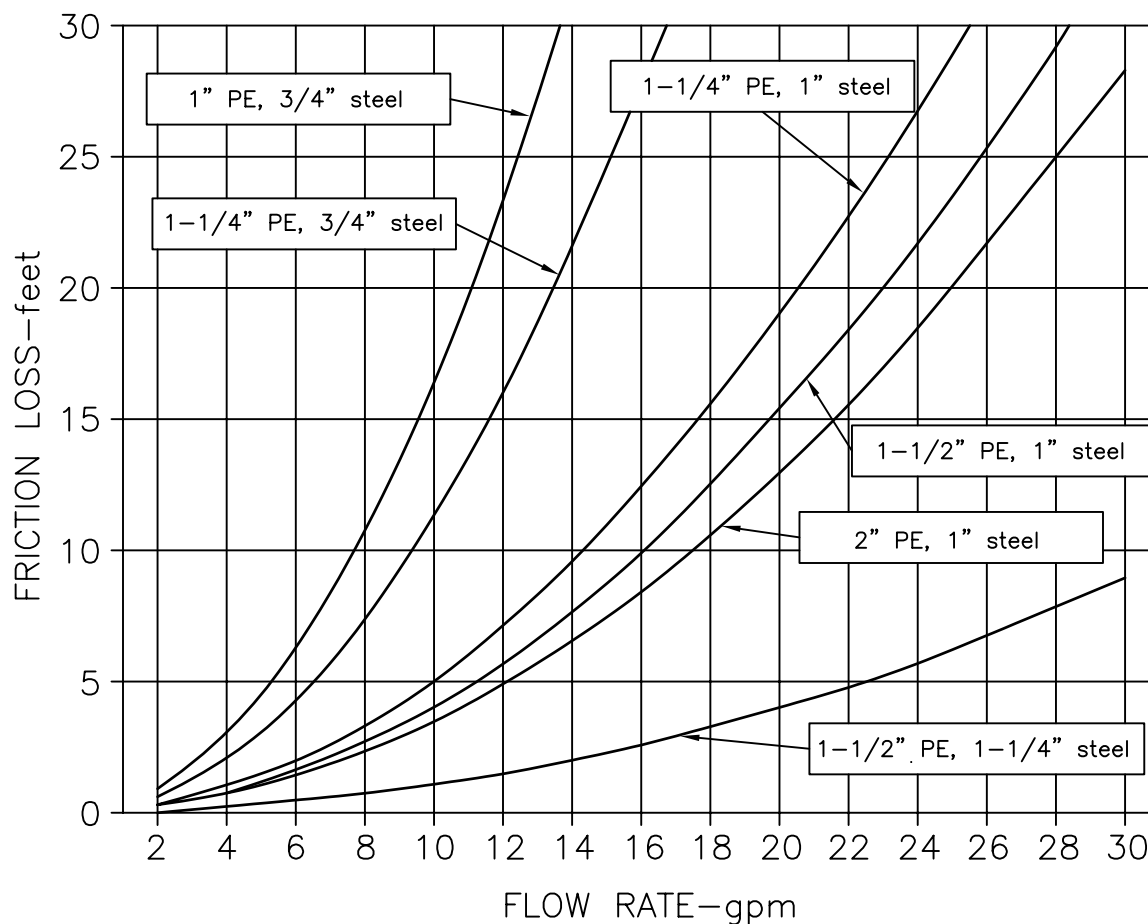
Figure 5.1 assumes the following conditions:

- 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.

It is becoming a more popular practice for submersible pumps to be suspended by schedule 80 PVC pipe with threaded connections. The friction loss in this installation would be similar to that for PE pipe.

Figure 5.1
ESTIMATED FRICTION LOSS AT WELL



Curve Type

- (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

Note:

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

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

$$H_f = (\text{gpm}/C)^{1.85185} \times 10.4057 / (d_i^{4.87037}) \times L$$

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 calculations).

The “C” factor used for PE and PVC plastic pipe is 135. Most research data shows that new PVC or PE has a “C” value of 150. Missouri recommends using a C=135 to account for increasing resistance as the pipe ages. This will permit minor losses such as “snaking” laid pipe and a normal quantity of couplers, tees and valves to be ignored.

It is very important that the correct inside diameter be used. The inside diameter will vary depending on the type of pipe or tubing used. Other forms of the Hazen-Williams Formula are:

Velocity

$$V = 1.318 C R^{0.63} S^{0.54}$$

$$V = 0.550 C D^{0.63} S^{0.54}$$

$$V = 0.115 C d^{0.63} S^{0.54}$$

Flow

$$Q = 16.66 C R^{2.63} S^{0.54}$$

$$Q = 0.432 C D^{2.63} S^{0.54}$$

$$Q = 0.000627 C d^{2.63} S^{0.54}$$

$$q = 7427 C R^{2.63} S^{0.54}$$

$$q = 193.9 C D^{2.63} S^{0.54}$$

$$q = 0.281 C d^{2.63} S^{0.54}$$

HEAD LOSS

$$HL = 0.600 \times \frac{V^{1.85}}{C^{1.85} R^{1.17}}$$

$$HL = \frac{841500 Q^{1.85}}{C^{1.85} d^{1.87}}$$

$$HL = 0.00566 \times \frac{Q^{1.85}}{C^{1.85} d^{1.87}}$$

$$HL = 3.04 \times \frac{V^{1.85}}{C^{1.85} D^{1.17}}$$

$$HL = \frac{6.936 \times 10^{-8} \times q^{1.85}}{C^{1.85} R^{1.87}}$$

$$HL = \frac{10.47 q^{1.85}}{C^{1.85} R^{4.87}}$$

$$HL = 54.66 \times \frac{V^{1.85}}{C^{1.85} d^{1.17}}$$

$$HL = \frac{5.861 \times 10^{-5} \times q^{1.85}}{C^{1.85} D^{4.87}}$$

$$HL = \frac{4.72 \times Q^{1.85}}{C^{1.85} D^{1.87}}$$

Units

HL = Head Loss in feet

C = Flow Factor (dimensionally)

R = Hydraulic Radius in feet

S = Slope in feet per foot

D = Inside Diameter in feet

q = Flow Rate in gallons per minute

Q = Flow Rate in cubic feet per second

Table 5.4

PVC PIPE, SDR 26
FRICTION LOSS ft/100 ft

Q (gpm)	1/2 inch	3/4 inch	1 inch	1-1/4 inch	1-1/2 inch	2 inch	2-1/2 inch	3 inch
			1.195 ID	1.532 ID	1.754 ID	2.193 ID	2.655 ID	3.230 ID
2.0			0.1790	0.0534	0.0276	0.0093	0.0037	0.0014
4.0			0.6461	0.1927	0.0997	0.0336	0.0132	0.0051
6.0			1.3691	0.4083	0.2112	0.0712	0.0280	0.0108
6.5			1.5878	0.4735	0.2450	0.0825	0.0325	0.0125
7.0			1.8214	0.5432	0.2810	0.0947	0.0373	0.0144
7.5			2.0696	0.6172	0.3193	0.1076	0.0424	0.0163
8.0			2.3323	0.6955	0.3598	0.1212	0.0478	0.0184
8.5			2.6094	0.7782	0.4026	0.1356	0.0535	0.0206
9.0			2.9008	0.8651	0.4475	0.1508	0.0594	0.0229
9.5			3.2063	0.9562	0.4946	0.1667	0.0657	0.0253
10.0			3.5258	1.0514	0.5439	0.1833	0.0722	0.0278
11.0			4.2064	1.2544	0.6489	0.2186	0.0862	0.0332
12.0			4.9418	1.4737	0.7624	0.2569	0.1012	0.0390
13.0			5.7314	1.7092	0.8842	0.2979	0.1174	0.0452
14.0			6.5745	1.9606	1.0143	0.3417	0.1347	0.0518
15.0			7.4705	2.2278	1.1525	0.3883	0.1530	0.0589
16.0			8.4188	2.5106	1.2988	0.4376	0.1725	0.0664
17.0			9.4191	2.8089	1.4531	0.4896	0.1930	0.0743
18.0		v>5 fps		3.1226	1.6154	0.5443	0.2145	0.0826
19.0		v>5 fps		3.4514	1.7855	0.6016	0.2371	0.0913
20.0		v>5 fps		3.7953	1.9634	0.6615	0.2607	0.1004

Hazen-Williams C = 135

ASTM-D-2241, PVC 1120, 1220 and 2120

Pressure Rating is 160 psi @ 73.4 F (72% of PR = 115 psi)

Table 5.5

PVC PIPE, SDR 21
FRICTION LOSS ft/100 ft

Q (gpm)	1/2 inch	3/4 inch	1 inch	1-1/4 inch	1-1/2 inch	2 inch	2-1/2 inch	3 inch
		0.930 ID	1.189 ID	1.502 ID	1.720 ID	2.149 ID	2.601 ID	3.166 ID
2.0		0.6070	0.1834	0.0588	0.0304	0.0103	0.0041	0.0016
4.0		2.1910	0.6622	0.2122	0.1097	0.0371	0.0146	0.0056
6.0		4.6423	1.4030	0.4496	0.2323	0.0785	0.0310	0.0119
6.5		5.3840	1.6272	0.5214	0.2695	0.0911	0.0360	0.0138
7.0		6.1760	1.8666	0.5981	0.3091	0.1045	0.0412	0.0158
7.5		7.0177	2.1210	0.6796	0.3512	0.1187	0.0469	0.0180
8.0		7.9086	2.3902	0.7659	0.3958	0.1338	0.0528	0.0203
8.5		8.8482	2.6742	0.8569	0.4428	0.1497	0.0591	0.0227
9.0		9.8362	2.9728	0.9525	0.4923	0.1664	0.0657	0.0252
9.5		10.8720	3.2858	1.0528	0.5441	0.1839	0.0726	0.0279
10.0		11.9554	3.6133	1.1577	0.5983	0.2023	0.0798	0.0306
11.0		v>5 fps	4.3107	1.3812	0.7138	0.2413	0.0952	0.0366
12.0		v>5 fps	5.0644	1.6227	0.8387	0.2835	0.1119	0.0430
13.0		v>5 fps	5.8736	1.8820	0.9727	0.3288	0.1298	0.0498
14.0		v>5 fps	6.7376	2.1588	1.1157	0.3772	0.1489	0.0571
15.0		v>5 fps	7.6559	2.4531	1.2678	0.4286	0.1691	0.0649
16.0		v>5 fps	8.6278	2.7645	1.4287	0.4830	0.1906	0.0732
17.0		v>5 fps	9.6529	3.0929	1.5985	0.5404	0.2133	0.0819
18.0		v>5 fps	v>5 fps	3.4383	1.7770	0.6007	0.2371	0.0910
19.0		v>5 fps	v>5 fps	3.8004	1.9641	0.6640	0.2621	0.1006
20.0		v>5 fps	v>5 fps	4.1790	2.1598	0.7301	0.2882	0.1106

Hazen-Williams C = 135

ASTM-D-2241, PVC 1120, 1220 and 2120

Pressure Rating is 200 psi @ 73.4 F (72% of PR = 144 psi)

Table 5.6

PVC PIPE, SDR 17
FRICTION LOSS ft/100 ft

Q (gpm)	1/2 inch	3/4 inch	1 inch	1-1/4 inch	1-1/2 inch	2 inch	2-1/2 inch	3 inch
		0.926 ID	1.161 ID	1.464 ID	1.676 ID	2.095 ID	2.537 ID	3.088 ID
2.0		0.6199	0.2060	0.0666	0.0345	0.0116	0.0046	0.0018
4.0		2.2375	0.7437	0.2404	0.1244	0.0420	0.0165	0.0063
6.0		4.7408	1.5757	0.5093	0.2636	0.0889	0.0350	0.0134
6.5		5.4982	1.8275	0.5907	0.3057	0.1031	0.0406	0.0156
7.0		6.3070	2.0963	0.6776	0.3507	0.1183	0.0466	0.0179
7.5		7.1666	2.3820	0.7699	0.3985	0.1344	0.0529	0.0203
8.0		8.0764	2.6844	0.8677	0.4491	0.1515	0.0596	0.0229
8.5		9.0360	3.0033	0.9708	0.5024	0.1695	0.0667	0.0256
9.0		10.0449	3.3386	1.0791	0.5585	0.1884	0.0742	0.0285
9.5		11.1027	3.6902	1.1928	0.6173	0.2082	0.0820	0.0315
10.0		12.2090	4.0579	1.3116	0.6788	0.2290	0.0901	0.0346
11.0	v>5 fps		4.8413	1.5648	0.8099	0.2732	0.1075	0.0413
12.0	v>5 fps		5.6877	1.8384	0.9515	0.3209	0.1263	0.0485
13.0	v>5 fps		6.5965	2.1322	1.1035	0.3722	0.1465	0.0563
14.0	v>5 fps		7.5668	2.4458	1.2658	0.4270	0.1681	0.0645
15.0	v>5 fps		8.5981	2.7791	1.4383	0.4851	0.1910	0.0733
16.0	v>5 fps		9.6896	3.1320	1.6209	0.5467	0.2152	0.0826
17.0	v>5 fps	v>5 fps		3.5041	1.8135	0.6117	0.2408	0.0925
18.0	v>5 fps	v>5 fps		3.8953	2.0160	0.6800	0.2677	0.1028
19.0	v>5 fps	v>5 fps		4.3055	2.2283	0.7516	0.2959	0.1136
20.0	v>5 fps	v>5 fps		4.7346	2.4503	0.8265	0.3253	0.1249

Hazen-Williams C = 135

ASTM-D-2241, PVC 1120, 1220 and 2120

Pressure Rating is 250 psi @ 73.4 F (72% of PR = 180 psi)

Table 5.7

PVC PIPE, SDR 13.5
FRICTION LOSS ft/100 ft

Q (gpm)	1/2 inch	3/4 inch	1 inch	1-1/4 inch	1-1/2 inch	2 inch	2-1/2 inch	3 inch
	0.716 ID	0.894 ID	1.121 ID	1.414 ID	1.654 ID	2.023 ID	2.449 ID	2.982 ID
2.0	2.1692	0.7357	0.2444	0.0789	0.0368	0.0138	0.0054	0.0021
4.0	7.8301	2.6555	0.8821	0.2847	0.1327	0.0498	0.0196	0.0075
6.0	16.5905	5.6265	1.8691	0.6032	0.2811	0.1054	0.0416	0.0159
6.5	v>5 fps	6.5255	2.1677	0.6996	0.3260	0.1223	0.0482	0.0185
7.0	v>5 fps	7.4853	2.4866	0.8025	0.3740	0.1402	0.0553	0.0212
7.5	v>5 fps	8.5055	2.8255	0.9119	0.4250	0.1594	0.0628	0.0241
8.0	v>5 fps	9.5853	3.1842	1.0277	0.4789	0.1796	0.0708	0.0271
8.5	v>5 fps	10.7241	3.5625	1.1498	0.5358	0.2009	0.0792	0.0304
9.0	v>5 fps	11.9215	3.9603	1.2782	0.5956	0.2234	0.0881	0.0338
9.5	v>5 fps	13.1769	4.3774	1.4128	0.6584	0.2469	0.0973	0.0373
10.0	v>5 fps	v>5 fps	4.8135	1.5535	0.7240	0.2715	0.1070	0.0410
11.0	v>5 fps	v>5 fps	5.7427	1.8534	0.8637	0.3239	0.1277	0.0489
12.0	v>5 fps	v>5 fps	6.7468	2.1775	1.0147	0.3805	0.1500	0.0575
13.0	v>5 fps	v>5 fps	7.8248	2.5254	1.1768	0.4413	0.1740	0.0667
14.0	v>5 fps	v>5 fps	8.9758	2.8968	1.3500	0.5062	0.1996	0.0765
15.0	v>5 fps	v>5 fps	10.1990	3.2916	1.5339	0.5752	0.2268	0.0869
16.0	v>5 fps	v>5 fps	v>5 fps	3.7095	1.7287	0.6483	0.2556	0.0980
17.0	v>5 fps	v>5 fps	v>5 fps	4.1503	1.9341	0.7253	0.2860	0.1096
18.0	v>5 fps	v>5 fps	v>5 fps	4.6137	2.1500	0.8063	0.3179	0.1218
19.0	v>5 fps	v>5 fps	v>5 fps	5.0995	2.3764	0.8912	0.3514	0.1347
20.0	v>5 fps	v>5 fps	v>5 fps	5.6076	2.6132	0.9800	0.3864	0.1481

Hazen-Williams C = 135

ASTM-D-2241, PVC 1120, 1220 and 2120

Pressure Rating is 315 psi @ 73.4 F (72% of PR = 227 psi)

Table 5.8

PVC (IPS) PIPE, SCHEDULE 40
FRICTION LOSS ft/100 ft

Q (gpm)	1/2 inch 600 PR 0.622 ID	3/4 inch 480 PR 0.824 ID	1 inch 450 PR 1.049 ID	1-1/4 inch 370 PR 1.380 ID	1-1/2 inch 330 PR 1.610 ID	2 inch 280 PR 2.067 ID	2-1/2 inch 300 PR 2.469 ID	3 inch 260 PR 3.048 ID
2.0	4.3052	1.0943	0.3377	0.0888	0.0419	0.0124	0.0052	0.0019
4.0	15.5401	3.9501	1.2189	0.3205	0.1513	0.0448	0.0189	0.0068
6.0	32.9268	8.3695	2.5825	0.6792	0.3206	0.0949	0.0399	0.0143
6.5	v>5 fps	9.7067	2.9952	0.7877	0.3718	0.1101	0.0463	0.0166
7.0	v>5 fps	11.1346	3.4358	0.9035	0.4265	0.1263	0.0531	0.0190
7.5	v>5 fps	12.6520	3.9040	1.0267	0.4846	0.1435	0.0604	0.0216
8.0	v>5 fps	14.2582	4.3996	1.1570	0.5461	0.1617	0.0681	0.0244
8.5	v>5 fps	15.9523	4.9224	1.2945	0.6110	0.1809	0.0761	0.0273
9.0	v>5 fps	17.7334	5.4720	1.4390	0.6792	0.2011	0.0846	0.0303
9.5	v>5 fps	19.6009	6.0482	1.5905	0.7507	0.2223	0.0936	0.0335
10.0	v>5 fps	v>5 fps	6.6509	1.7490	0.8256	0.2445	0.1029	0.0369
11.0	v>5 fps	v>5 fps	7.9347	2.0867	0.9849	0.2917	0.1227	0.0440
12.0	v>5 fps	v>5 fps	9.3220	2.4515	1.1571	0.3427	0.1442	0.0517
13.0	v>5 fps	v>5 fps	10.8115	2.8432	1.3420	0.3974	0.1672	0.0599
14.0	v>5 fps	v>5 fps	12.4018	3.2614	1.5394	0.4559	0.1918	0.0688
15.0	v>5 fps	v>5 fps	14.0920	3.7059	1.7492	0.5180	0.2180	0.0781
16.0	v>5 fps	v>5 fps	v>5 fps	4.1764	1.9713	0.5838	0.2457	0.0881
17.0	v>5 fps	v>5 fps	v>5 fps	4.6726	2.2055	0.6531	0.2749	0.0985
18.0	v>5 fps	v>5 fps	v>5 fps	5.1943	2.4517	0.7260	0.3055	0.1095
19.0	v>5 fps	v>5 fps	v>5 fps	5.7413	2.7099	0.8025	0.3377	0.1210
20.0	v>5 fps	v>5 fps	v>5 fps	6.3134	2.9799	0.8825	0.3714	0.1331

Hazen-Williams C = 135

ASTM-D-1785, PVC 1120, 1220 and 2120

Pressure Rating (PR) @ 73 F varies with pipe diameter and is shown with psi units

Table 5.9

PVC (IPS) PIPE, SCHEDULE 80
FRICTION LOSS ft/100 ft

Q (gpm)	1/2 inch 850 PR 0.546 ID	3/4 inch 690 PR 0.742 ID	1 inch 630 PR 0.957 ID	1-1/4 inch 520 PR 1.278 ID	1-1/2 inch 470 PR 1.500 ID	2 inch 400 PR 1.939 ID	2-1/2 inch 420 PR 2.323 ID	3 inch 370 PR 2.900 ID
2.0	8.1216	1.8233	0.5280	0.1291	0.0592	0.0169	0.0070	0.0024
4.0	29.3161	6.5814	1.9059	0.4659	0.2136	0.0612	0.0254	0.0086
6.0	62.1157	13.9448	4.0383	0.9872	0.4525	0.1296	0.0538	0.0182
6.5	v>5 fps	16.1729	4.6835	1.1449	0.5248	0.1503	0.0623	0.0212
7.0	v>5 fps	18.5519	5.3725	1.3133	0.6020	0.1724	0.0715	0.0243
7.5	v>5 fps	21.0803	6.1047	1.4923	0.6840	0.1959	0.0813	0.0276
8.0	v>5 fps	23.7564	6.8796	1.6817	0.7709	0.2208	0.0916	0.0311
8.5	v>5 fps	26.5790	7.6970	1.8815	0.8624	0.2470	0.1025	0.0348
9.0	v>5 fps	29.5466	8.5564	2.0916	0.9587	0.2746	0.1139	0.0387
9.5	v>5 fps	32.6581	9.4575	2.3119	1.0597	0.3035	0.1259	0.0427
10.0	v>5 fps	v>5 fps	10.3999	2.5422	1.1653	0.3338	0.1384	0.0470
11.0	v>5 fps	v>5 fps	12.4074	3.0330	1.3902	0.3982	0.1652	0.0561
12.0	v>5 fps	v>5 fps	14.5767	3.5633	1.6333	0.4678	0.1940	0.0659
13.0	v>5 fps	v>5 fps	16.9058	4.1326	1.8943	0.5426	0.2250	0.0764
14.0	v>5 fps	v>5 fps	19.3926	4.7405	2.1729	0.6224	0.2582	0.0876
15.0	v>5 fps	v>5 fps	22.0355	5.3866	2.4690	0.7072	0.2933	0.0996
16.0	v>5 fps	v>5 fps	v>5 fps	6.0704	2.7825	0.7970	0.3306	0.1122
17.0	v>5 fps	v>5 fps	v>5 fps	6.7916	3.1131	0.8917	0.3698	0.1255
18.0	v>5 fps	v>5 fps	v>5 fps	7.5500	3.4607	0.9912	0.4111	0.1396
19.0	v>5 fps	v>5 fps	v>5 fps	8.3450	3.8251	1.0956	0.4544	0.1542
20.0	v>5 fps	v>5 fps	v>5 fps	9.1766	4.2063	1.2048	0.4997	0.1696

Hazen-Williams C = 135

ASTM-D-1785, PVC 1120, 1220 and 2120, Non-threaded pipe

Pressure Rating (PR) @ 73 F varies with pipe diameter and is shown with psi units

Table 5.10

**PE PIPE, SIDR-PR
FRICTION LOSS ft/100 ft**

Q (gpm)	1/2 inch	3/4 inch	1 inch	1-1/4 inch	1-1/2 inch	2 inch	2-1/2 inch	3 inch
	0.622 ID	0.824 ID	1.049 ID	1.380 ID	1.610 ID	2.067 ID	2.469 ID	3.048 ID
2.0	4.3052	1.0943	0.3377	0.0888	0.0419	0.0124	0.0052	0.0019
4.0	15.5401	3.9501	1.2189	0.3205	0.1513	0.0448	0.0189	0.0068
6.0	32.9268	8.3695	2.5825	0.6792	0.3206	0.0949	0.0399	0.0143
6.5	v>5 fps	9.7067	2.9952	0.7877	0.3718	0.1101	0.0463	0.0166
7.0	v>5 fps	11.1346	3.4358	0.9035	0.4265	0.1263	0.0531	0.0190
7.5	v>5 fps	12.6520	3.9040	1.0267	0.4846	0.1435	0.0604	0.0216
8.0	v>5 fps	14.2582	4.3996	1.1570	0.5461	0.1617	0.0681	0.0244
8.5	v>5 fps	15.9523	4.9224	1.2945	0.6110	0.1809	0.0761	0.0273
9.0	v>5 fps	17.7334	5.4720	1.4390	0.6792	0.2011	0.0846	0.0303
9.5	v>5 fps	19.6009	6.0482	1.5905	0.7507	0.2223	0.0936	0.0335
10.0	v>5 fps	v>5 fps	6.6509	1.7490	0.8256	0.2445	0.1029	0.0369
11.0	v>5 fps	v>5 fps	7.9347	2.0867	0.9849	0.2917	0.1227	0.0440
12.0	v>5 fps	v>5 fps	9.3220	2.4515	1.1571	0.3427	0.1442	0.0517
13.0	v>5 fps	v>5 fps	10.8115	2.8432	1.3420	0.3974	0.1672	0.0599
14.0	v>5 fps	v>5 fps	12.4018	3.2614	1.5394	0.4559	0.1918	0.0688
15.0	v>5 fps	v>5 fps	14.0920	3.7059	1.7492	0.5180	0.2180	0.0781
16.0	v>5 fps	v>5 fps	v>5 fps	4.1764	1.9713	0.5838	0.2457	0.0881
17.0	v>5 fps	v>5 fps	v>5 fps	4.6726	2.2055	0.6531	0.2749	0.0985
18.0	v>5 fps	v>5 fps	v>5 fps	5.1943	2.4517	0.7260	0.3055	0.1095
19.0	v>5 fps	v>5 fps	v>5 fps	5.7413	2.7099	0.8025	0.3377	0.1210
20.0	v>5 fps	v>5 fps	v>5 fps	6.3134	2.9799	0.8825	0.3714	0.1331

PE MATERIALS AND PRESSURE RATINGS

Material	SIDR	PR (psi)	72% PR (psi)
3408	15	100	72
3306 & 3406	15	80	58
3408	11.5	125	90
3306 & 3406	11.5	100	72
3408	9	160	115
3306 & 3406	9	125	90
3408	7	200	144
3306 & 3406	7	160	115
3408	5.3	250	180
3306 & 3406	5.3	200	144

Hazen-Williams C = 135

ASTM-D-2239, PE Pipe

Pressure Rating (PR) @ 73 F varies with pipe material

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 on very limited real data, proposes the upper limit working pressures for Schedule 40 and 80 PVC fittings as tabulated in Table 5.11. 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 5.11
Estimated Upper Limit Working Pressures for
Schedule 40 and Schedule 80 PVC Fittings

Nominal	Outside	Schedule 40 Pressure Rating		Schedule 80 Pressure Rating	
Diameter (in)	Diameter (in)	Burst (psi)	Working (psi)	Burst (psi)	Working (psi)
1/2	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

PART	6.1	PIPELINE PRESSURE CONTROL	6-1
	6.1.1	Need for Pressure Control	6-1
	6.1.2	Pressure Reducing Valves	6-1
	6.1.3	Grade Break at Tank	6-4
PART	6.2	SURGE CONTROL	6-6
	6.2.1	Pressure Tank as Surge Chamber	6-6
	6.2.2	Minimize Frequency of Pump Cycle	6-7
		Flow Control Valve	6-9
		Flow Controlled Pressure Switch	6-9
		Pump Cycle Timer	6-9
	6.2.3	Install Air Valve	6-11
	6.2.4	Use Slow Closing Valves	6-11
	6.2.5	Control Flow Rate at Float Valve	6-11
	6.2.6	Operation Plan	6-11

FIGURE

Figure	6.1	Typical Pressure Reducing Valve Installation	6-2
Figure	6.2	Pressure Valve Parts and Design Charts	6-3
Figure	6.3	Float Valve Box	6-5
Figure	6.4	Operation of a Surge Chamber	6-7
Figure	6.5	Remote Multi-Tank Installation	6-8
Figure	6.6	Flow Rate Controller Valves	6-10
Figure	6.7	Flow Controlled Pressure Switch	6-11

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 pressures at hydrants 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. Where pressure exceeds 80 psi, it 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: (1) Install a pressure reducing valve and (2) Install a tank with a float valve and a gravity pipeline extension.

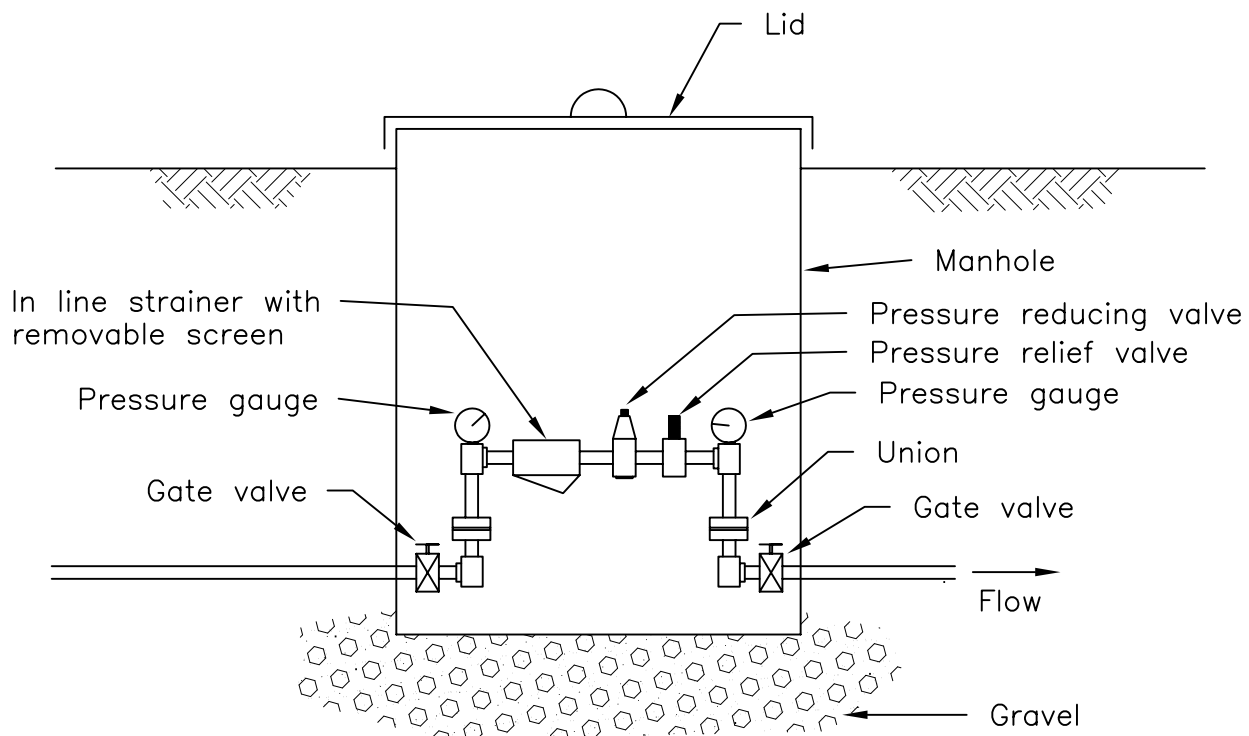
Pressure reducing valves or tank/float valves should be used as a last resort. They are mechanical devices that can and do sometimes fail. In many cases there is no other way to maintain pressures below 80 psi, so a pressure reducing device must be installed.

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

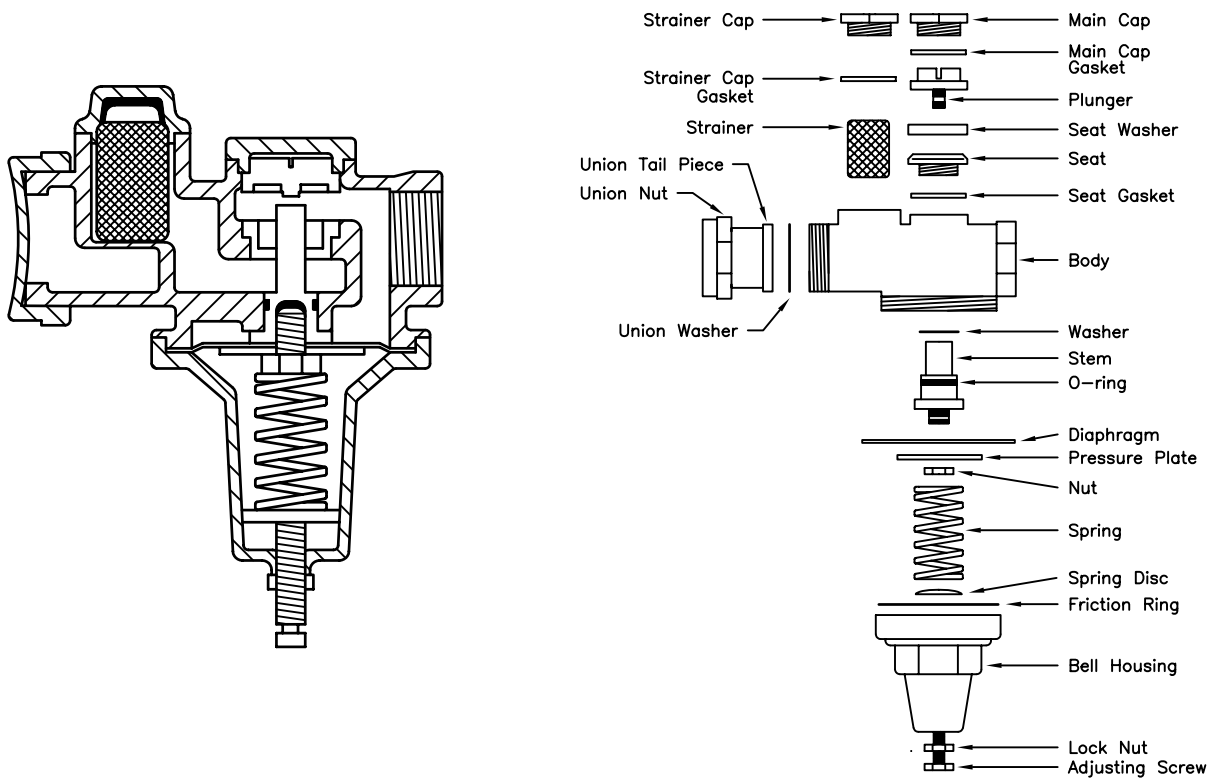


Pressure reducing valve size should be selected based on manufacturer's recommendations. Too small a valve will create very high velocities in the valve and cause rapid valve failure. Too large a valve will cause poor pressure regulation.

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)

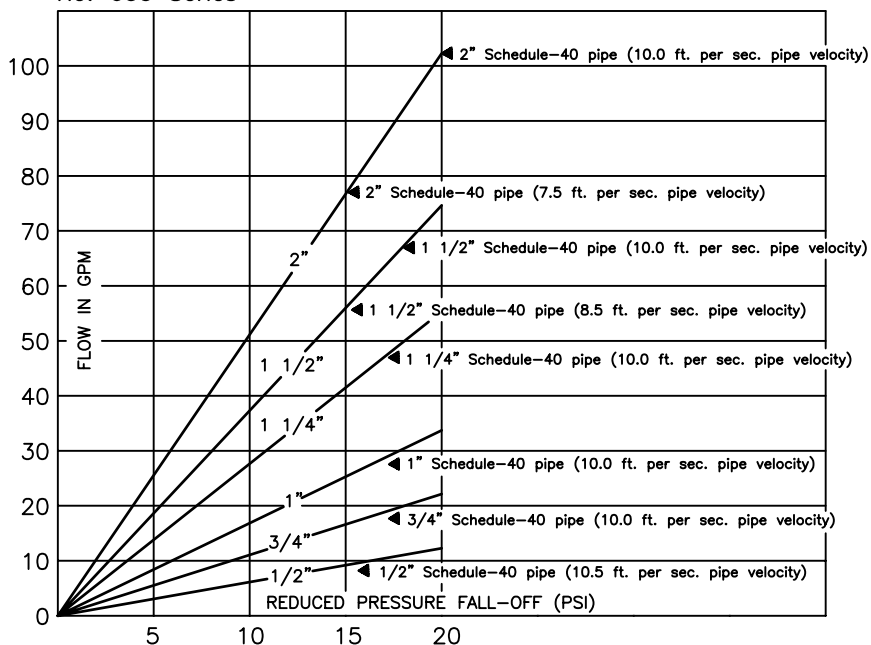
Wilkins No. 600 series pressure reducing valves.

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
1/2"			9.47
3/4"			16.60
1"	(9.5)	25.0	26.90
1 1/4"	(9.0)	42.0	46.70
1 1/2"	(8.5)	54.8	64.50
2"	(7.5)	77.5	104.60

No. 600 Series



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 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 $(75 \times 2.31) = 173$ feet above valve elevation. If the valve were to operate at design flow, hydraulic grade line would start at the valve at $[(75 - 20) \times 2.31] = 127$ feet above valve elevation.

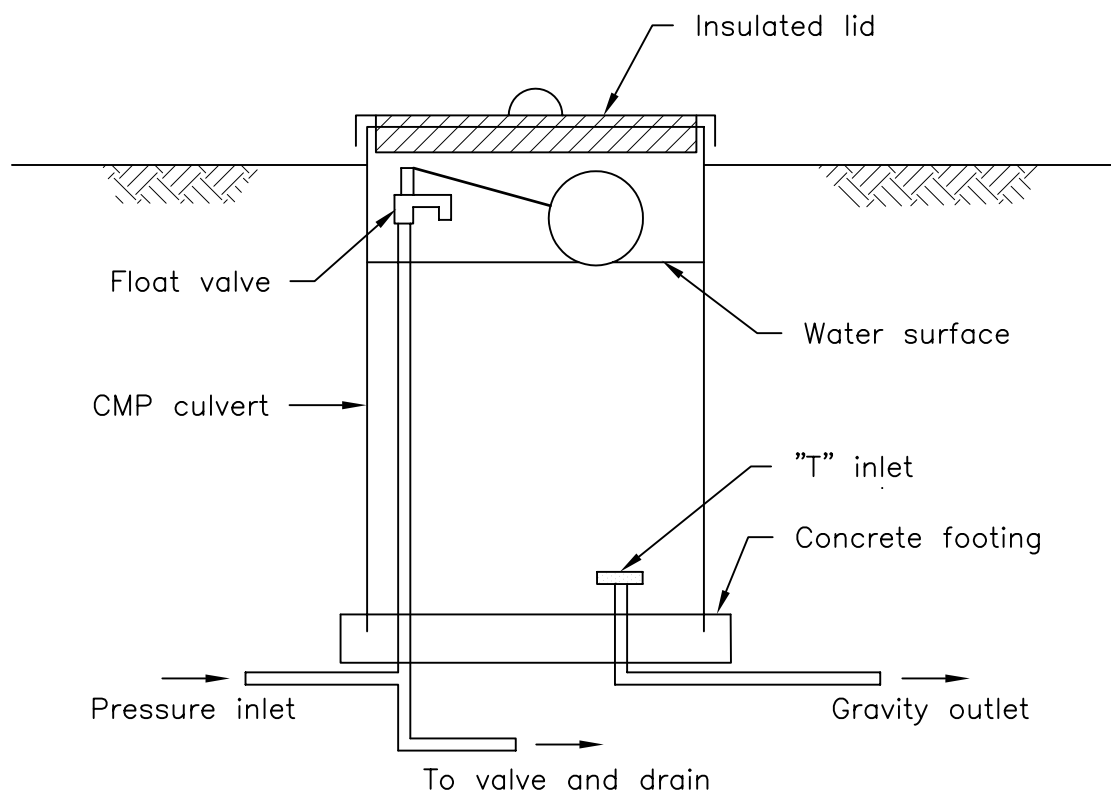
Figure 6.2 illustrates typical manufacturer information concerning valve fall-off values.

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. Surge pressures can be much greater than operating pressure, and can even be greater than static pressure in the pipeline.

In 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 water 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.

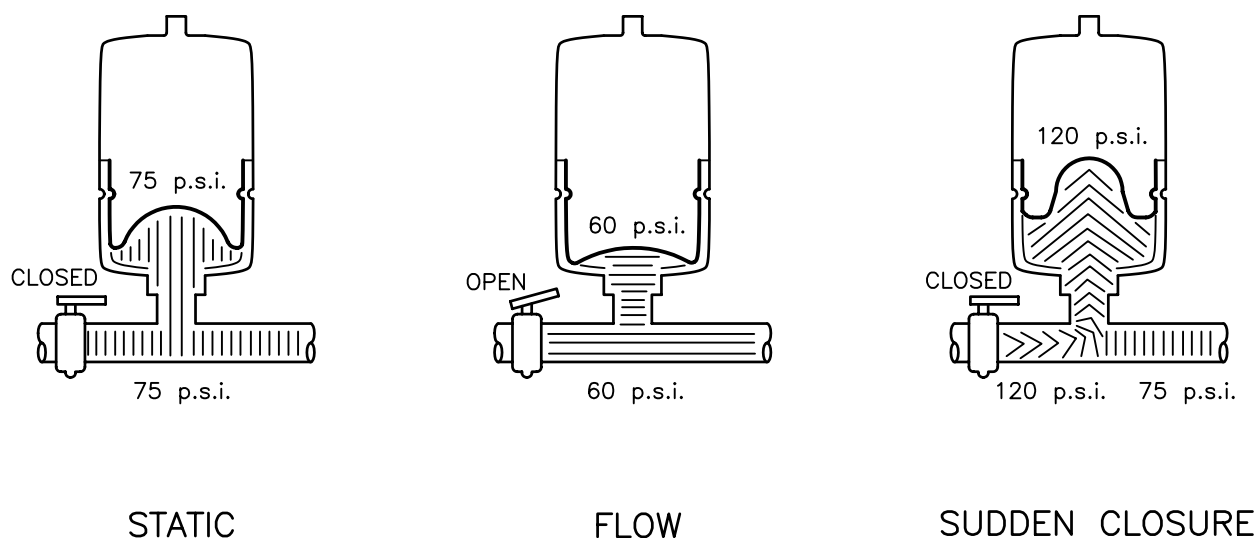
Another frequent cause of surges is rapidly turning off a hydrant. Frost free hydrants can be shut off very rapidly by slamming down the handle. This is sure to cause surges in the pipeline. Float valves will also be turned rapidly on or off if something causes the water in the tank to slosh around.

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 may 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.

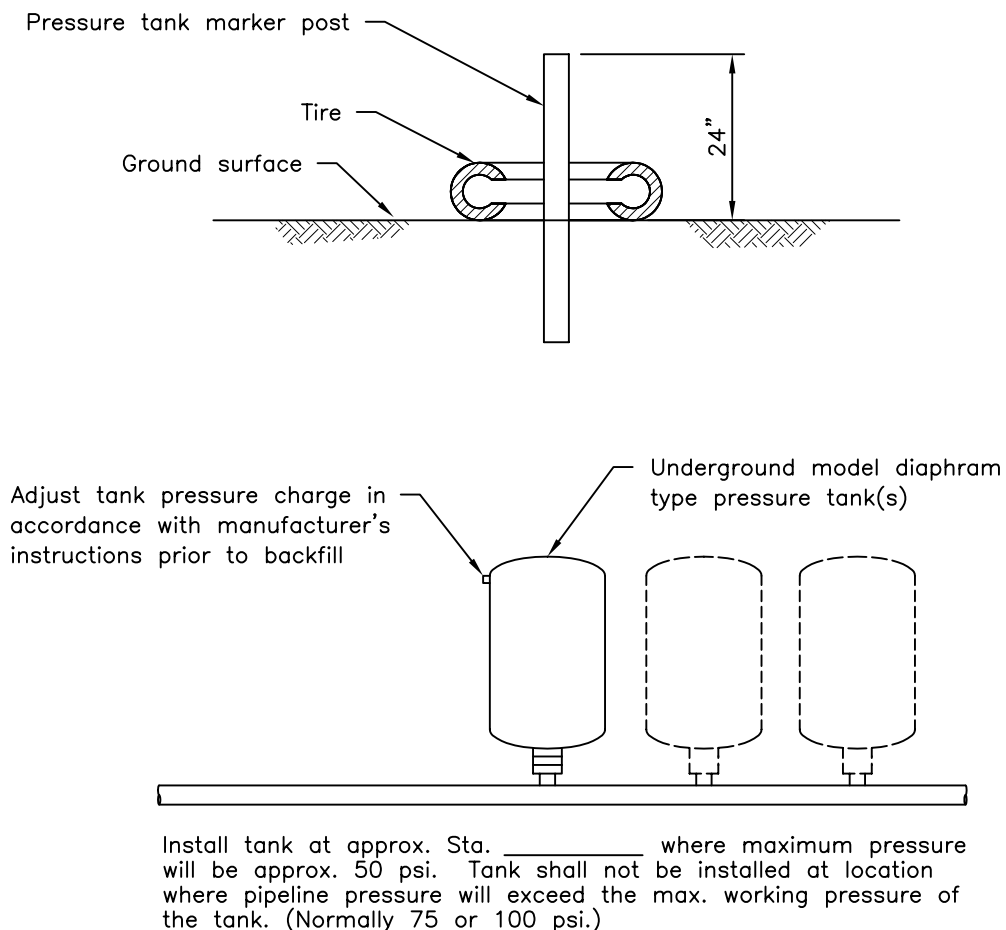
It is sometimes proposed that a homemade surge chamber be installed. This is a piece of pipe capped at one end and an air valve installed in the outer end. The chamber is filled with compressed air after the system is pressurized with water.

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 build up 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:

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.

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.

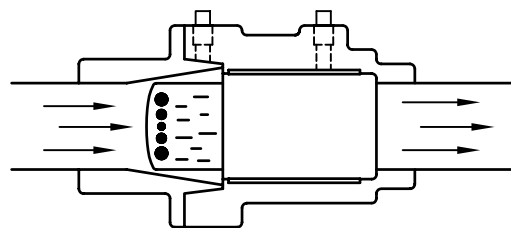
Pump Cycle Timer

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

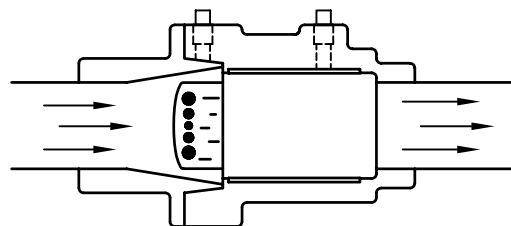
Below the control range

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 $\pm 5\%$ 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 area exposed, the valve acts as a fixed orifice device to allow the continuation of flow.

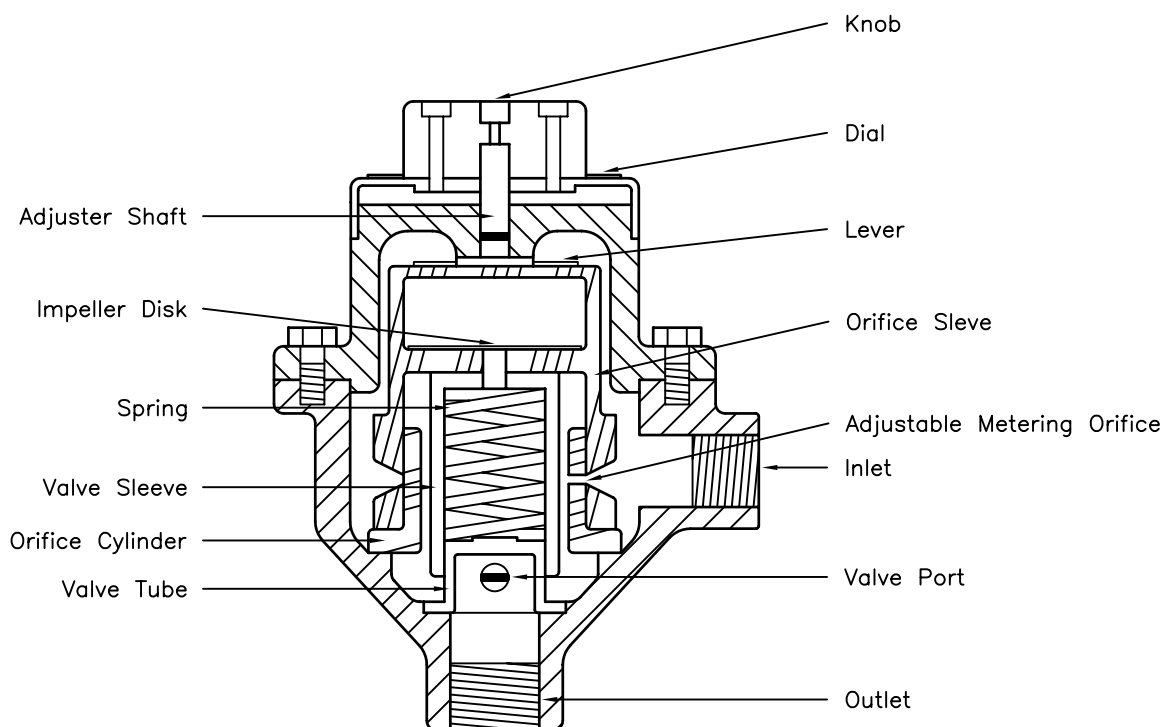
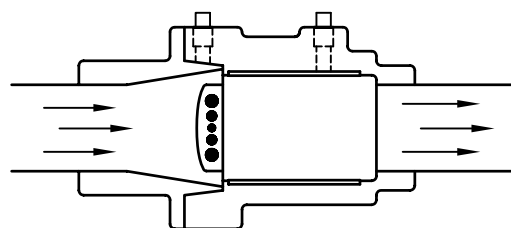
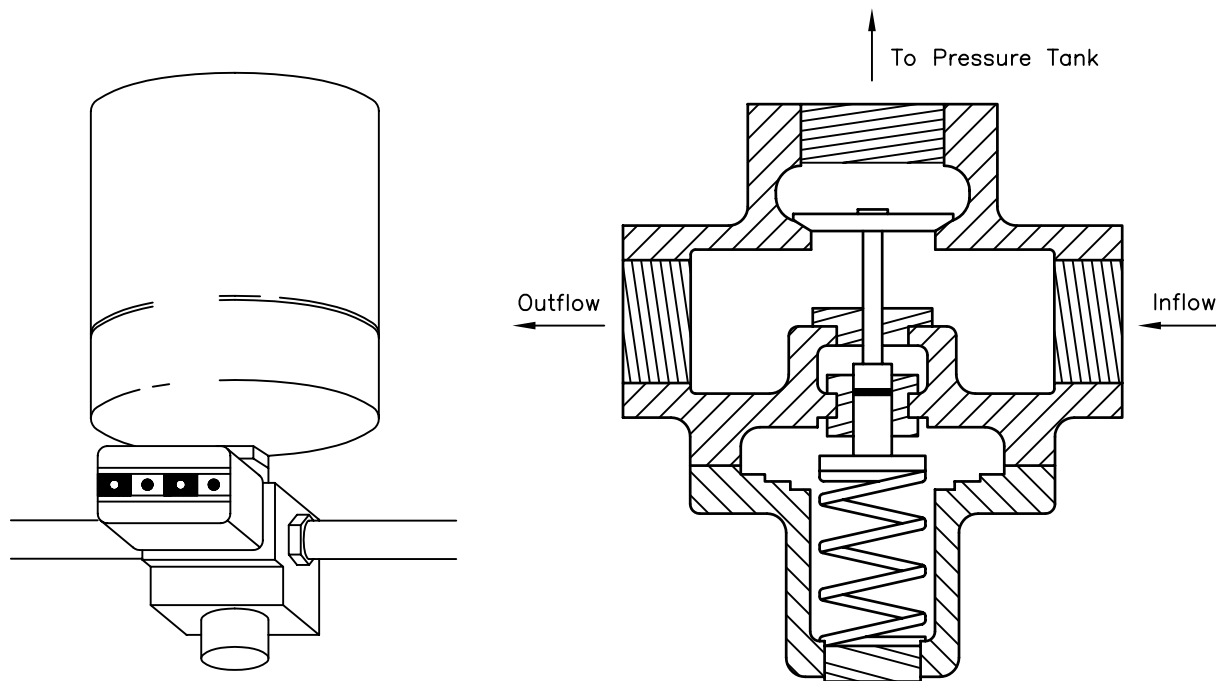


Figure 6.7
FLOW CONTROLLED PRESSURE SWITCH



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.

9.2.6 Operation Plan

Provide an operation plan to the operator cautioning 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

PART	7.1 GENERAL	7-1
PART	7.2 AIR GAS/PROBLEMS	7-1
PART	7.3 AIR IN LOW HEAD GRAVITY PIPELINES	7-3
PART	7.4 AIR CONTROL IN HIGH HEAD, LONG PIPELINES	7-3
PART	7.5 HOW AIR VALVES WORK	7-8
PART	7.6 AIR VALVE INSTALLATION	7-12

FIGURES

Figure	7.1 Releasing Air from Pipeline	7-2
Figure	7.2 Typical System with Air Valves	7-4
Figure	7.3 Vacuum Relief	7-5
Figure	7.4 Release of Large Volumes of Air During Filling	7-6
Figure	7.5 Water and Pressure Keep Float Valve Closed	7-6
Figure	7.6 Air Release Valve for Releasing Air While Pipe is Under Pressure	7-7
Figure	7.7 Typical Air Release Valves	7-9
Figure	7.8 Typical Air Relief/Vacuum Valves (two way)	7-10
Figure	7.9 Typical Air/Vac/Air Release Valves (three way)	7-11
Figure	7.10 Air Valve Installation	7-12

CHAPTER 7

AIR CONTROL

7.1 GENERAL

Air trapped in a livestock watering pipeline 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 lengths.

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 other openings.
- There are various forms of gases 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

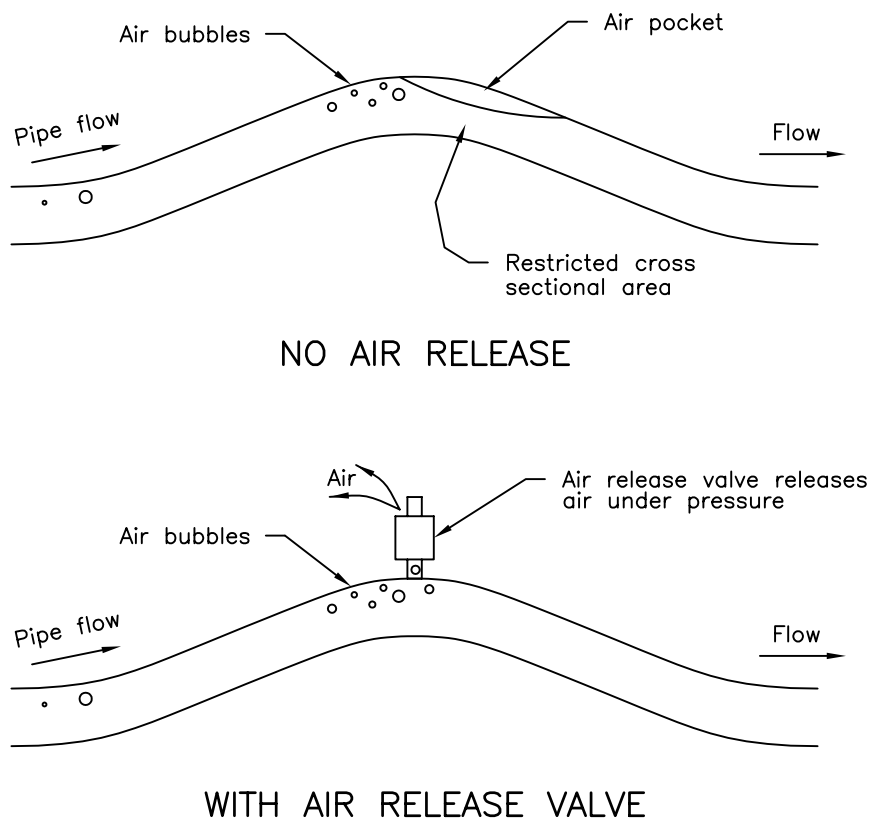


Figure 7.1 illustrates what happens when air is trapped at a high point in a pipeline. A bubble is formed at the high point. The effect is to reduce the cross-sectional area of the pipeline and thus restrict flow. This has the same effect as inserting a short length of small diameter pipe in the pipeline. 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 water hammer 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.
- Install hydrants at all summits in the line so the air can be vented manually.

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.

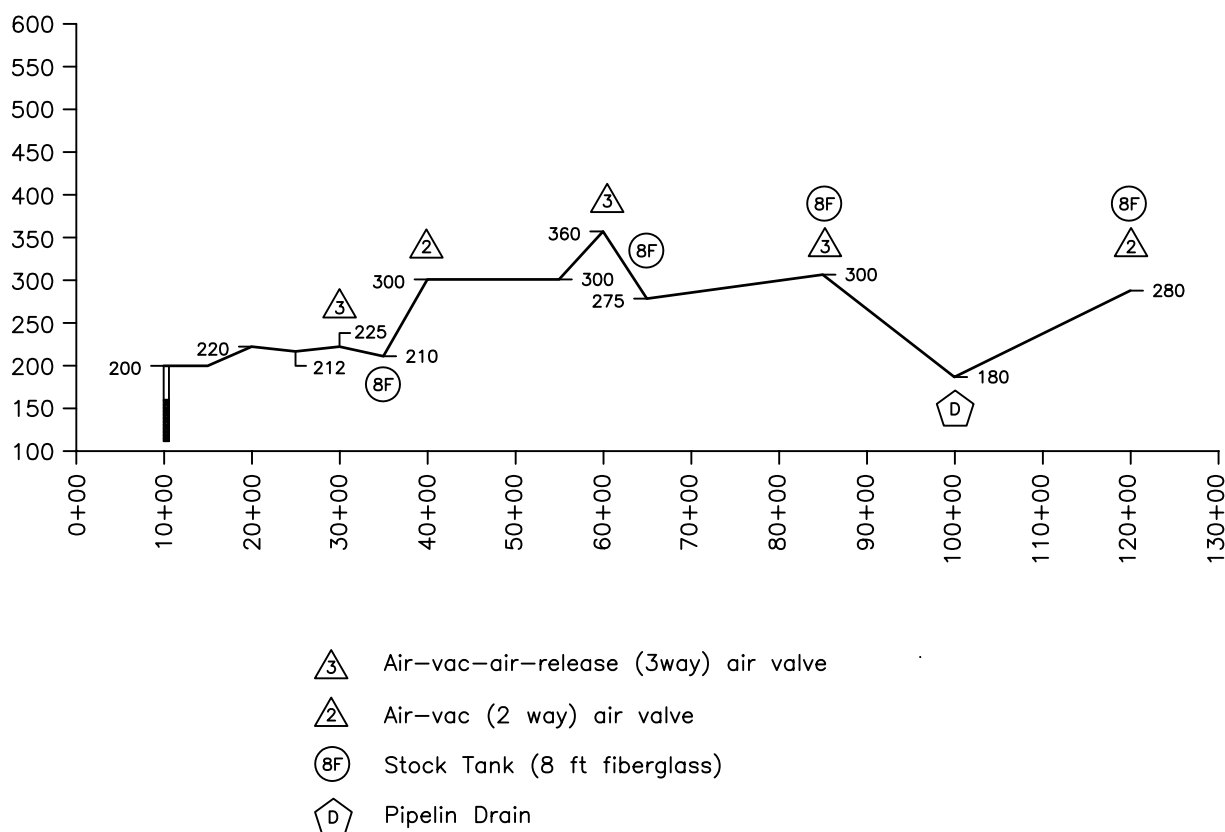
7.4 AIR CONTROL IN HIGH HEAD, LONG PIPELINES

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.
- Install hydrants at summits so the airlock can be vented manually.

- * Install air valve at summits to control the entry and exhausting of air. Figure 7.2 shows this type of installation.
- * Install hydrants at summits so the air lock can be vented manually.

Figure 7.2
TYPICAL SYSTEM WITH AIR VALVES

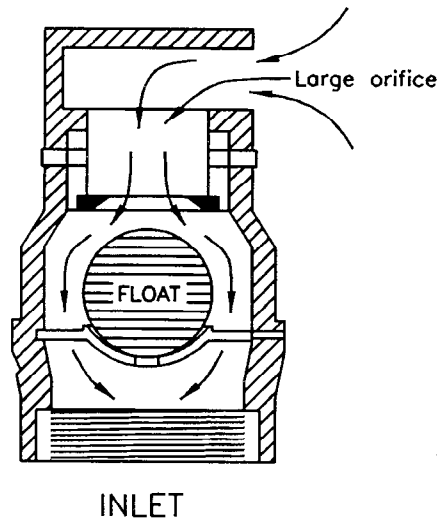


There are three types of functions that air valves perform:

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 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, water hammer 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 VOLUMES OF AIR DURING FILLING

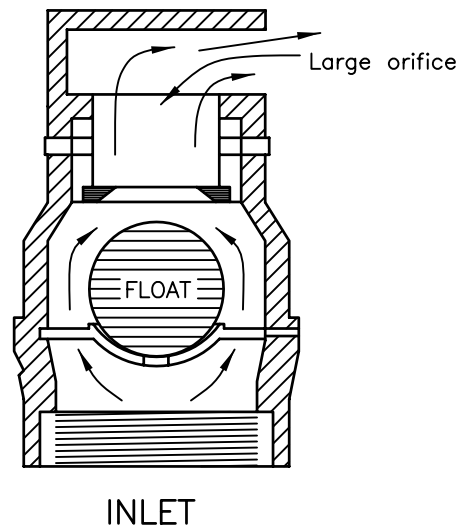
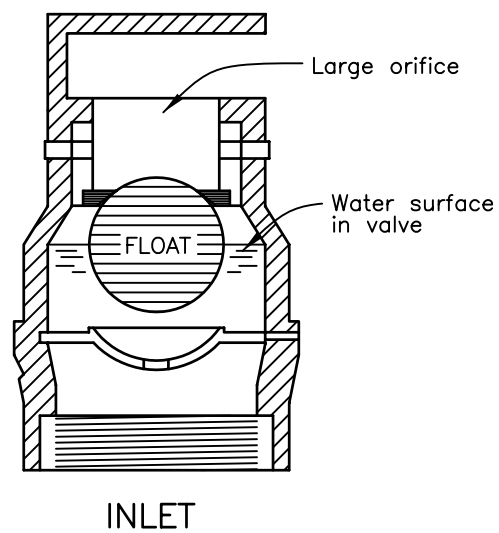


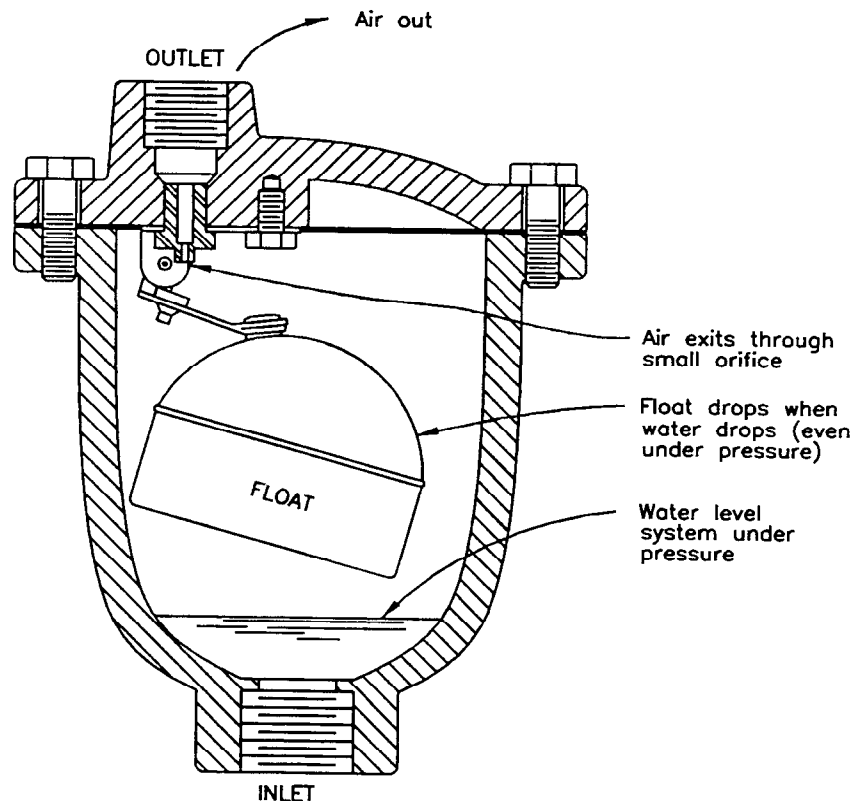
Figure 7.5
WATER AND PRESSURE KEEP FLOAT VALVE CLOSED



3. During operation of the pipeline, air bubbles and other gases come out of solution and build up 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 summit. 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 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 illustrate 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 in flow 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

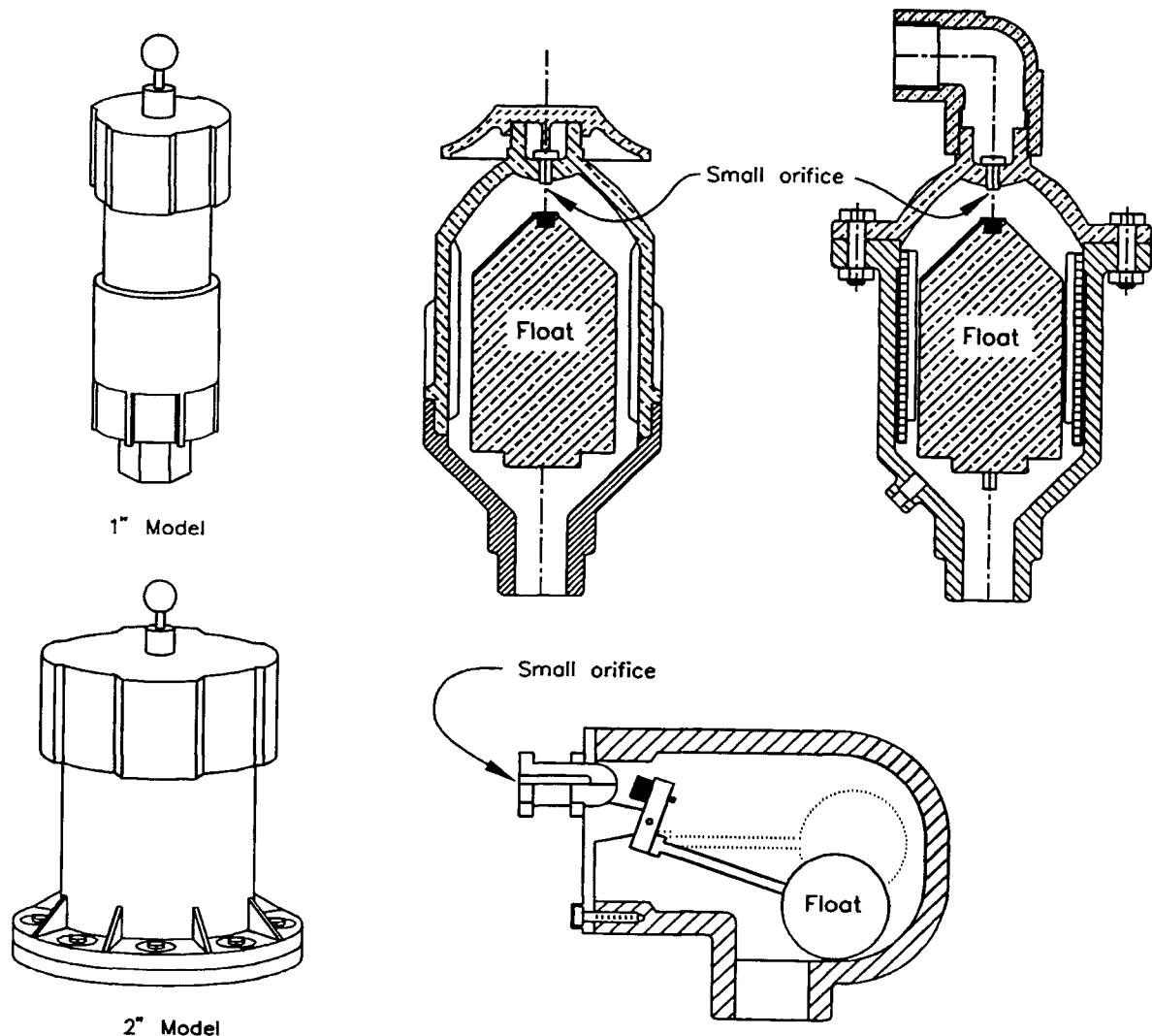


Figure 7.8
TYPICAL AIR RELIEF/VACUUM VALVES (TWO WAY)

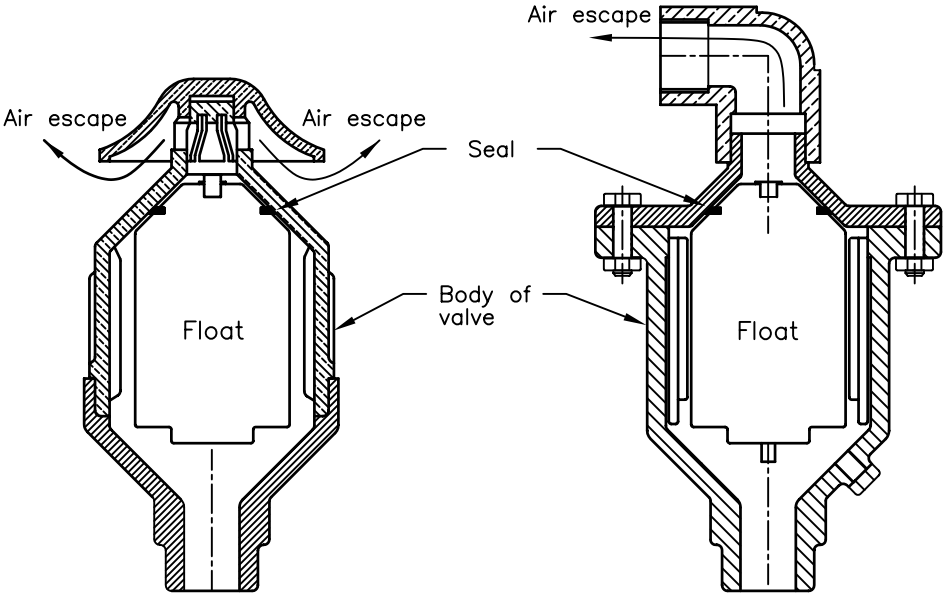
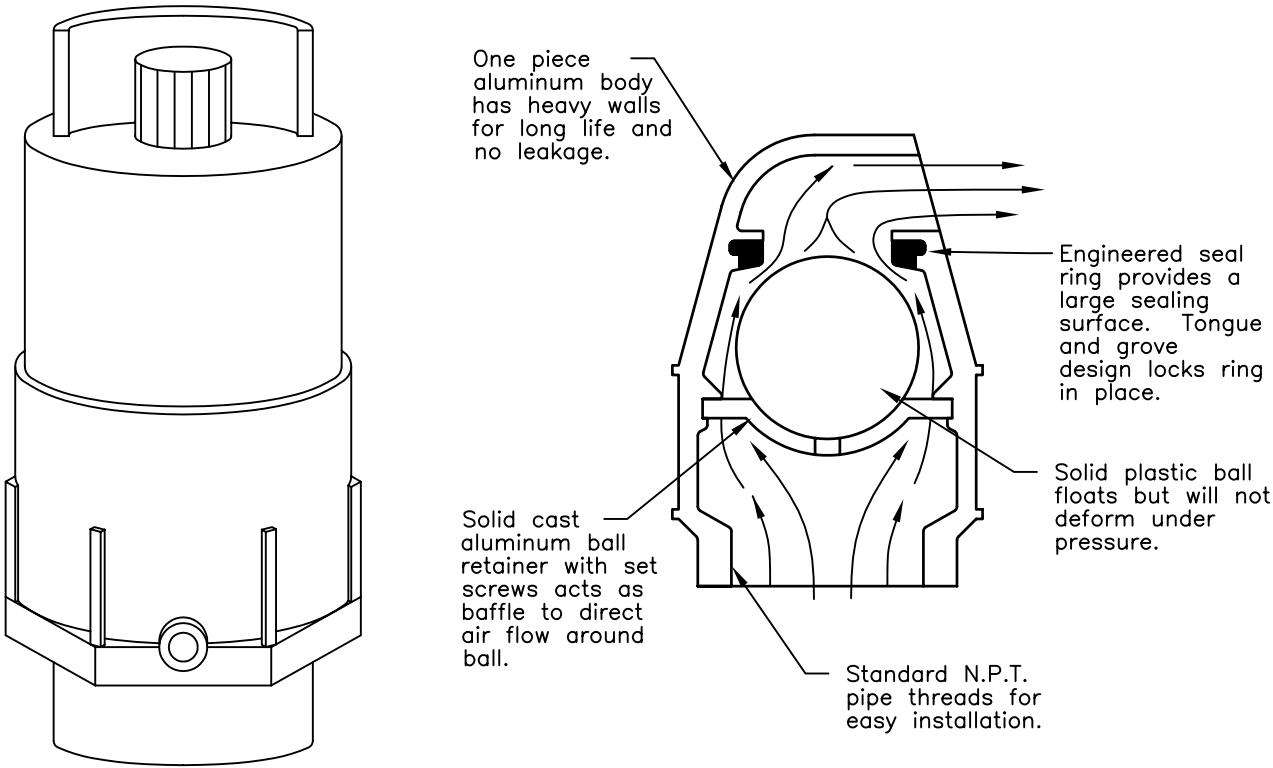
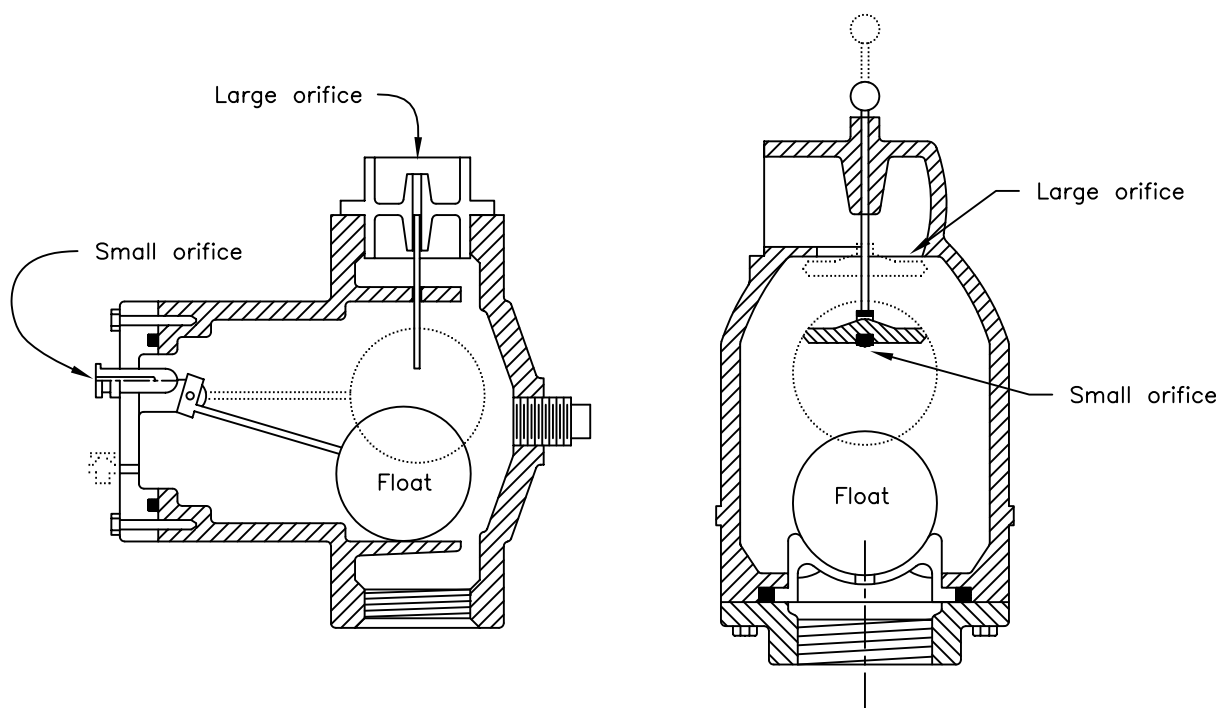
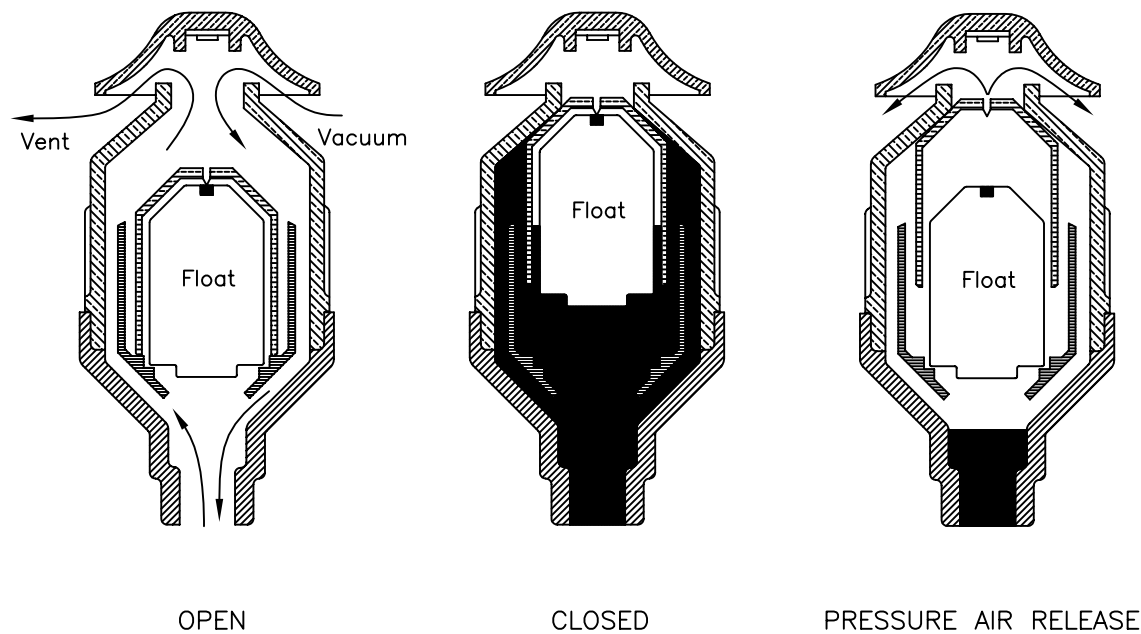
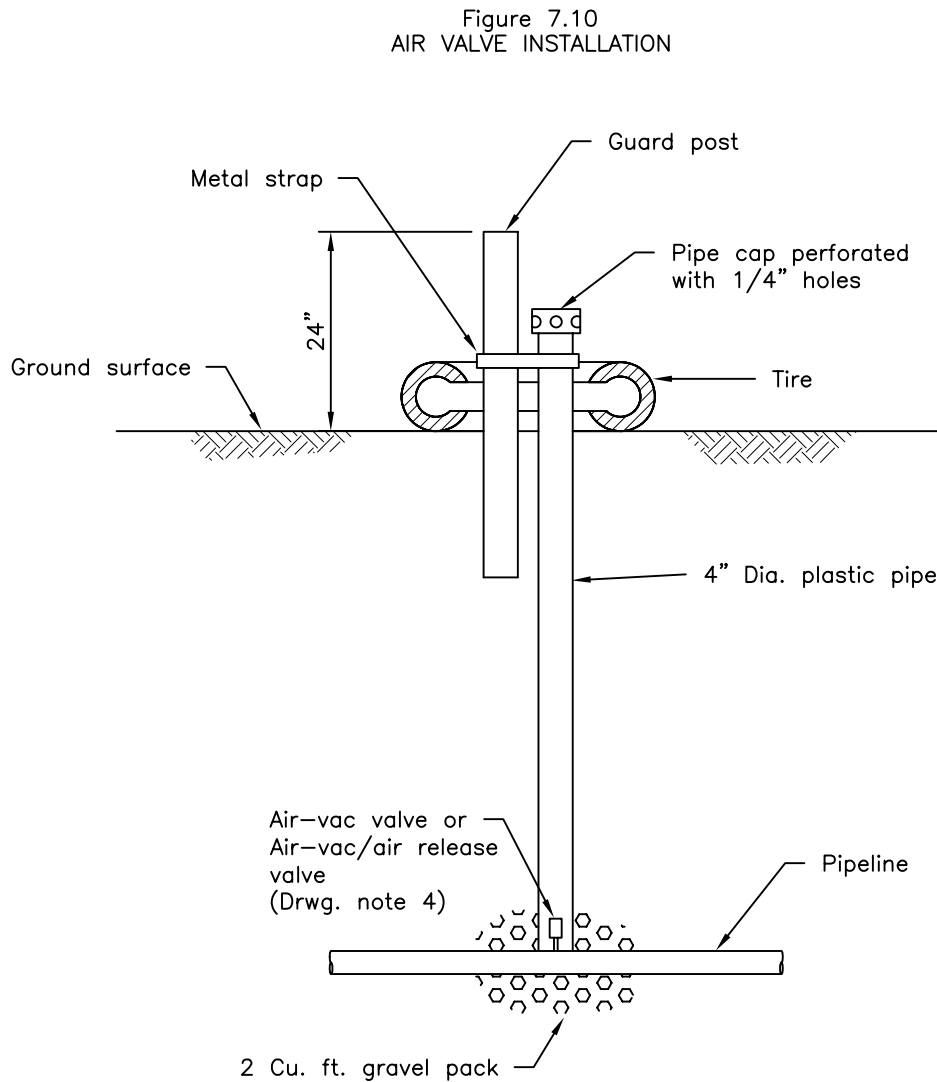


Figure 7.9
TYPICAL AIR/VAC/AIR RELEASE VALVES (THREE WAY)



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.



Chapter 8

System Accessories

CHAPTER 8 PIPELINE SYSTEM ACCESSORIES**TABLE OF CONTENTS**

PART	8.1	SPRING FED PIPELINE ENTRANCE	8-1
PART	8.2	WELLS AND SUMPS	8-5
PART	8.3	PUMPS	8-5
	8.3.1	Submersible Electric Pump, Jet, Turbine and Piston Pump. For Details see MWPS-14.	8-5
	8.3.2	Windmill	8-5
	8.3.3	Wind Generator Powered Pump	8-10
	8.3.4	Solar Powered Pump System	8-11
	8.3.5	Internal Combustion Engine Powered Pumps	8-14
	8.3.6	Hydraulic Rams	8-15
PART	8.4	PRESSURE TANKS	8-18
	8.4.1	Plain Pressure Tank	8-19
	8.4.2	Diaphragm-Type Tank	8-21
	8.4.3	Tank Pressure Rating	8-21
	8.4.4	For additional details of Pressure Tanks See MWPS-14.	8-21
PART	8.5	PRESSURE SWITCHES	8-32
	8.5.1	Switch Characteristics	8-32
	8.5.2	Pressure Guages	8-32
PART	8.6	ELETRICAL PUMP CONTROL EQUIPMENT	8-33
	8.6.1	Automatic Water Level Control	8-33
	8.6.2	Remote Control Pump Float Switch	8-35
PART	8.7	STOCKWATER TANKS	8-37
	8.7.1	Tank Materials	8-37
		Concrete Tanks	8-37
		Fiberglass Tanks	8-43
		Plastic Tanks	8-43
		Galvanized Steel Tanks	8-45
	8.7.2	Water Inlet Protection including Float Valve	8-49
	8.7.3	Protection Around Tanks	8-53
	8.7.4	Tank Overflows	8-53
	8.7.5	Inlet to Pipeline from Tank	8-55
PART	8.8	STORAGE TANKS	8-56
PART	8.9	PIPELINE DRAINS	8-62

FIGURES

Figure	8.1	Typical Spring Box and Pipe Collection	8-1
Figure	8.2	Typical Spring Box and Direct Collection	8-2
Figure	8.3	Water Collection without Spring Box	8-3
Figure	8.4	Typical Spring Fed Pipeline	8-4
Figure	8.5	Windmill as Supply to Tank	8-6
Figure	8.6	Windmill Connected to Pipeline	8-7
Figure	8.7	Wind Generator Powered Pump	8-10
Figure	8.8	Typical Solar Submersible and Rotary Vane Type Pumps	8-12
Figure	8.9	Jack Type of Solar Pump	8-13
Figure	8.10	Propane Powered, Automatic Generator for Pump	8-14
Figure	8.11	Typical Hydraulic Ram Installation	8-16
Figure	8.12	Small Plastic Hydraulic Rams	8-16
Figure	8.13	Large Steel Hydraulic Rams	8-17
Figure	8.14	How a Pressure Tank Works	8-18

CHAPTER 8 PIPELINE SYSTEM ACCESSORIES**TABLE OF CONTENTS****FIGURES (CONT.)**

Figure	8.15 Multiple Pressure Tank Installation	8-19
Figure	8.16 Plain Pressure Tank Capacity	8-20
Figure	8.17 Float Switch Pump Control	8-33
Figure	8.18 Water Level in Storage Tank and in Well	8-34
Figure	8.19 Remote Float Operated Switching Equipment	8-35
Figure	8.20 Water Level Control Switches	8-36
Figure	8.21 Concrete Tank	8-39
Figure	8.22 Concrete Trough	8-40
Figure	8.23 Tank Made from Concrete Pipe	8-41
Figure	8.24 Frost Proof Concrete Tank	8-42
Figure	8.25 Frost Free Fiberglass Tank	8-44
Figure	8.26 Tank Made from Corrugated Steel Segments	8-46
Figure	8.27 Manufactured Steel Tank	8-47
Figure	8.28 Frost Free Steel Tank	8-48
Figure	8.29 Typical Tank Layout Plans	8-50
Figure	8.30 Tank Details	8-51
Figure	8.31 Layout Using Submerged Float Valve	8-52
Figure	8.32 Overflows	8-54
Figure	8.33 Pipeline Tank Inlet	8-55
Figure	8.34 Commercial Steel Water Storage Tank	8-57
Figure	8.35 Fabricated Steel Storage Tank	8-58
Figure	8.36 Constructed Corrugated Steel Storage Tank	8-59
Figure	8.37 Fiberglass Storage Tank	8-60
Figure	8.38 Water Harvesting System Using Rubberized Fabric Storage Bag	8-61
Figure	8.39 Pipeline Drains	8-63

TABLES

Table	8.1	Approximate Windmill Capacity	8-8
Table	8.2	Windmill Pumping Head	8-9
Table	8.3 to 8.7	Diaphragm Pressure Tank Size Selection Minimum Recommended Total Storage Tank Size	8-22 to 8-26
Table	8.8 to 8.12	Plain Pressure Tank Size Selection, Minimum Recommended Total Storage Tank Size	8-27 to 8-31

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. Other spring development plans are shown in Missouri Standard Drawings and Specifications Handbook.

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 Handbook provides information on developing springs and spring water collection systems.

Figure 8.1
TYPICAL SPRING BOX AND PIPE COLLECTION

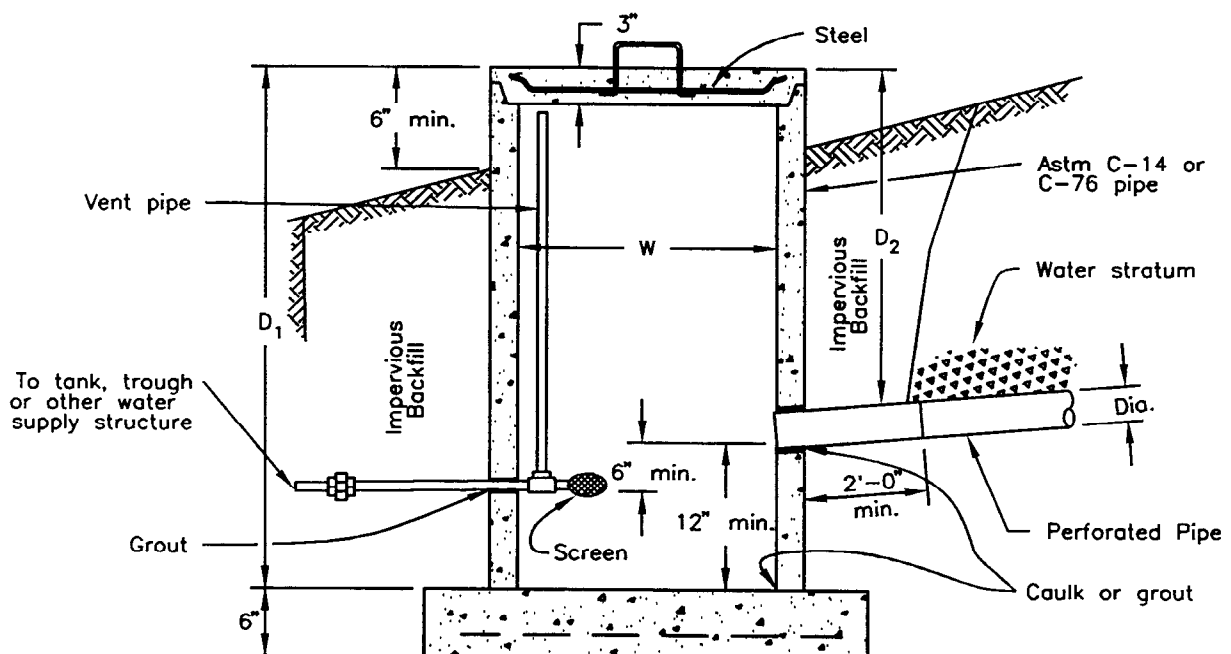


Figure 8.2
TYPICAL SPRING BOX DIRECT COLLECTION

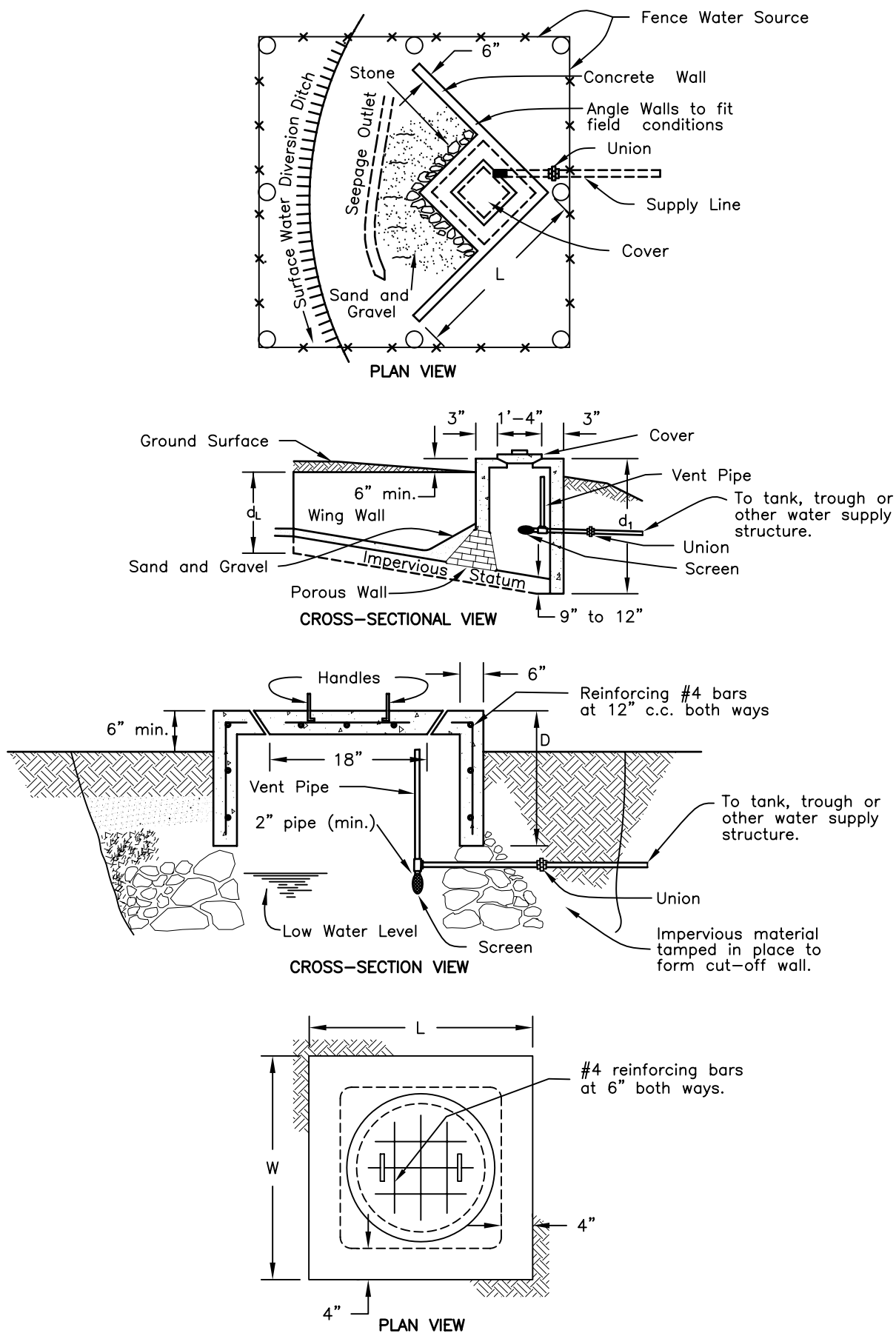
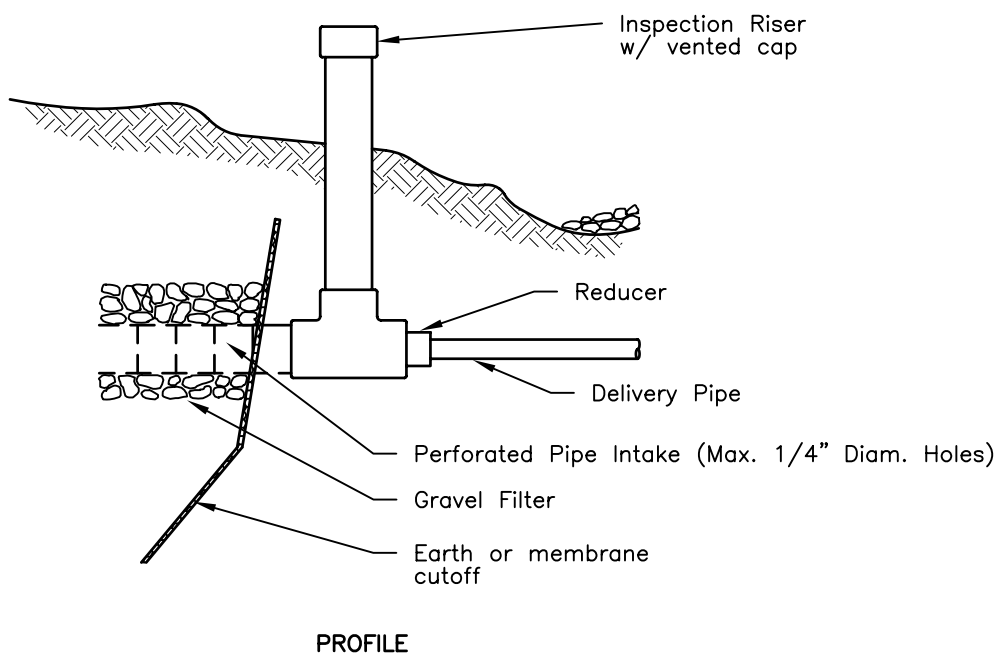
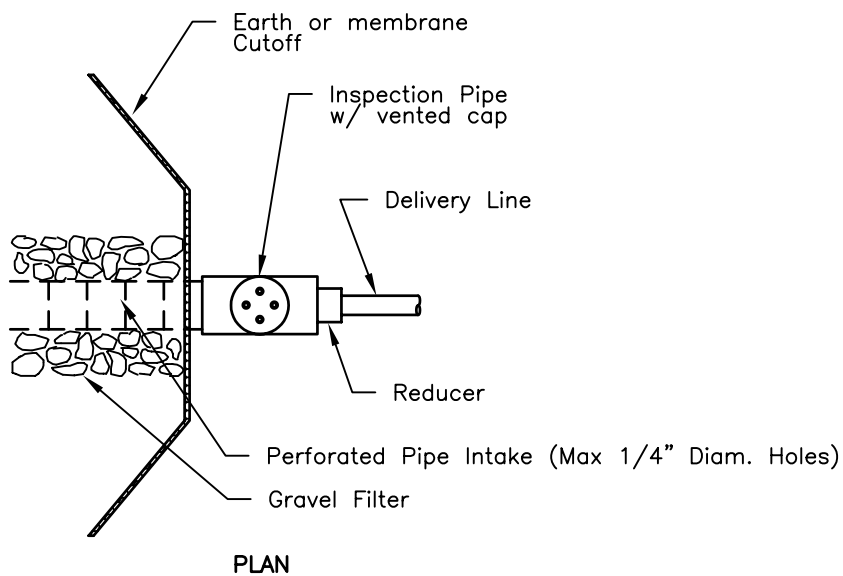


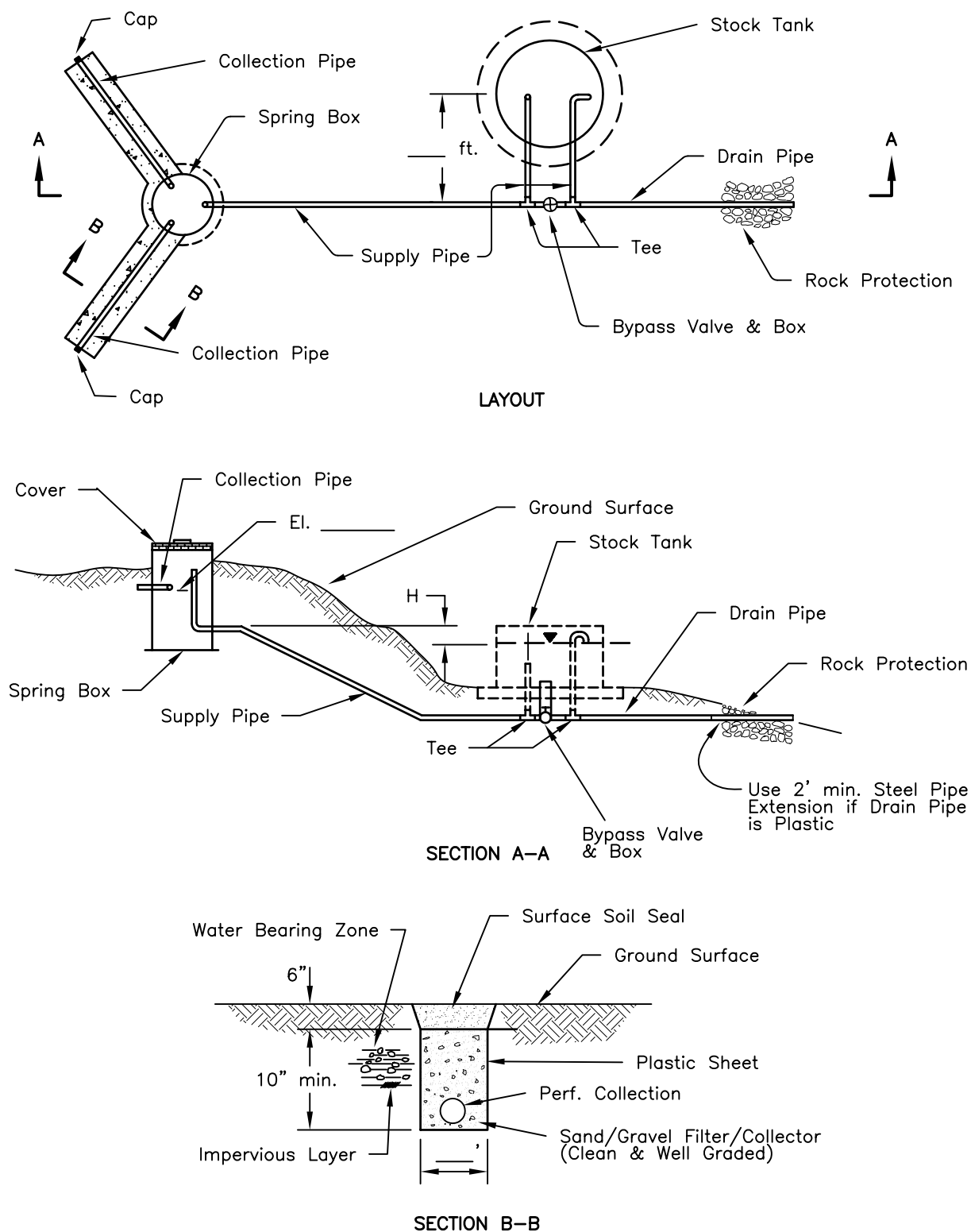
Figure 8.3
WATER COLLECTION WITHOUT SPRING BOX



Note:

1. 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.
2. Drilling 24-1/4" diameter holes per foot will make a good perforated pipe intake for 4 inch diameter PVC pipe.

Figure 8.4
TYPICAL SPRING FED PIPELINE



8.2 WELLS AND SUMPS

Figure 8.6 illustrates a typical pitless adapter type of submersible pump installation. The pitless adapter 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 Handbook (EFH) 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, Jet, Turbine and Piston Pumps.

FOR DETAILS SEE SHEETS 25 TO 38 OF MIDWEST PLAN SERVICE PUBLICATION MWPS-14.

8.3.2 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 water storage to carry over during periods of little or no wind. Windmills also require frequent checking and maintenance.

Figure 8.5
WINDMILL AS SUPPLY TO TANK

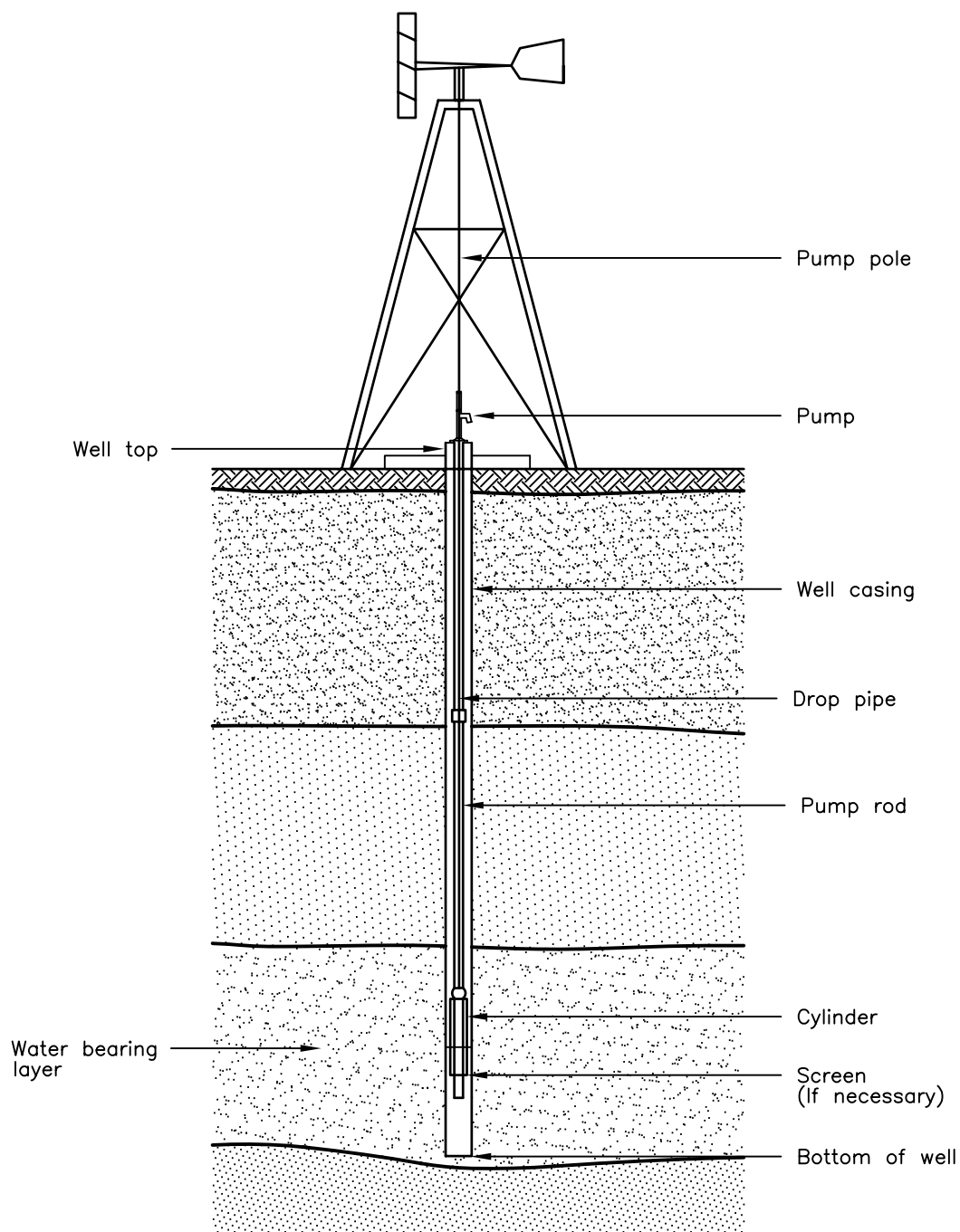


Figure 8.6 illustrates how to connect a windmill to a pipeline. When designing a windmill supplied pipeline the total dynamic head equals static head plus losses in the drop pipe plus pipeline losses.

Figure 8.6
WINDMILL CONNECTED TO PIPELINE

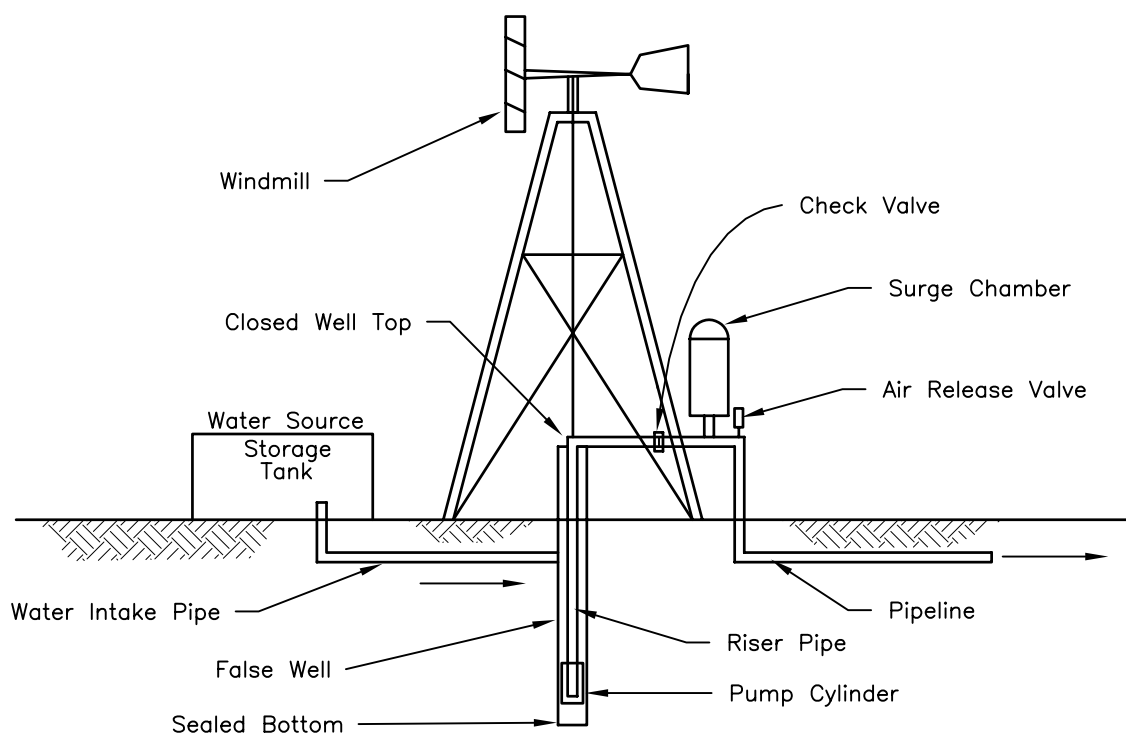


Table 8.1 tabulates approximate windmill capacities and Table 8.2 tabulates approximate pumping heads. These are based on winds exceeding 12 mph. Short stroke systems increase pumping head by 1/3 and reduce pumping capacity by 1/4.

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
(Gallons per hour)

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
 (feet)

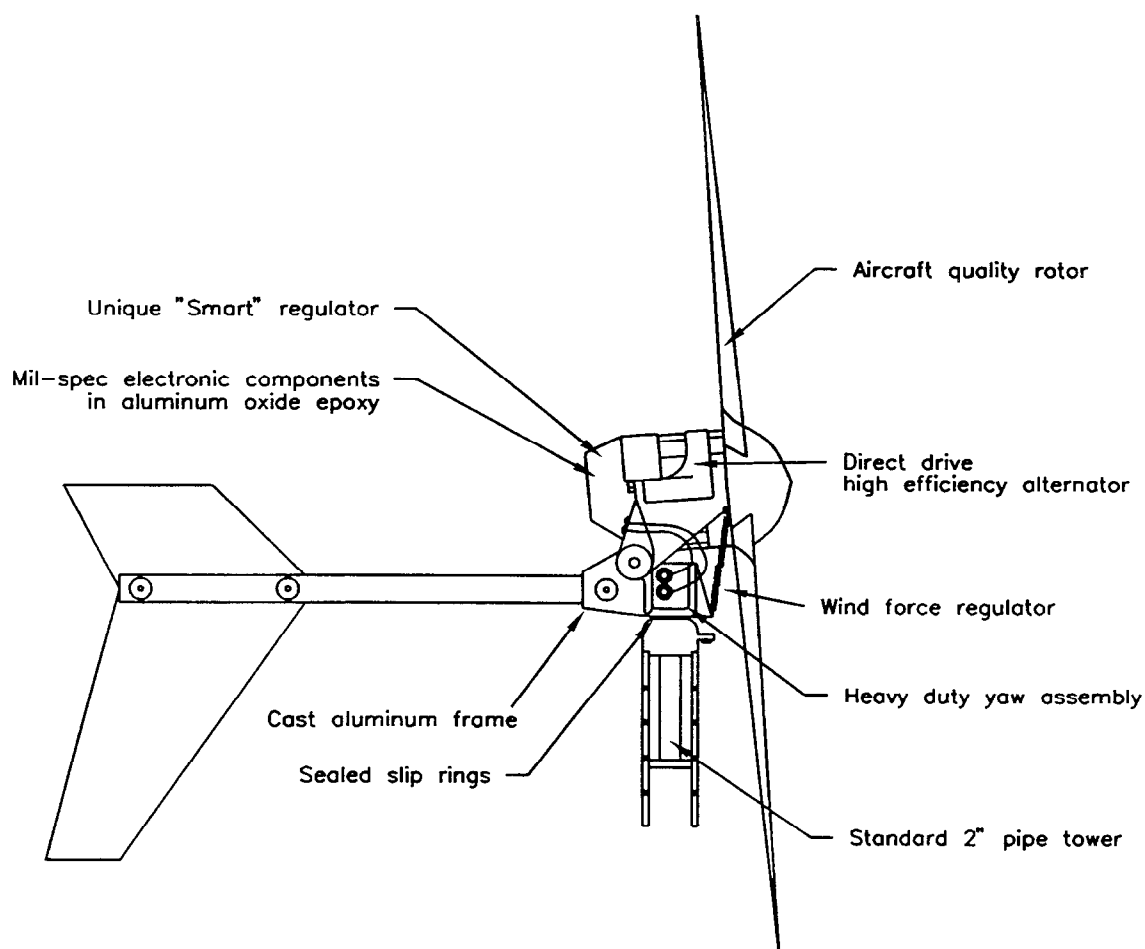
Cylinder Diameter (inches)	Wheel Diameter (feet)					
	6	8	10	12	14	16
3/4	130	185	280	420	600	1000
1-7/8	120	175	260	390	560	920
2	95	140	215	320	460	750
2-1/4	77	112	170	250	360	590
2-1/2	65	94	140	210	300	490
2-3/4	56	80	120	180	260	425
3	47	68	100	155	220	360
3-1/4	41	58	88	130	185	305
3-1/2	35	50	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	7	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

8.3.3 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 8.7 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 8.7
WIND GENERATOR POWERED PUMP



8.3.4 Solar Powered Pump System

Solar powered pumps have the advantage of operating as long as there is adequate sunlight. In many parts of Missouri 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 8.8 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 pannel allows greater power gain throughout the day. These are simple systems without batteries or converters.

Figure 8.9 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 8.8
TYPICAL SOLAR SUBMERSIBLE AND ROTARY VANE TYPE PUMPS

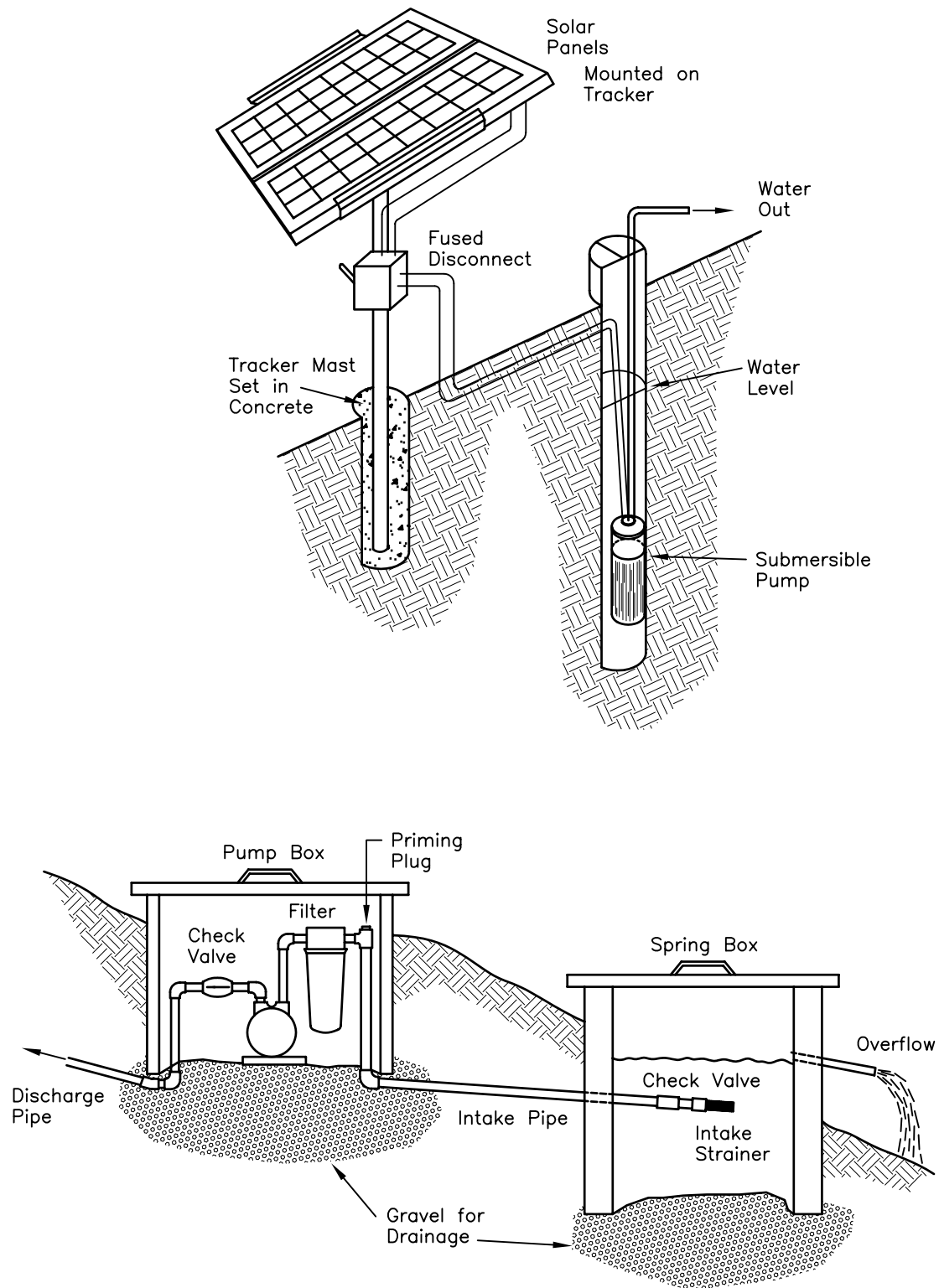
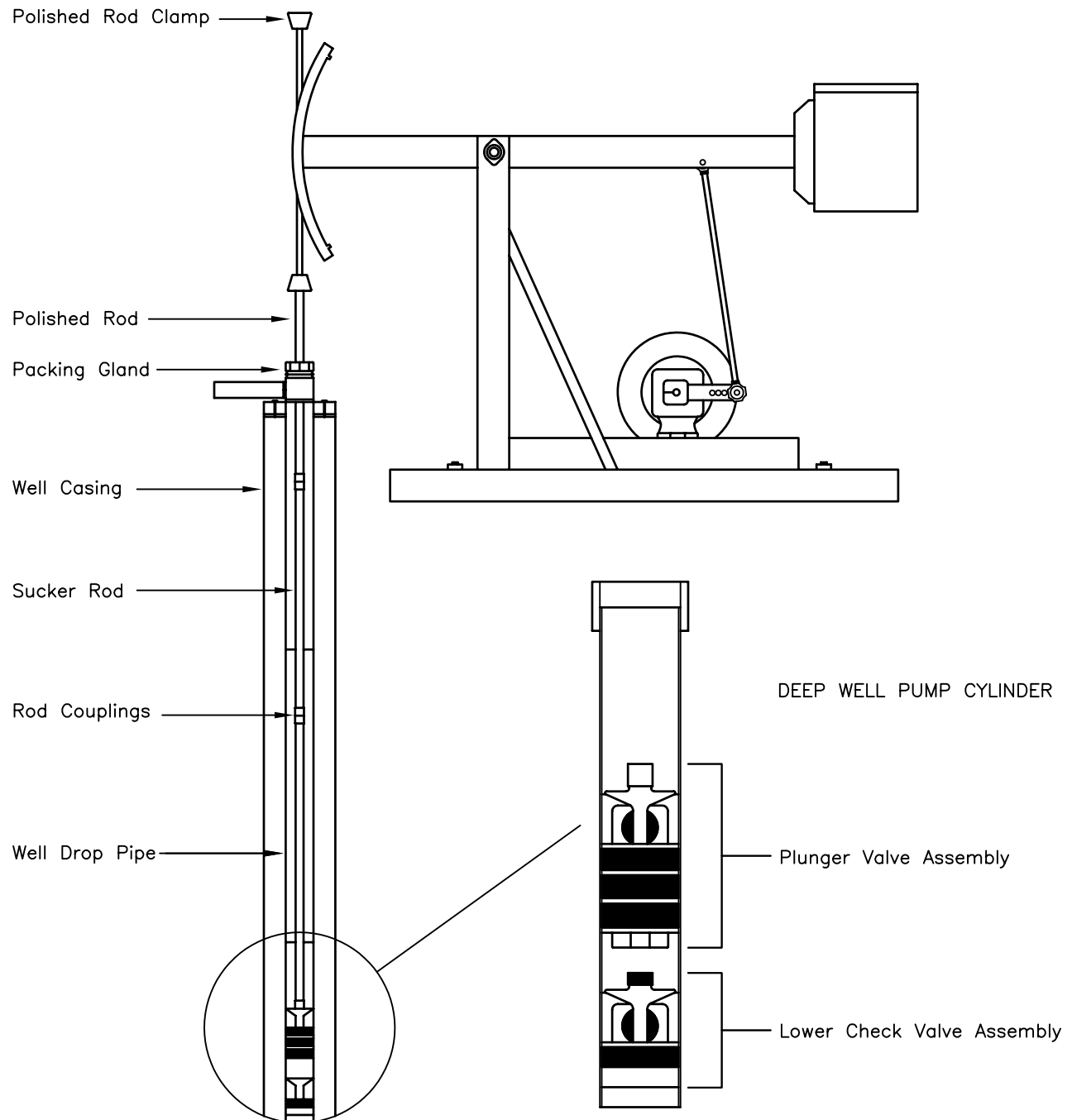


Figure 8.9
JACK TYPE SOLAR PUMP



8.3.5 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.

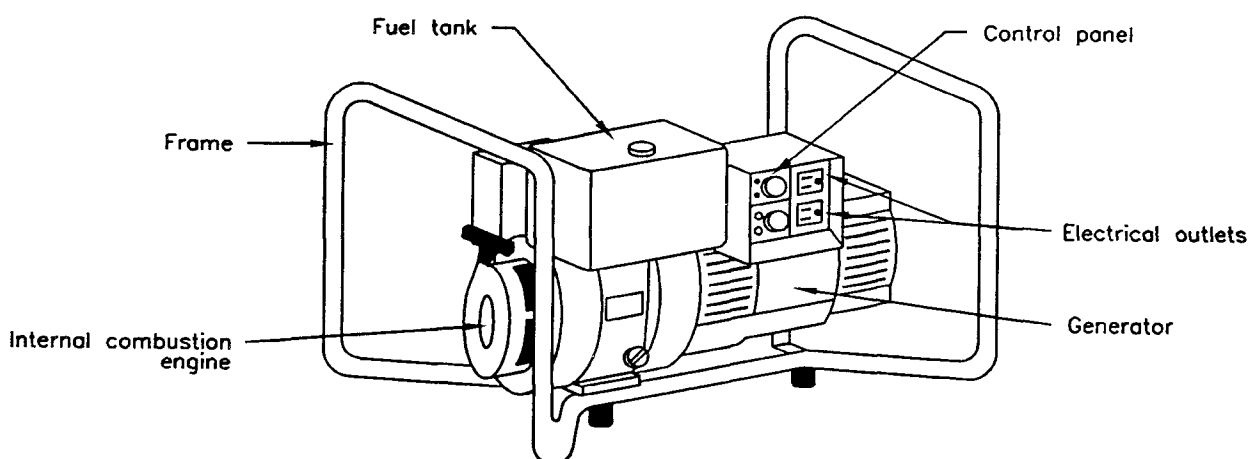
Engine operated systems require frequent monitoring. A large water storage tank should be part of the system to supplement times when the system fails or for some other reason is not started on time.

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 engine 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 can 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 8.10 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.

Figure 8.10
PORTABLE GENERATOR FOR PUMP



8.3.6 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 8.11 illustrates how this type of system is set up. A poppet valve in the ram opens allowing water to flow. As the water gains velocity in the supply pipe, it causes the poppet 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 (water hammer) 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 8.11
TYPICAL HYDRAULIC RAM INSTALLATION

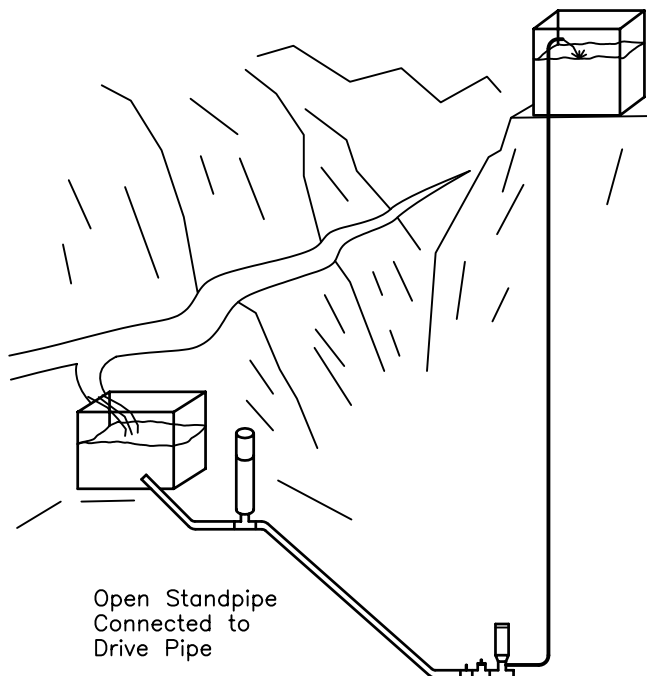


Figure 8.12
SMALL PLASTIC HYDRAULIC RAM

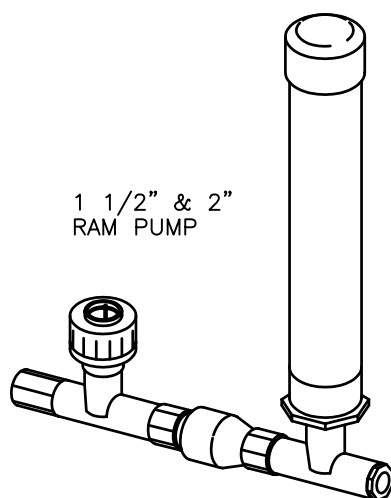
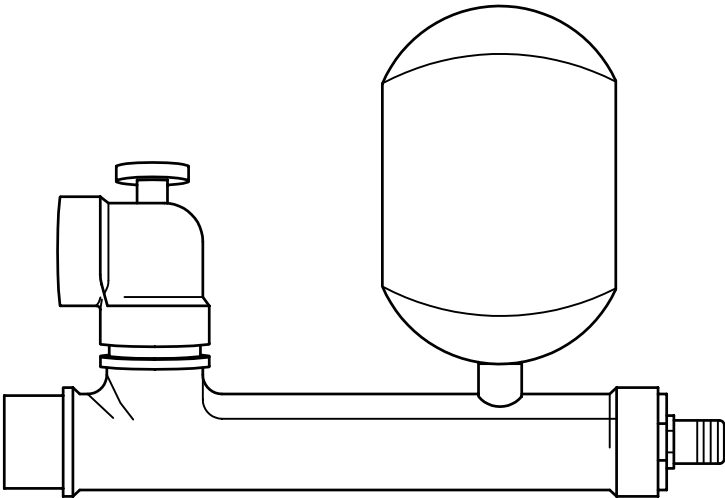
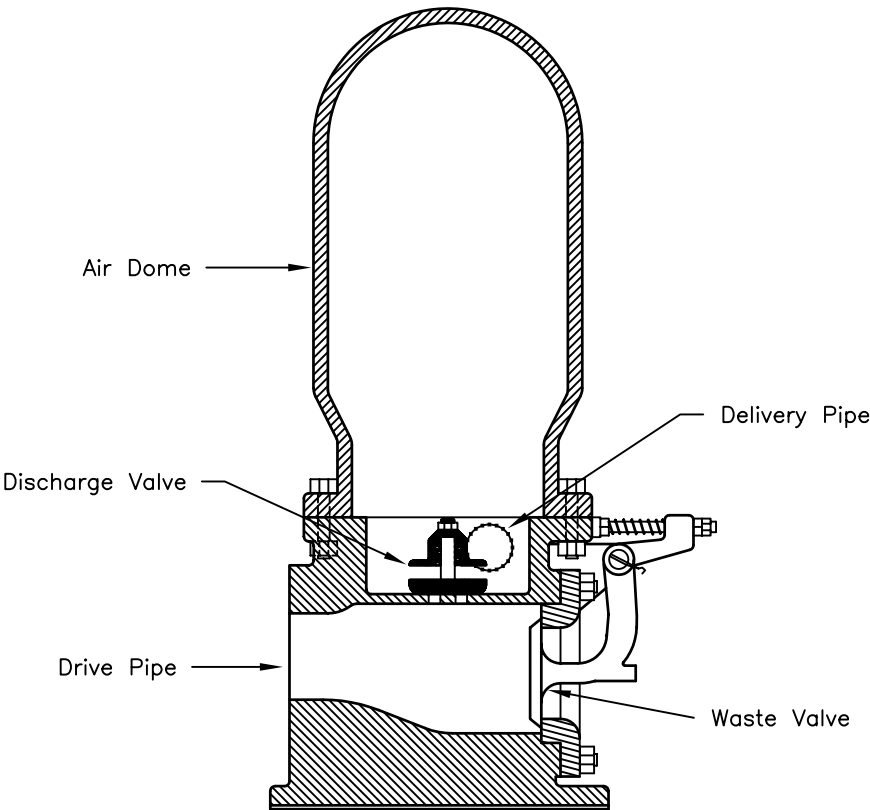


Figure 8.13
LARGE STEEL HYDRAULIC RAMS



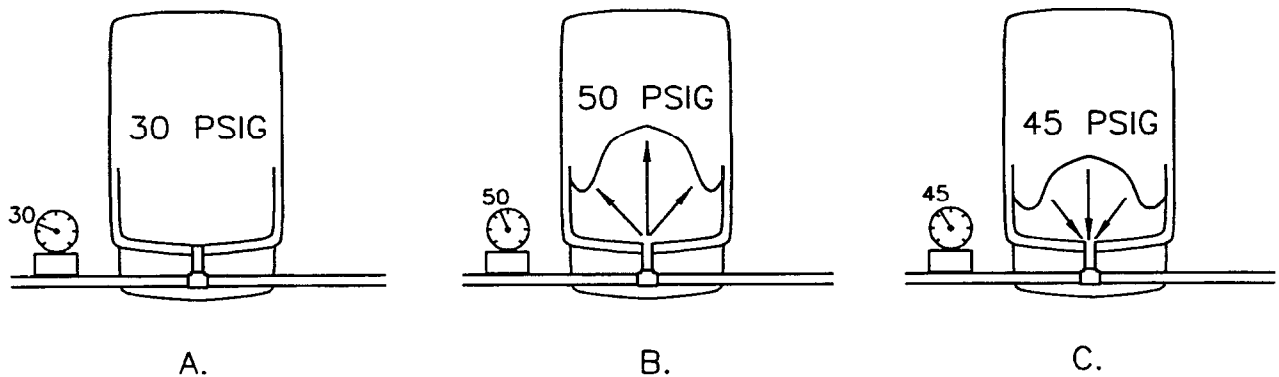
8.4 PRESSURE TANKS

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 8.14 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 8.14
HOW A PRESSURE TANK WORKS

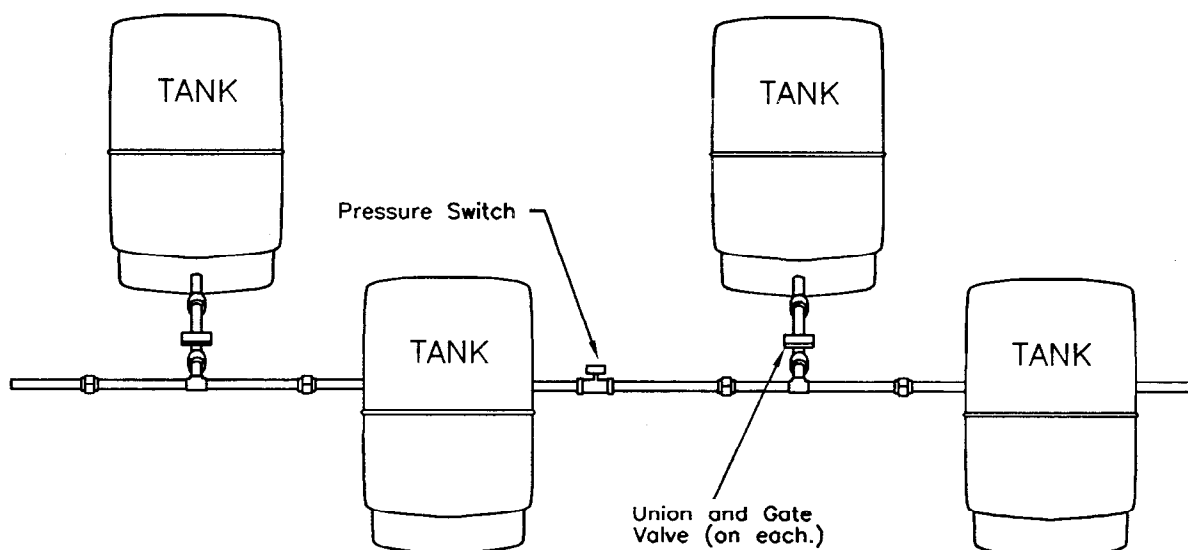


Cut-in pressure is that pressure at which the pump is automatically turned on. Cut-out is the pressure at which the pump is turned off.

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 8.15 illustrates how this is done.

Figure 8.15
MULTIPLE PRESSURE TANK INSTALLATION



8.4.1 Plain Pressure Tank

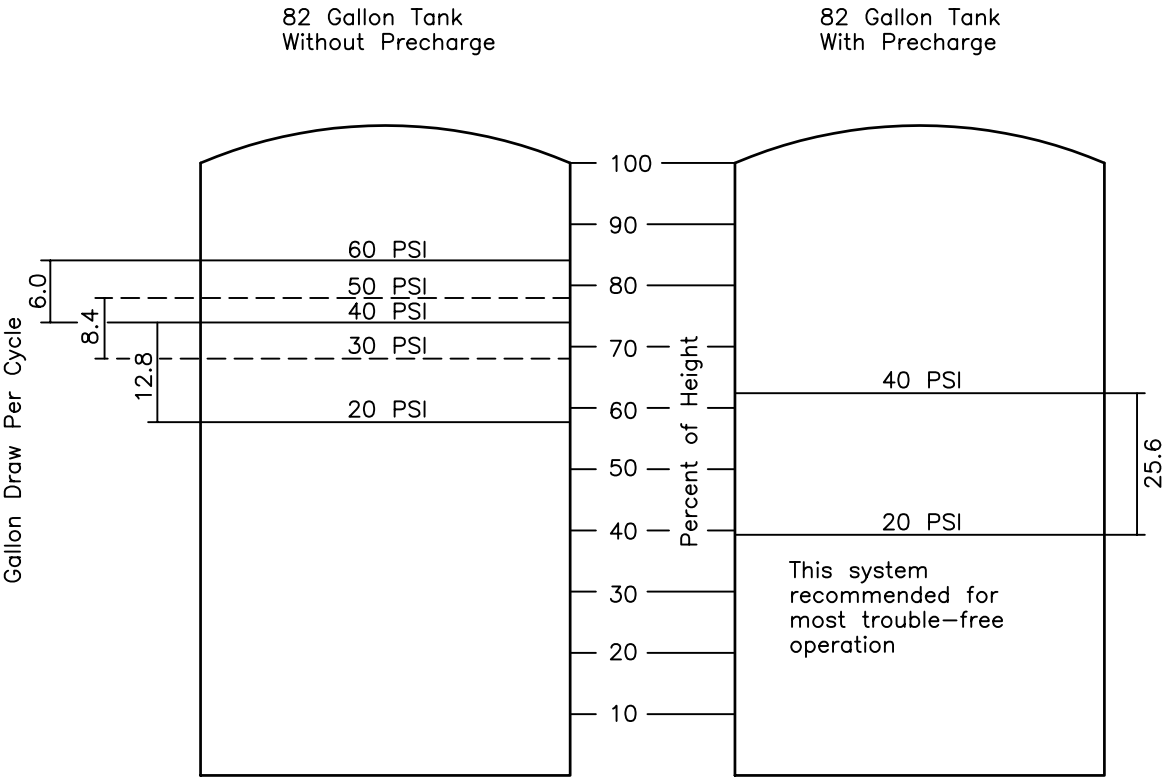
In a plain pressure tank, air can be lost over time. This loss is due to absorption into the water or, if pressure in the system falls below a certain point, air can escape into the pipeline.

Figure 8.16 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 8.16. 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 8.16, 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 8.16
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 8.14. Air cannot be absorbed by water and air can-not 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 it's 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.

8.4.4 FOR ADDITIONAL DETAILS OF PRESSURE TANKS AND CONTROLS SEE MIDWEST PLAN SERVICE PUBLICATION MWPS-14, PAGES 39 THRU 40.

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

The minimum storage tank size in tables 8.3 through 8.12 are intended as a guide. Other sizes as recommended by pump manufacturers and pump installers may be used.

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)	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. Any adjustment should be made by an experienced pump installer.

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 high 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.

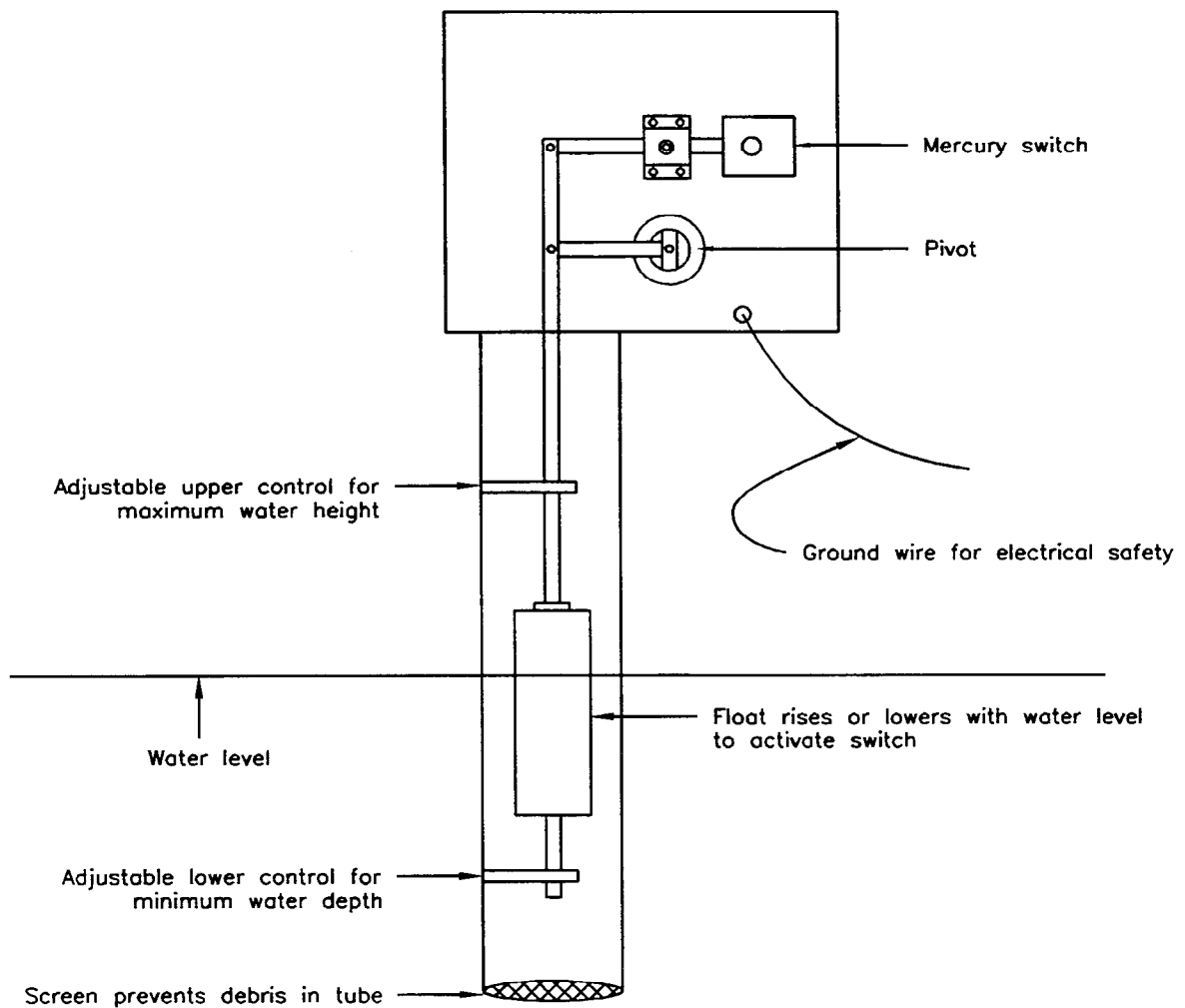
8.6 Electrical Pump Control Equipment

8.6.1 Automatic Water Level Control

A float switch which directly controls a pump is illustrated in Figure 8.17

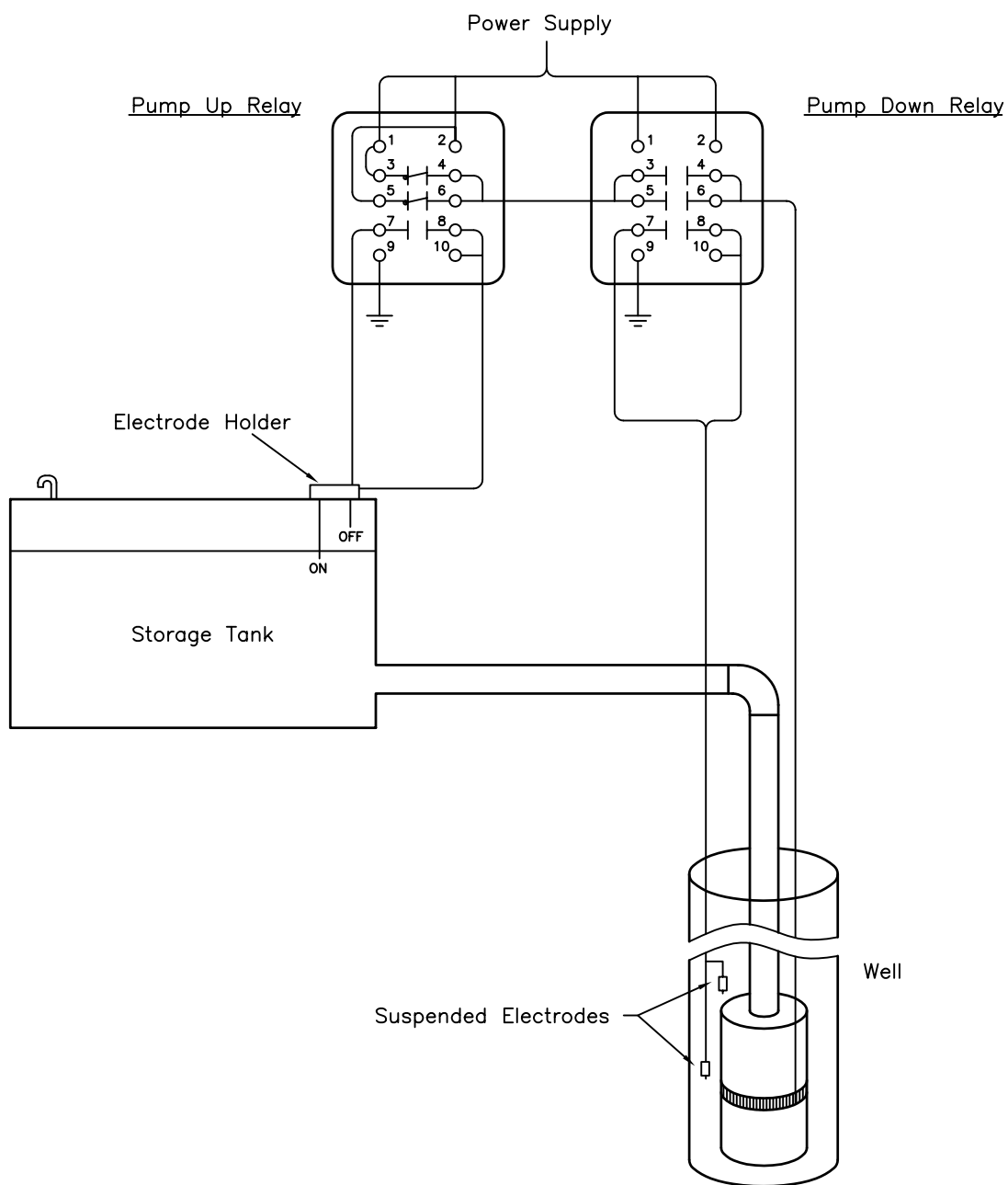
In addition to controlling the filling of a single tank, these types of switches can be used to fill a tank from which a gravity pipeline system is fed.

Figure 8.17
FLOAT SWITCH PUMP CONTROL



A mechanism to control a pump based on water levels in both well and tank is shown in Figure 8.18. This should be used where water level in the well must control the pump.

Figure 8.18
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 8.19 illustrates typical switching equipment for a remote tank. Figure 8.20 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.

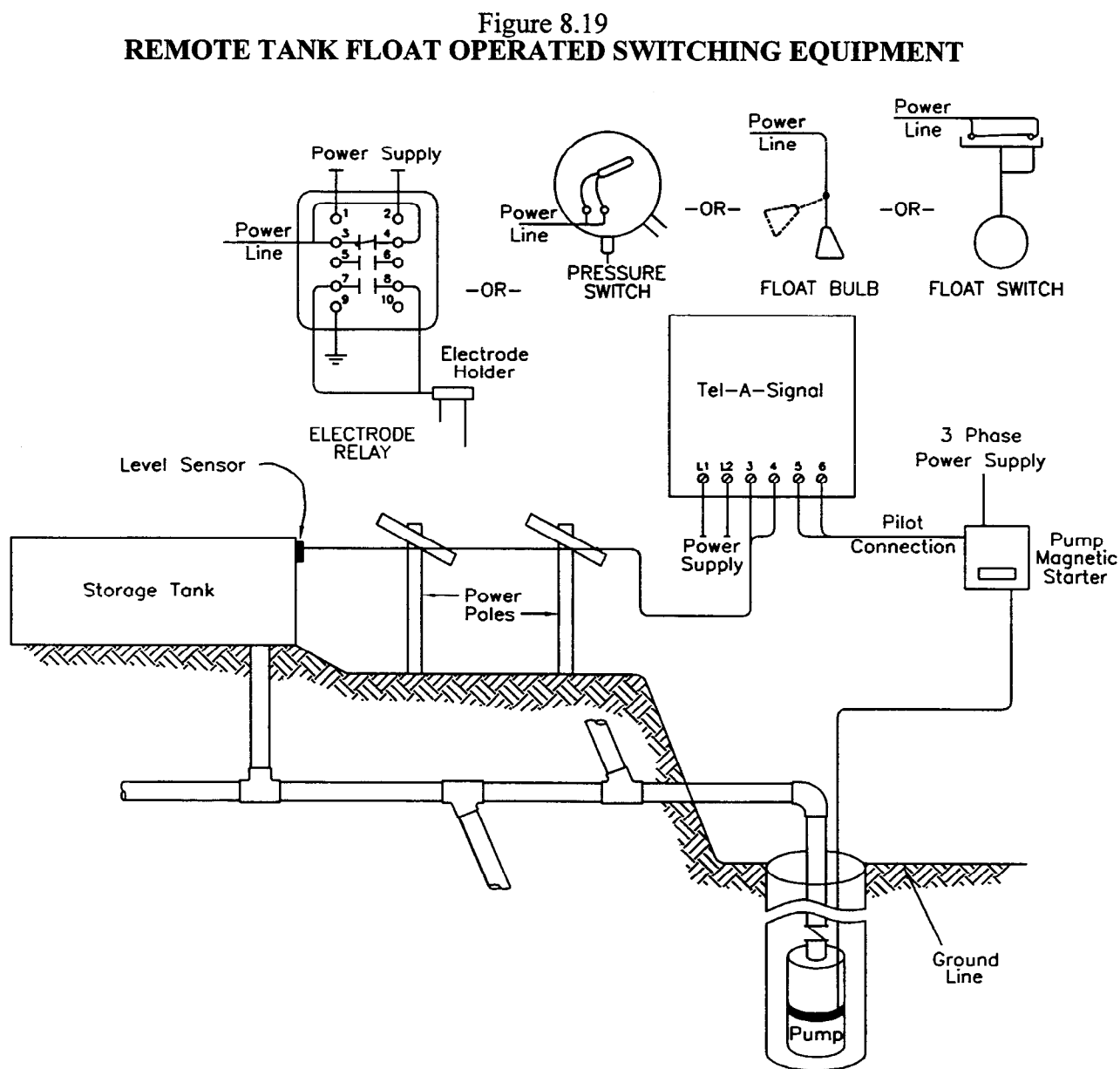
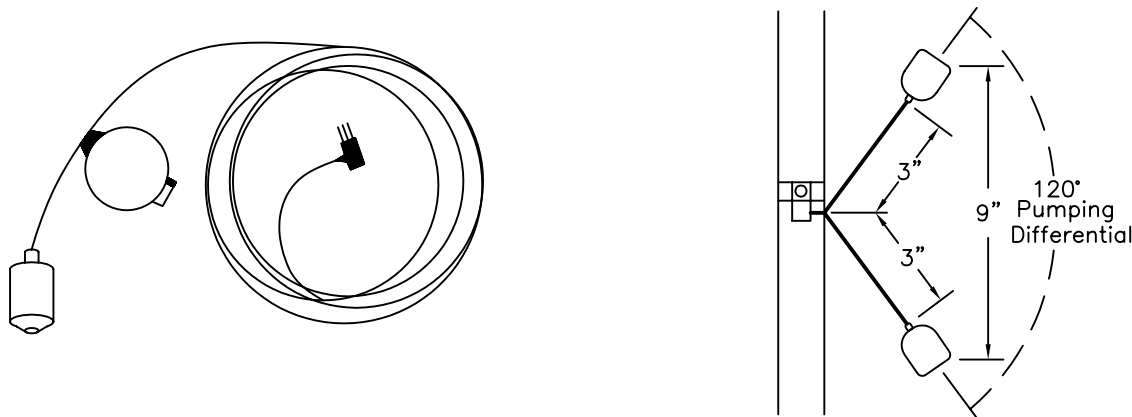
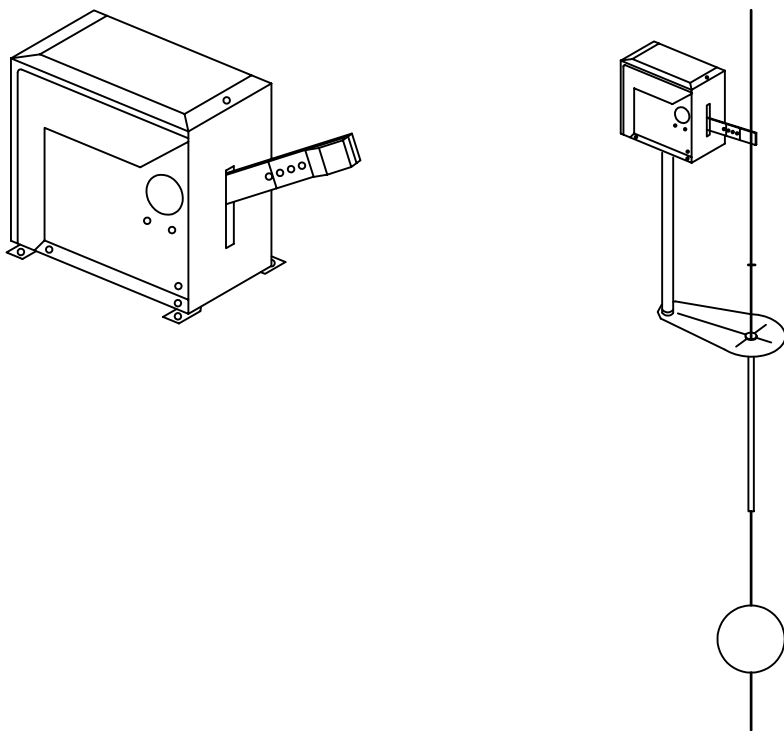


Figure 8.20
WATER LEVEL CONTROL SWITCHES



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, 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.

A floating bird board or equivalent in a stockwater tank will help prevent the accidental drowning of birds and other small animals. Rodent escape boards are also beneficial. This will also help to reduce contamination of water supply.

8.7.1 Tank Materials

Materials should be chosen not only for economic reasons, but to resist attack by the particular environmental hazards existing 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 Missouri. 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 8.21 illustrates a typical concrete tank. Figure 8.22 details a concrete trough. Figure 8.23 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.

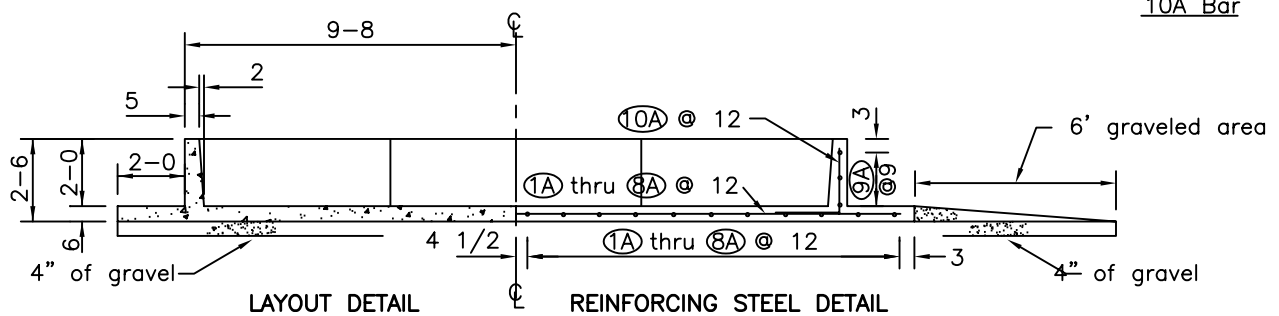
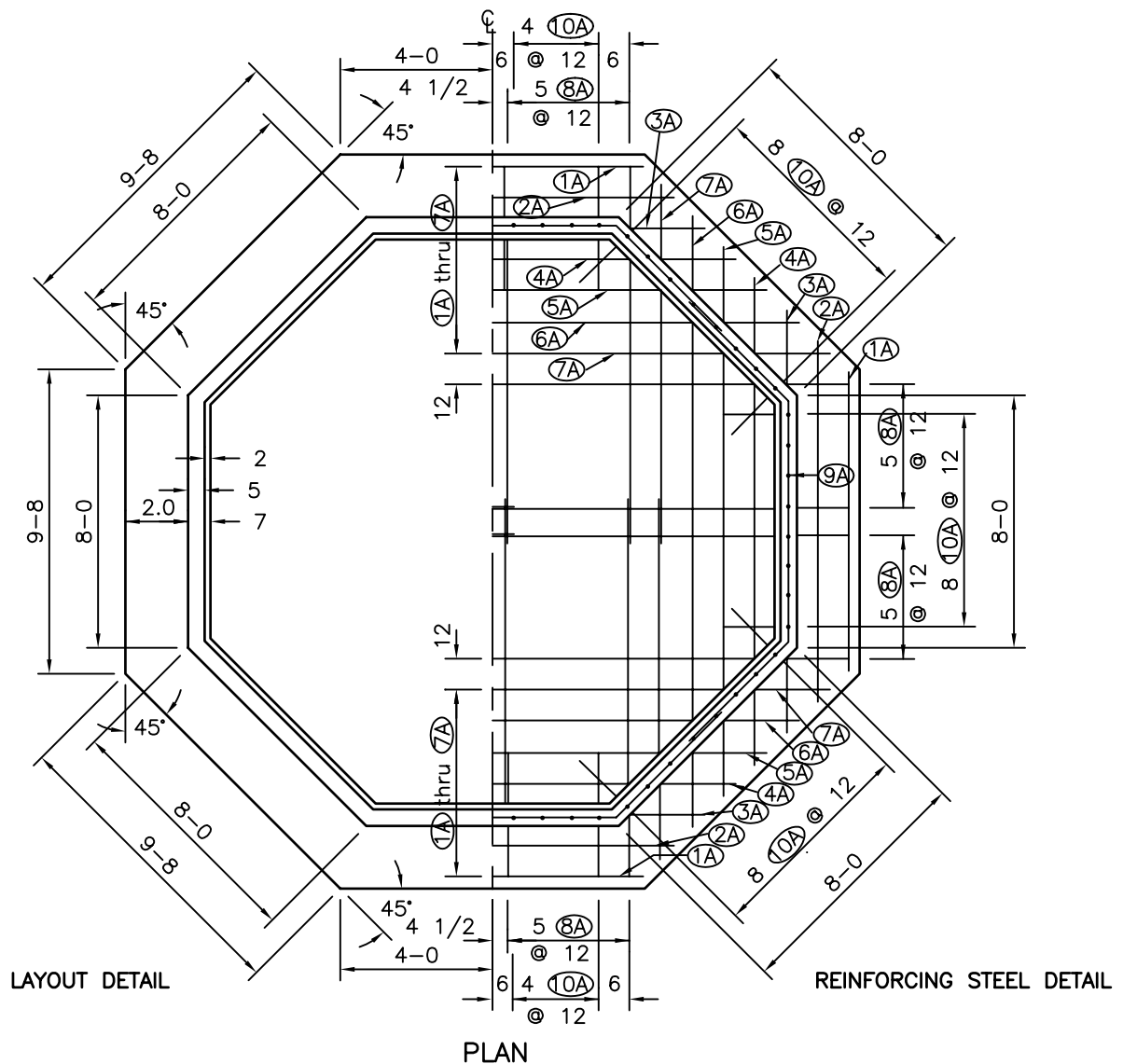
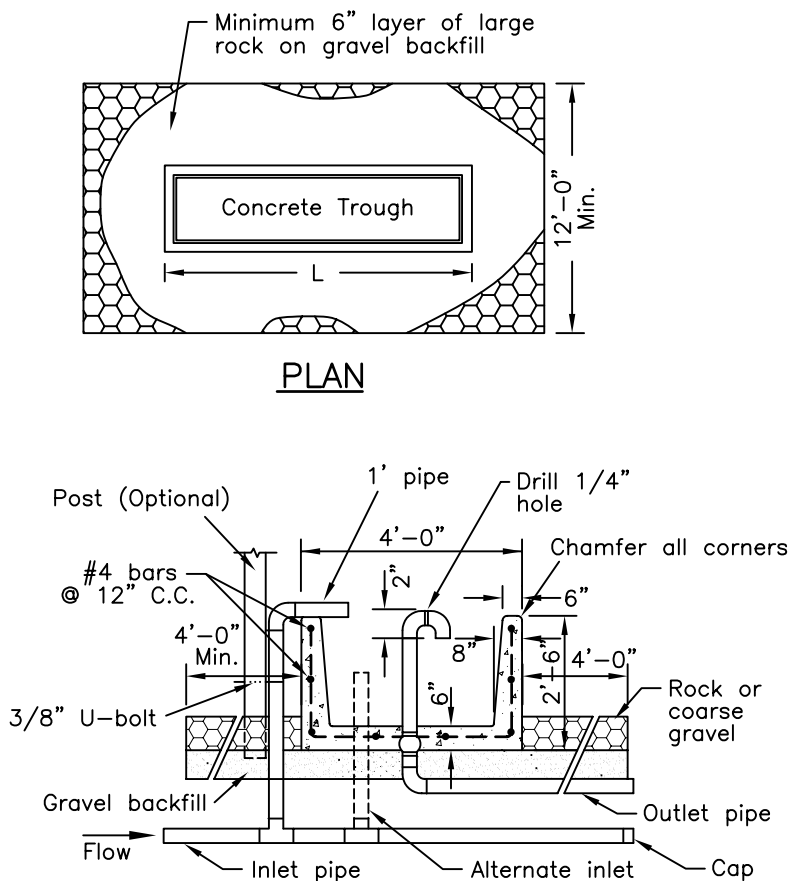
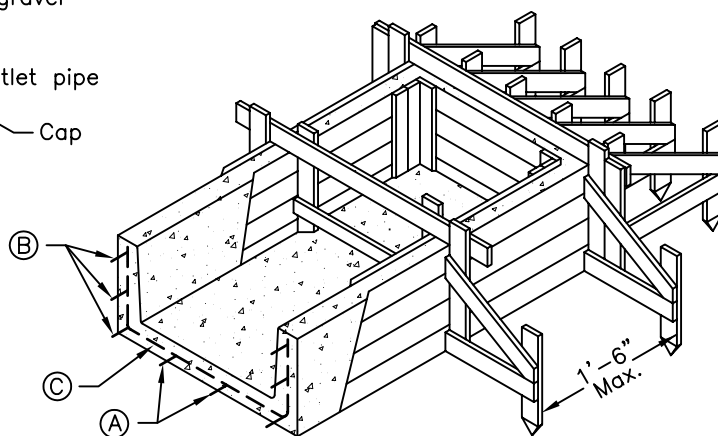
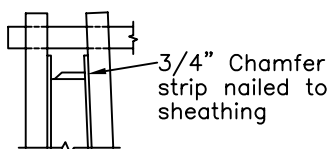
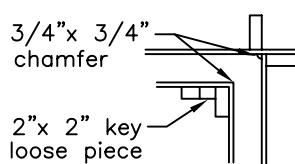
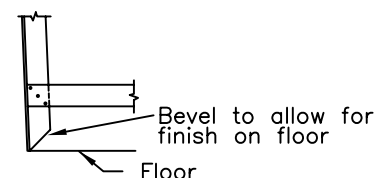
Figure 8.21
CONCRETE TANK

Figure 8.22
CONCRETE TROUGH

MATERIALS FOR VARYING LENGTHS OF TROUGHS				
Length Feet	Total Steel Length	Total Steel Weight	Concrete Cu. Yds.	Gals. of Water
6	120	80.0	1.15	225
7	135	90.3	1.31	267
8	151	100.9	1.47	310
9	166	110.9	1.63	353
10	182	121.3	1.79	396
11	187	131.8	1.95	459
12	215	142.3	2.11	482
13	228	152.3	2.27	525
14	244	163.0	2.44	560
15	260	173.8	2.73	611

G.I. outlet pipe consists of three 2" Ells, one 2" coupling, one short nipple, one 2" pipe— 2'-3" long, and one 2" pipe 6'-0" to 10'-0" long.

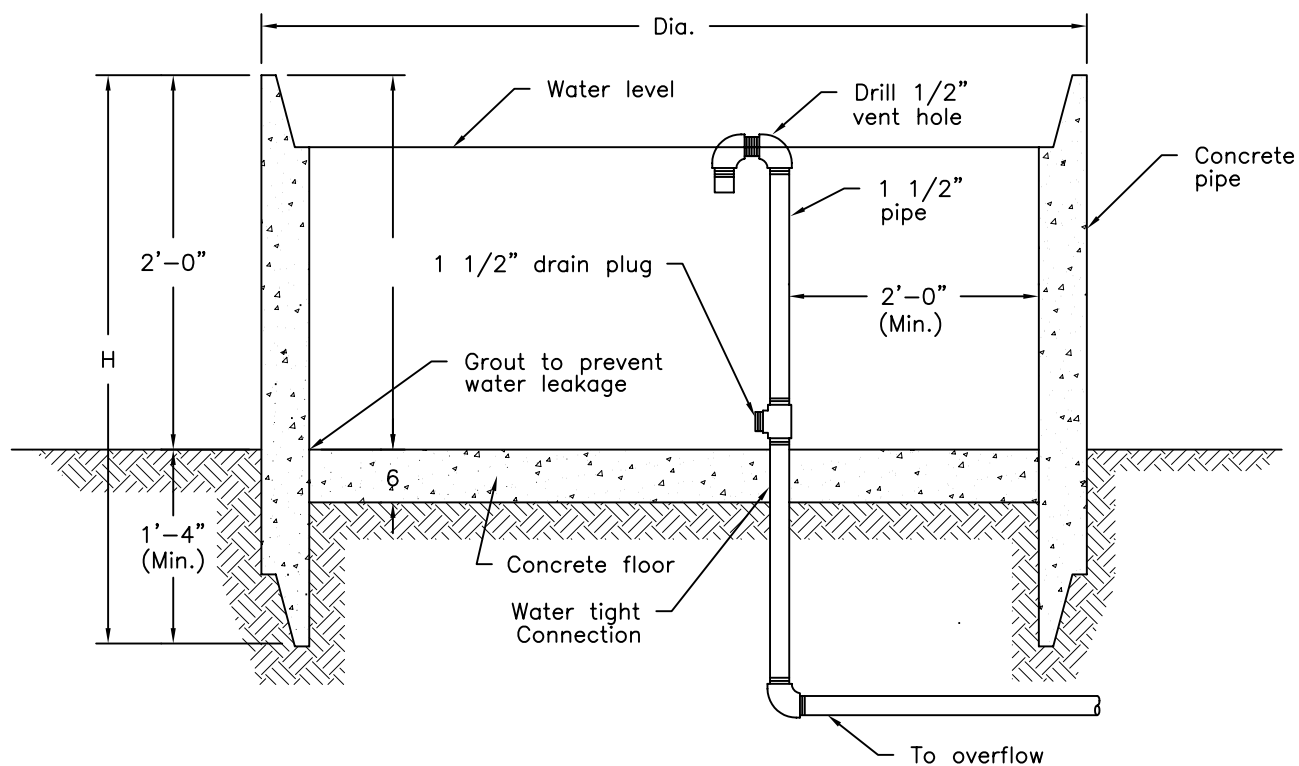
STEEL SCHEDULE			
Type	Location	No.	Bending
A	Floor	2	2'-1" $\overbrace{\text{L-5"}}$ 2'-1"
B	Walls	6	2'-6" $\overbrace{\text{L-5"}}$ 2'-6"
C	Floor & Walls	L+1	2'-1" $\overbrace{\text{3-8}}$ 2'-1"

FORM FRAMINGTOP FORMCORNER FORMINSIDE BRACE

Notes:

1. Unless otherwise shown reinforcing steel shall be #4 bars at 12" C.C. in both directions.
2. Bar splices shall be 30 bar diameters (15 inches).
3. Steel shall not be closer than 3 inches from bottom floor slab or 2 inches from top of floor slab or outside wall surface.

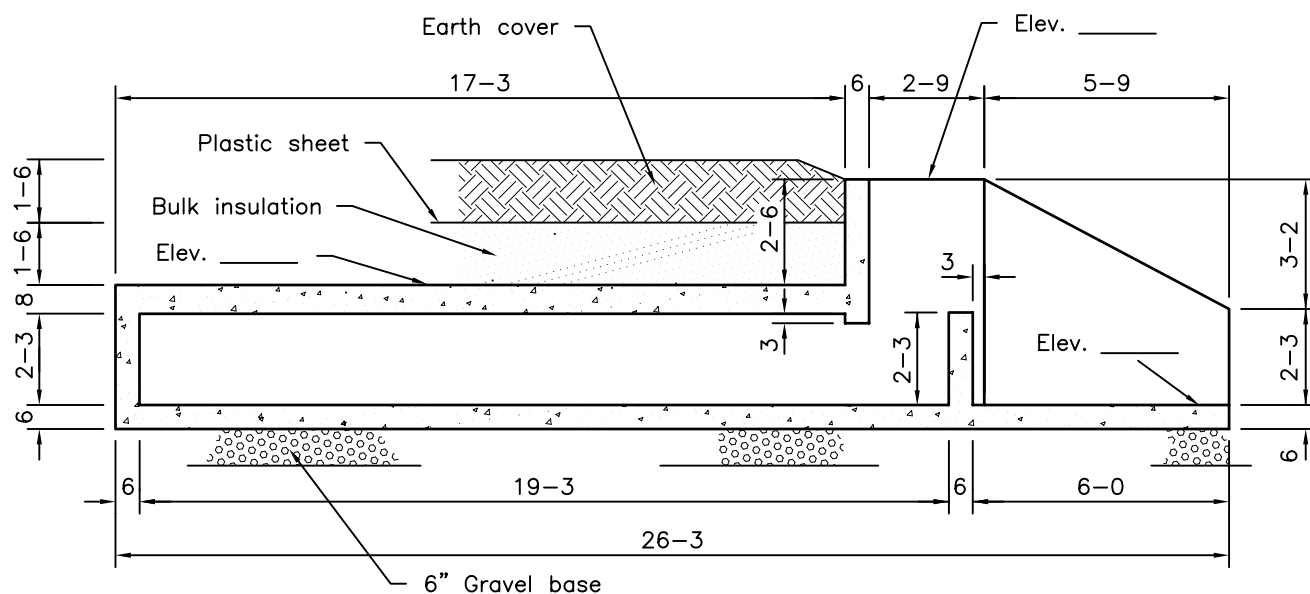
Figure 8.23
TANK MADE FROM CONCRETE PIPE



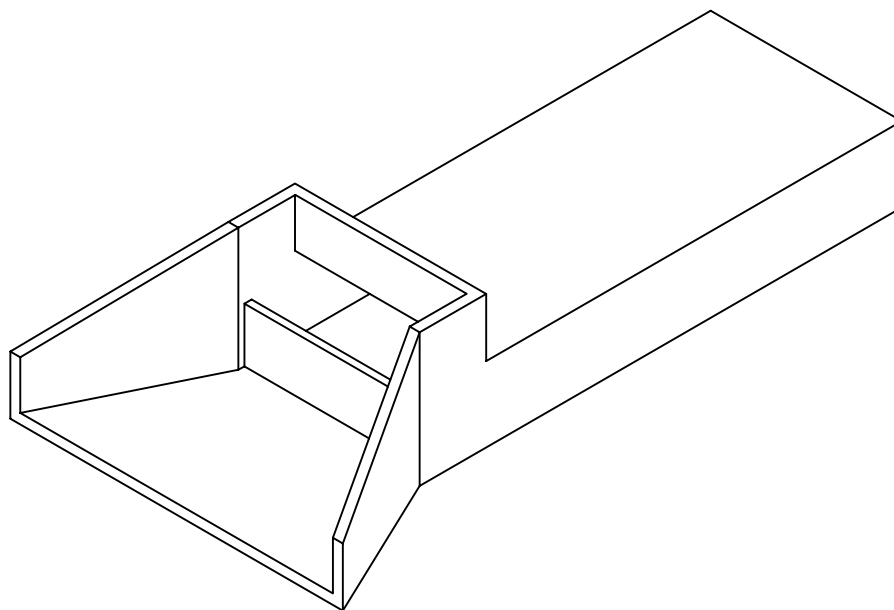
Note:

1. 1 1/2" pipe shall be galvanized steel or other pipe of equivalent strength and durability.
2. Precast concrete pipe or equivalent may be used for the tank.

Figure 8.24
FROST PROOF CONCRETE TANK



SECTION VIEW



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.

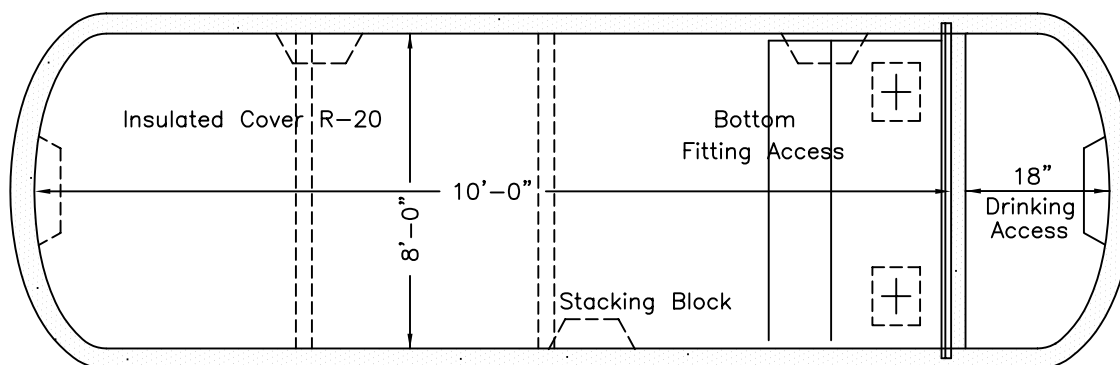
Thickness of fiberglass will determine how resistant the tank is to mechanical damage. It is possible to repair damaged fiberglass, which is one advantage of using this material.

Tank 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. Figure 8.25 details a frost free tank made out of fiberglass

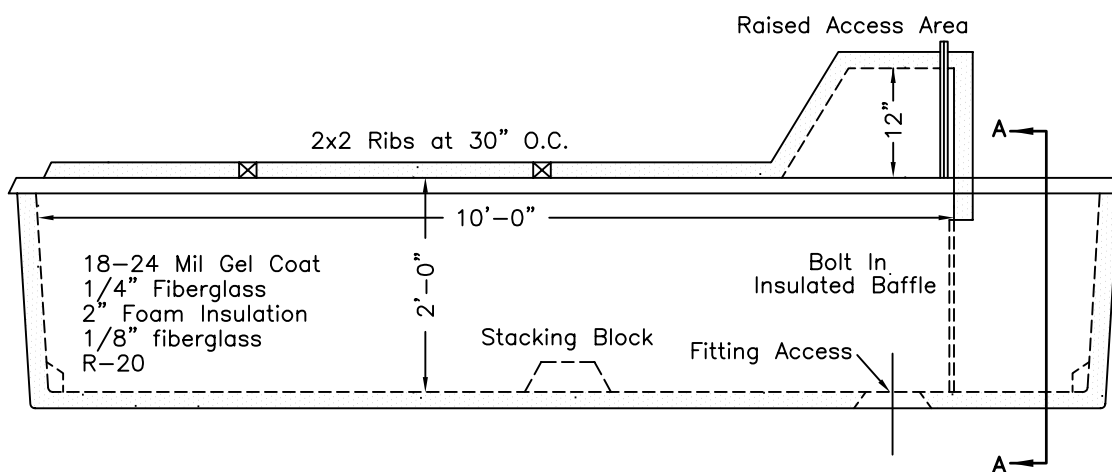
Plastic Tanks

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. Some companies manufacture tanks out of polyethylene.

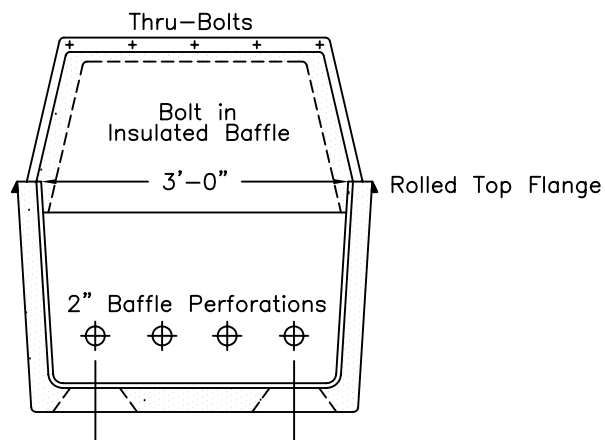
Figure 8.25
FROST FREE FIBERGLASS TANK



PLAN VIEW



ELEVATION



SECTION-AA

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.

- 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.

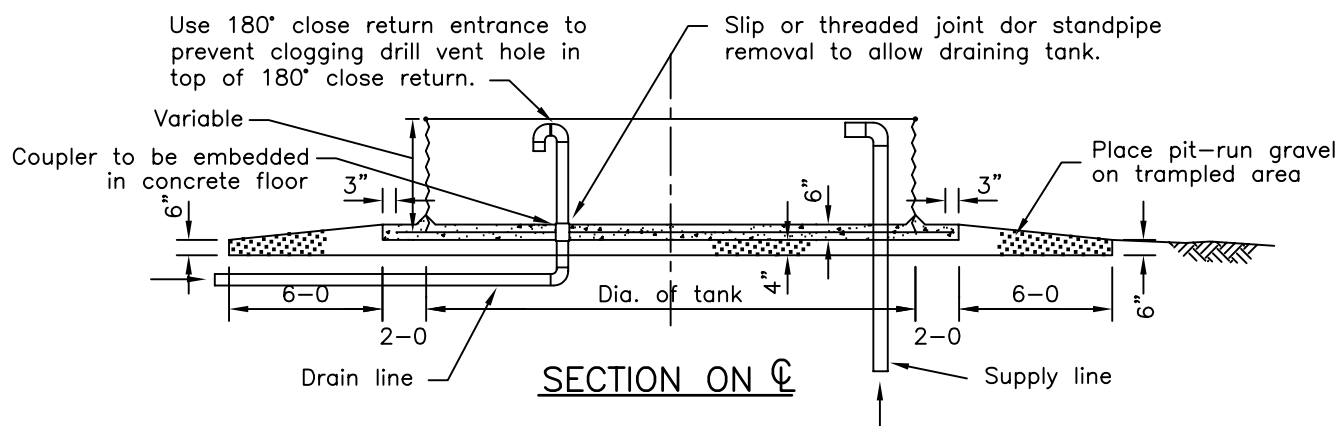
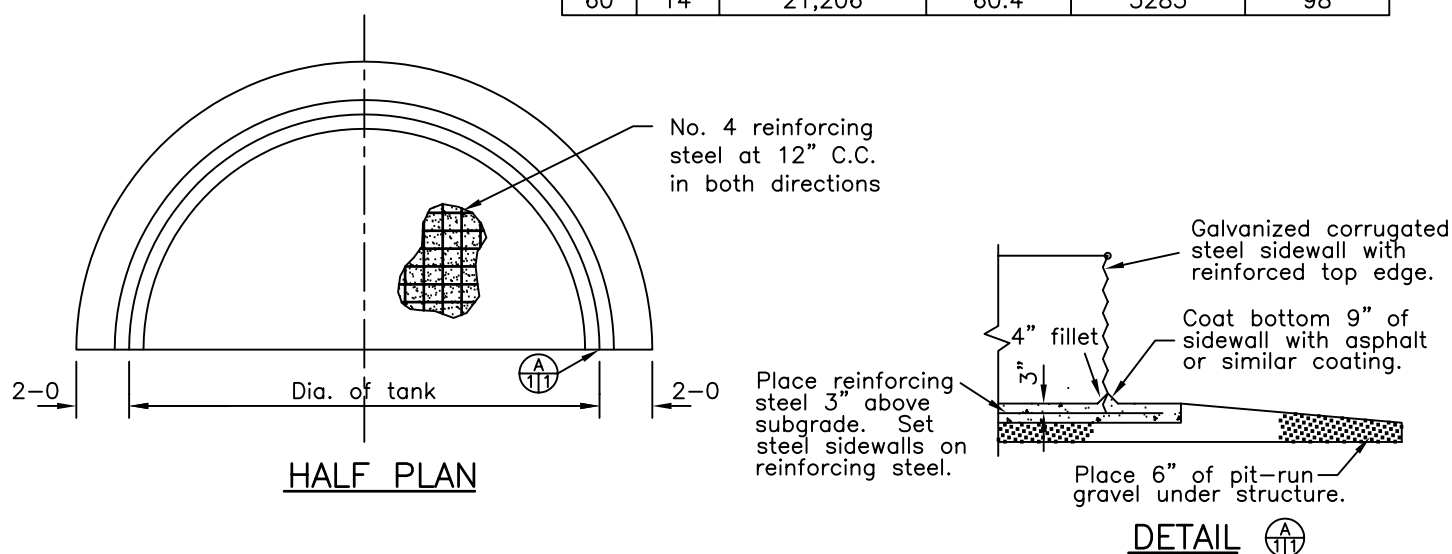
- Manufactured steel stock tanks

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 8.26 details a tank made from corrugated steel plate segments. Figure 8.27 illustrates typical manufactured steel tanks. Figure 8.28 shows a commercially available frost free steel tank which is fabricated from corrugated steel pipe.

Figure 8.26
TANK MADE FROM CORRUGATED STEEL SEGMENTS

BILL OF MATERIALS					
DIA. (Ft.)	MIN. Gage	CAPACITY (Gal.) Per inch depth	CONCRETE (Cu. Yds.)	REINFORCING STEEL (Lbs.)	GRAVEL (Cu. Yds.)
10	16	589	3.0	245	15
12	16	848	3.9	320	17
14	16	1154	4.9	389	19
16	16	1508	6.0	512	21
18	16	1909	7.2	615	23
20	16	2356	8.7	688	26
22	16	2851	10.1	815	28
24	16	3393	11.7	986	31
25	16	3682	12.5	1030	32
30	16	5301	17.2	1514	40
40	14	9425	28.7	2507	56
50	14	14,726	43.1	3750	75
60	14	21,206	60.4	5285	98



Notes:

1. Unless otherwise shown reinforcing steel shall be #4 bars at 12" C.C. in both directions.
2. Bar splices shall be 30 bar diameters (15 inches).
3. Steel shall not be closer than 3 inches from bottom floor slab or 2 inches from top of floor slab.

Figure 8.27
MANUFACTURED STEEL TANK

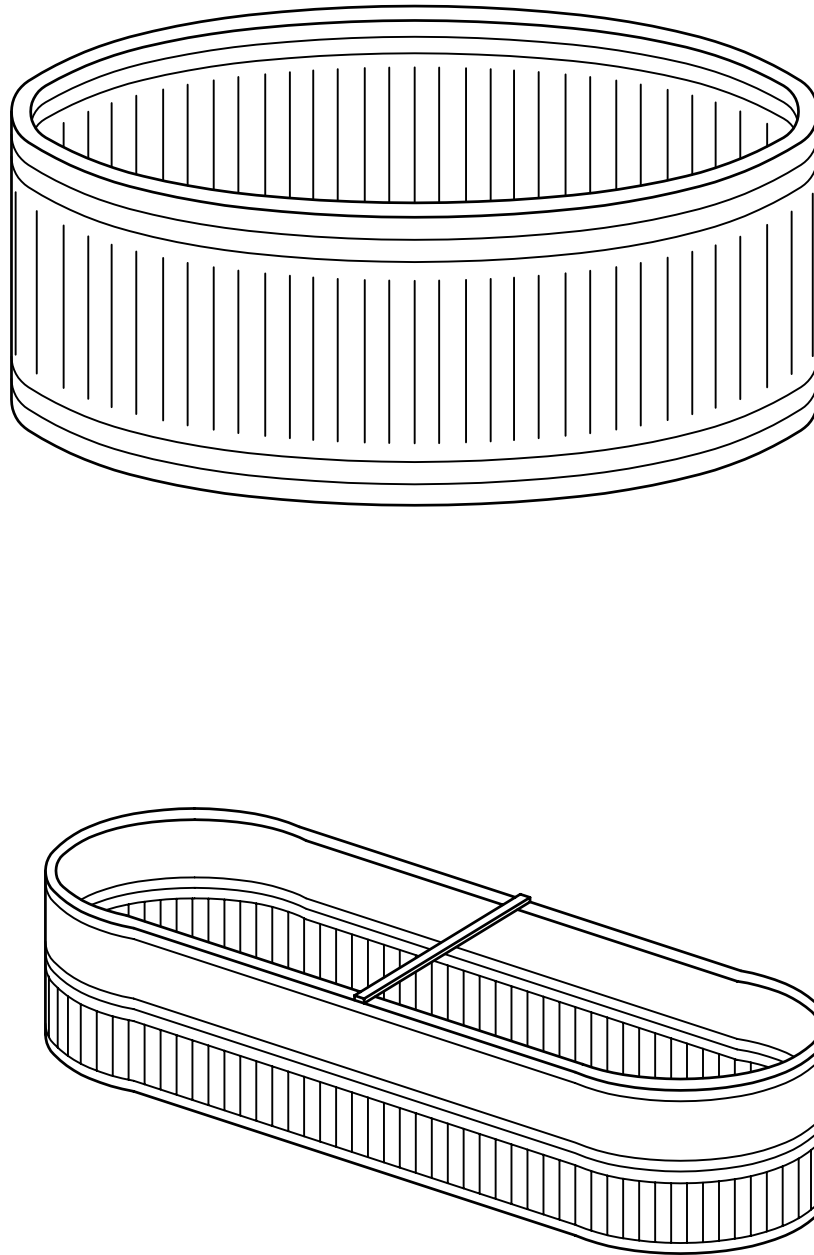
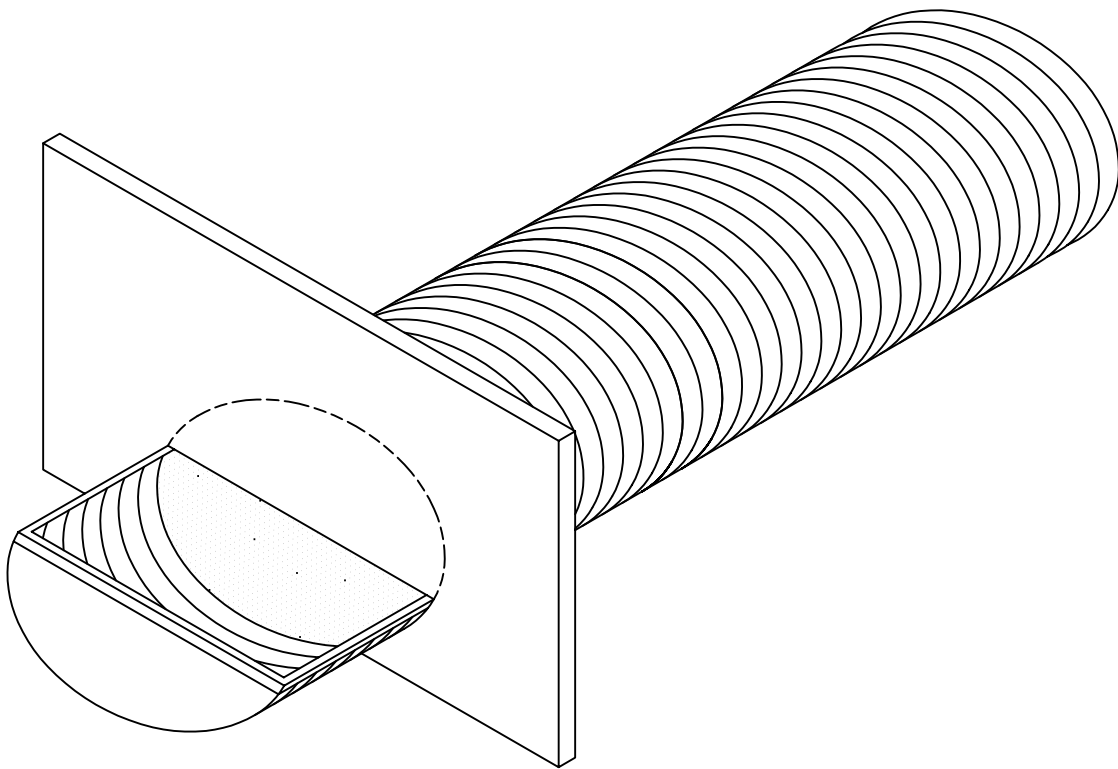


Figure 8.28
FROST FREE STEEL TANK



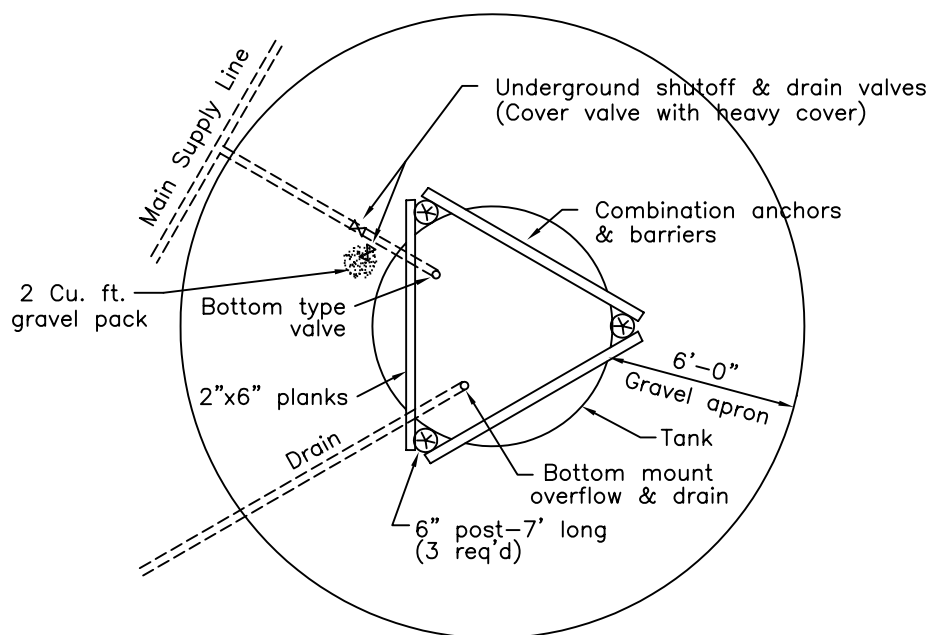
8.7.2 Water Inlet Protection including Float Valves

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.

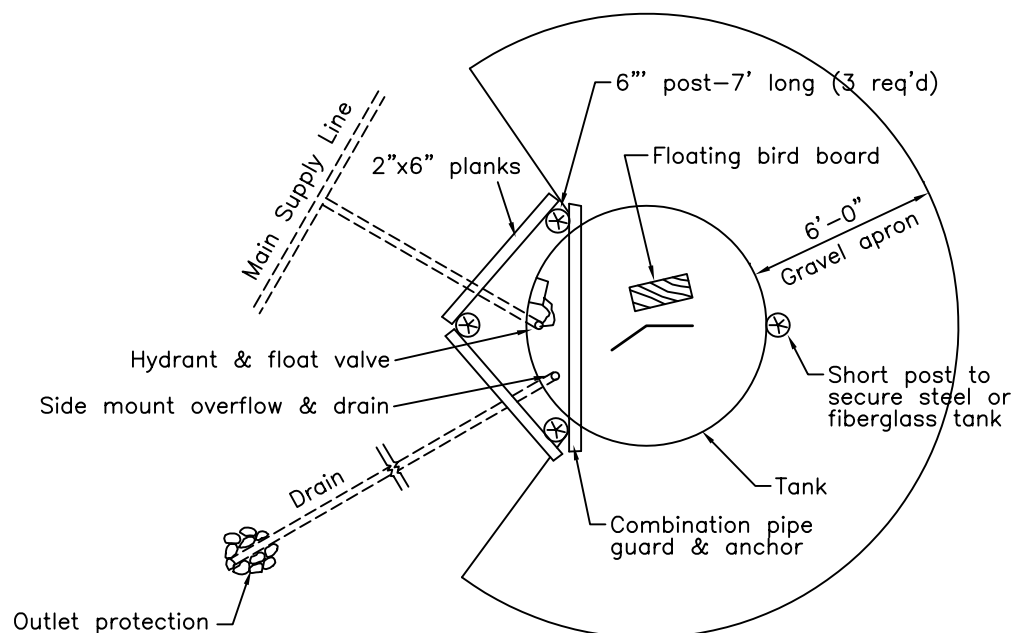
Combination float valves and thermostatically controlled valves are available which will open in the event that temperature of the water gets down to just above freezing. These are installed at the bottom of the tank. The valve opens to provide a constant flow during periods of freezing weather. It is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

Figures 8.29 through 8.31 illustrate commonly used systems of tank and inlet protection.

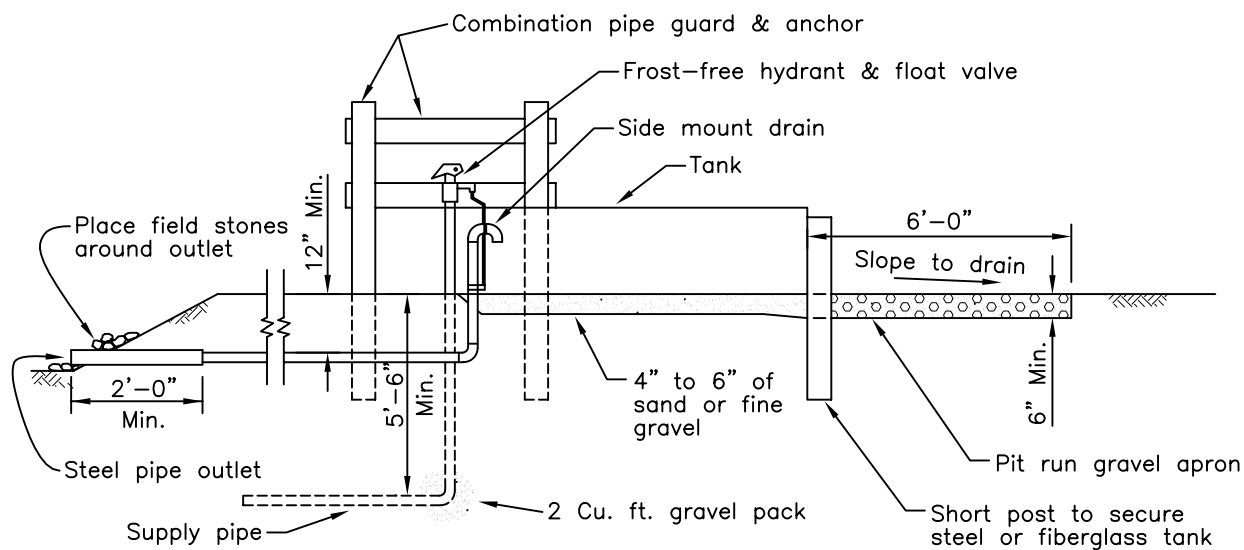
Figure 8.29
TYPICAL TANK LAYOUT PLANS



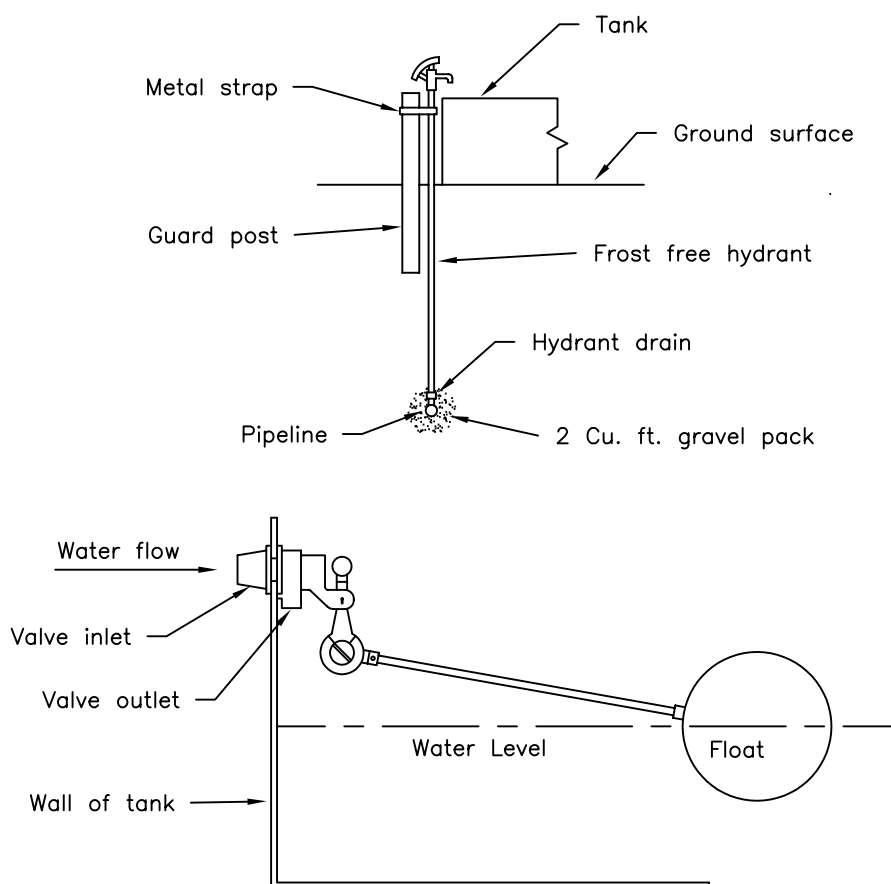
TYPICAL TANK LAYOUT
W/ BOTTOM VALVE & STOCK BARRIER



TYPICAL TANK LAYOUT
W/ SIDE DRAIN & PIPE GUARD

Figure 8.30
TANK DETAILS

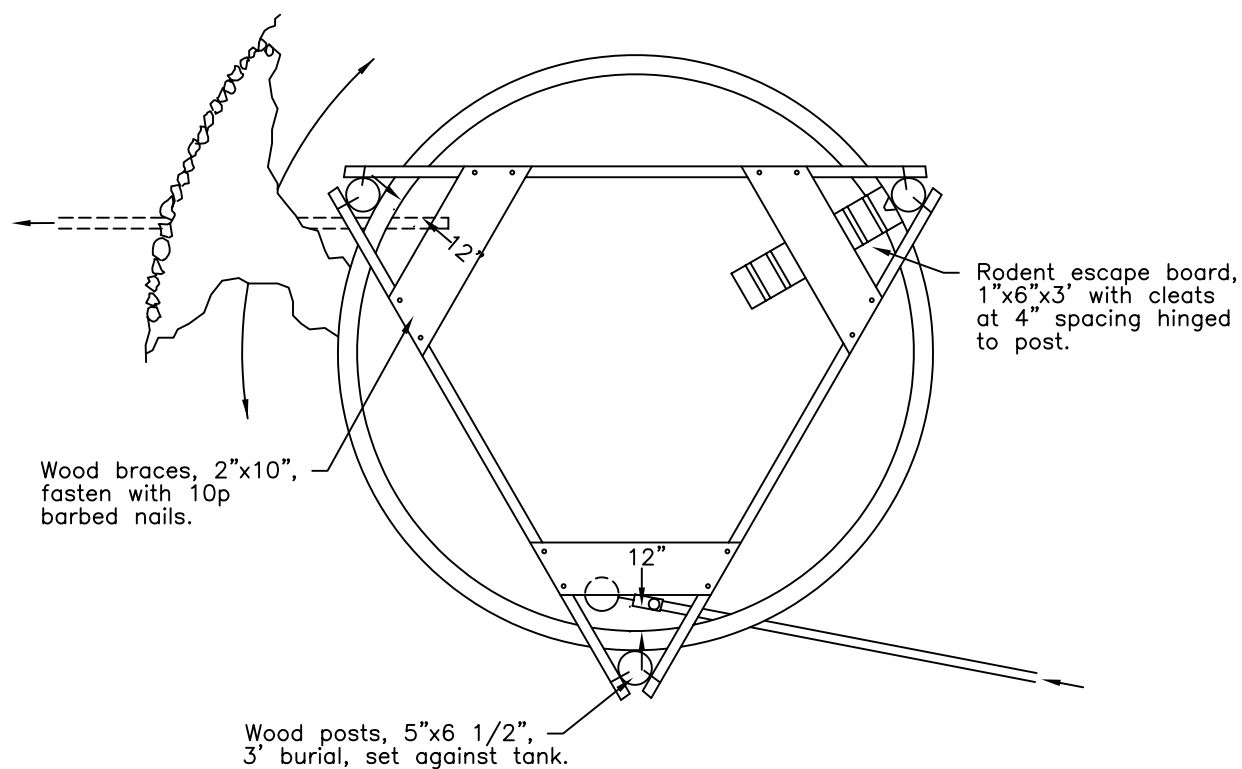
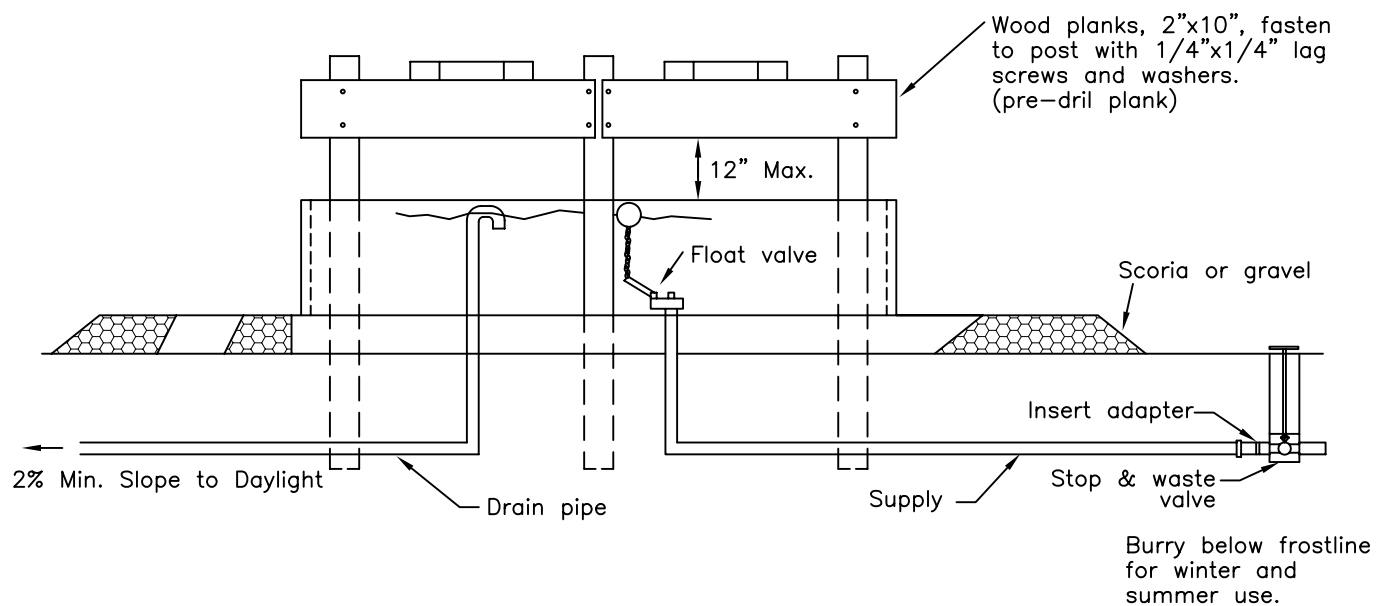
TYPICAL TANK SECTION



HYDRANT DETAILS

Note:
Alternate inlet shown on Figure 8.31.

Figure 8.31
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 8.29 through 8.31 show examples of good tank bases.

8.7.4 Tank Overflows

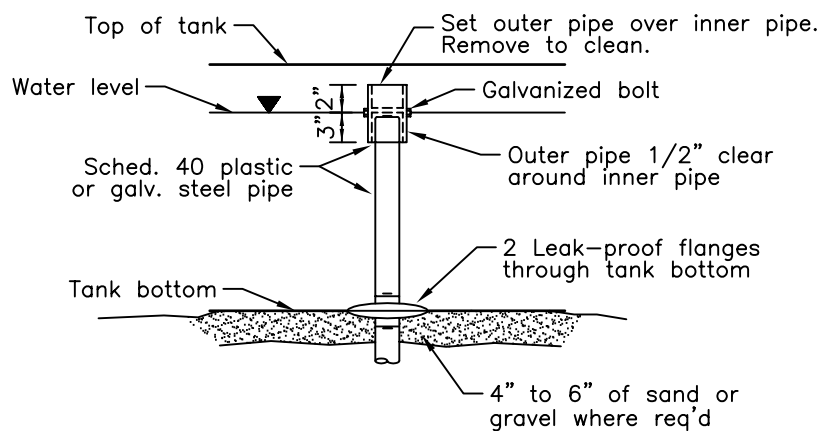
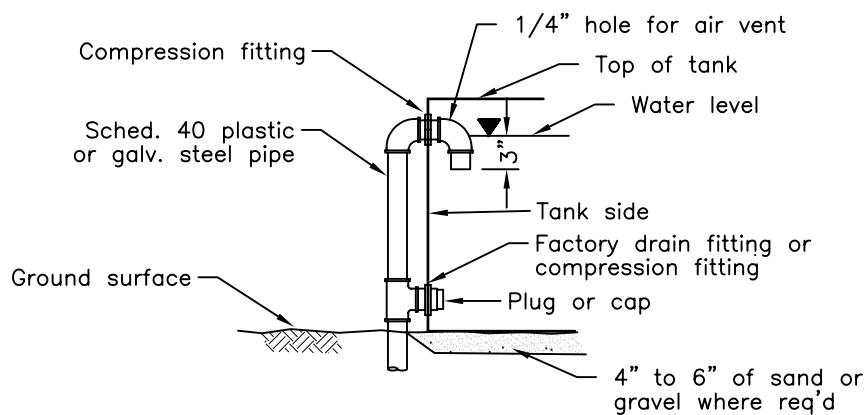
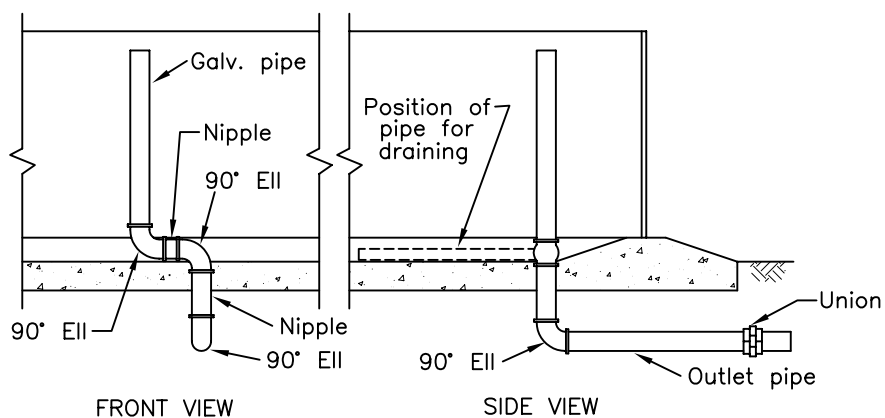
Tank overflows are required when there is no control on the amount of water coming into the tank. They are also highly recommended even when a float valve is used to control flow into the tank. Float valves occasionally do not close properly and an overflow is insurance against damage caused by overflow.

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 8.32 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.

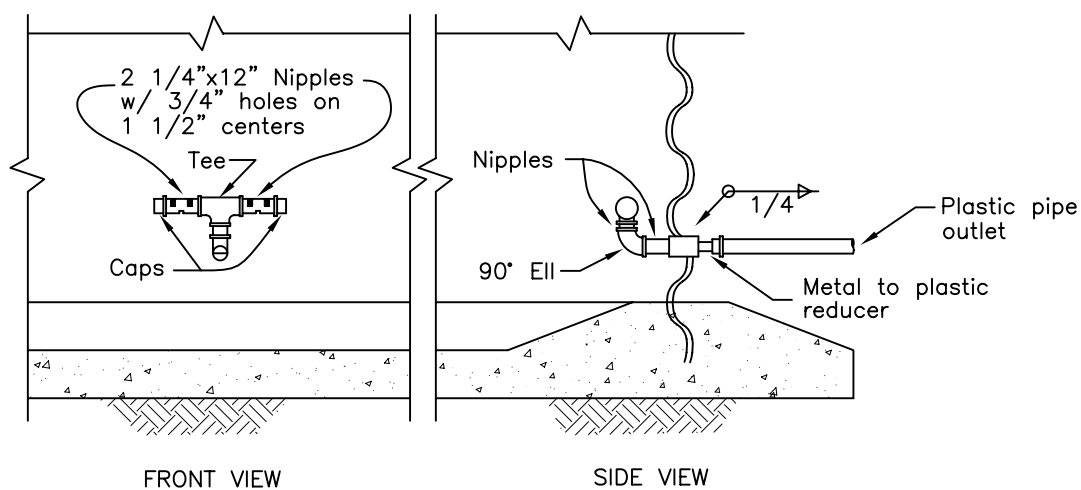
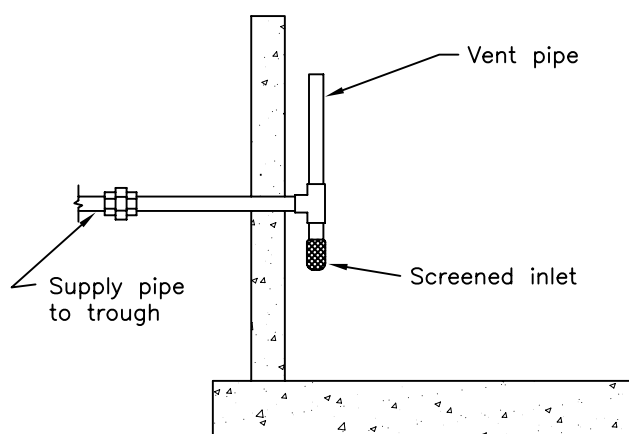
Figure 8.32
OVERFLOWSTYPICAL BOTTOM MOUNT
OVERFLOW & DRAINTYPICAL SIDE MOUNT
OVERFLOW & DRAINSWIVEL STORAGE TANK OUTLET

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 8.33 illustrates two types of inlet designs.

Figure 8.33

PIPELINE TANK INLET

STORAGE TANK OUTLET

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 the 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 8.34 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.

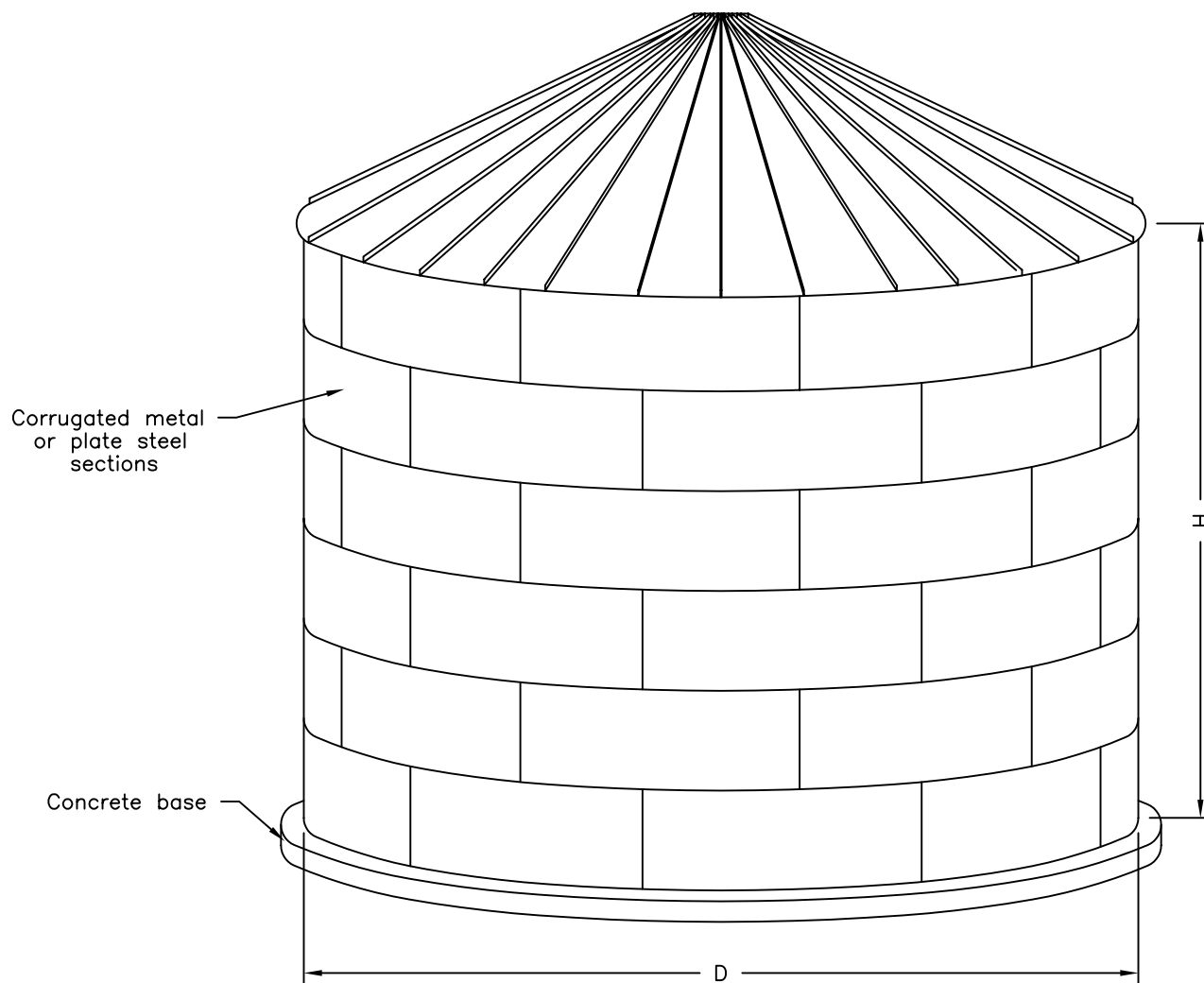
Figure 8.35 illustrates typical plans for a tank fabricated from sheet steel. The inside should be epoxy coated. The outside would be coated with coal tar material or epoxy. Cathodic protection may be needed depending on the corrosivity of the soil.

Figure 8.36 illustrates a large steel tank constructed out of corrugated structural plates.

Figure 8.37 depicts one type of fiberglass storage tank.

Figure 8.38 illustrates a storage bag-type installation. A large rubberized fabric or plastic water storage bag is used for long-term storage. Figure 8.38 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 8.34
COMMERCIAL STEEL WATER STORAGE TANK



$$\text{Capacity} = \frac{\pi}{4} (D)^2 \times H \text{ (Cubic Ft.)} \times 7.5 \text{ gallons per cubic ft.}$$

D=Diameter of tank (in feet)

H=Height of tank (in feet)

Notes:

1. Gage of metal and coating to be as recommended by manufacturer.
2. All joints shall be watertight. All joints shall be welded or bolted as recommended by manufacturer.

Figure 8.35
FABRICATED STEEL STORAGE TANK

TANK SIZE		
Size (Gallons)	Diameter	Length
550	4' x 6'	
1000	4' x 11'	
2000	6' x 12'	
5000	8' x 14'	
6000	8' x 16'	
8000	8' x 21'	
10000	9' x 21'	
12000	9' x 25'	

STEEL GAUGE	
Gallons	Gauge Min.
to 560	12
561-1100	10
1101-4000	3/16"
4001-12000	1/4"
12001-20000	5/16"

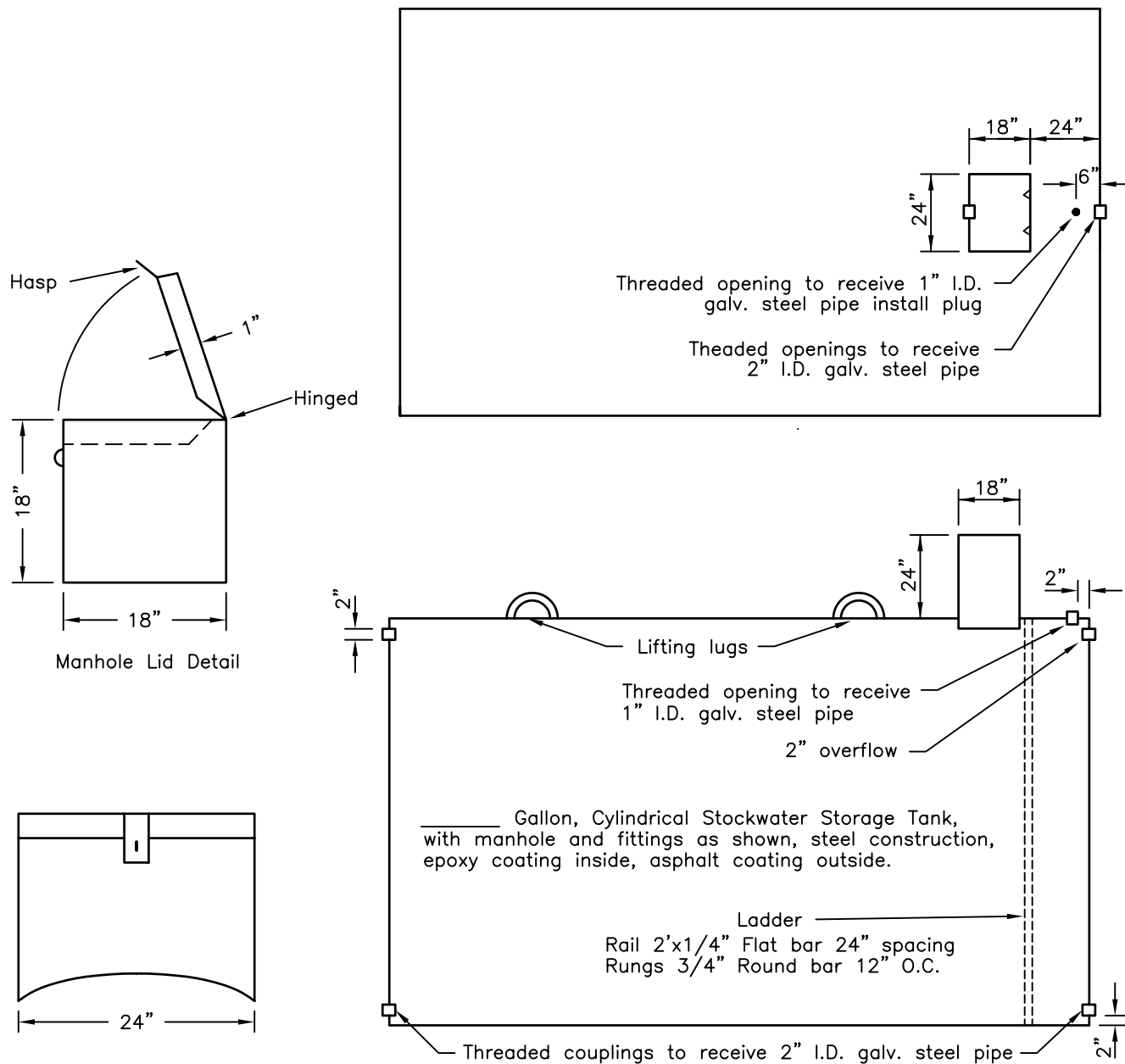
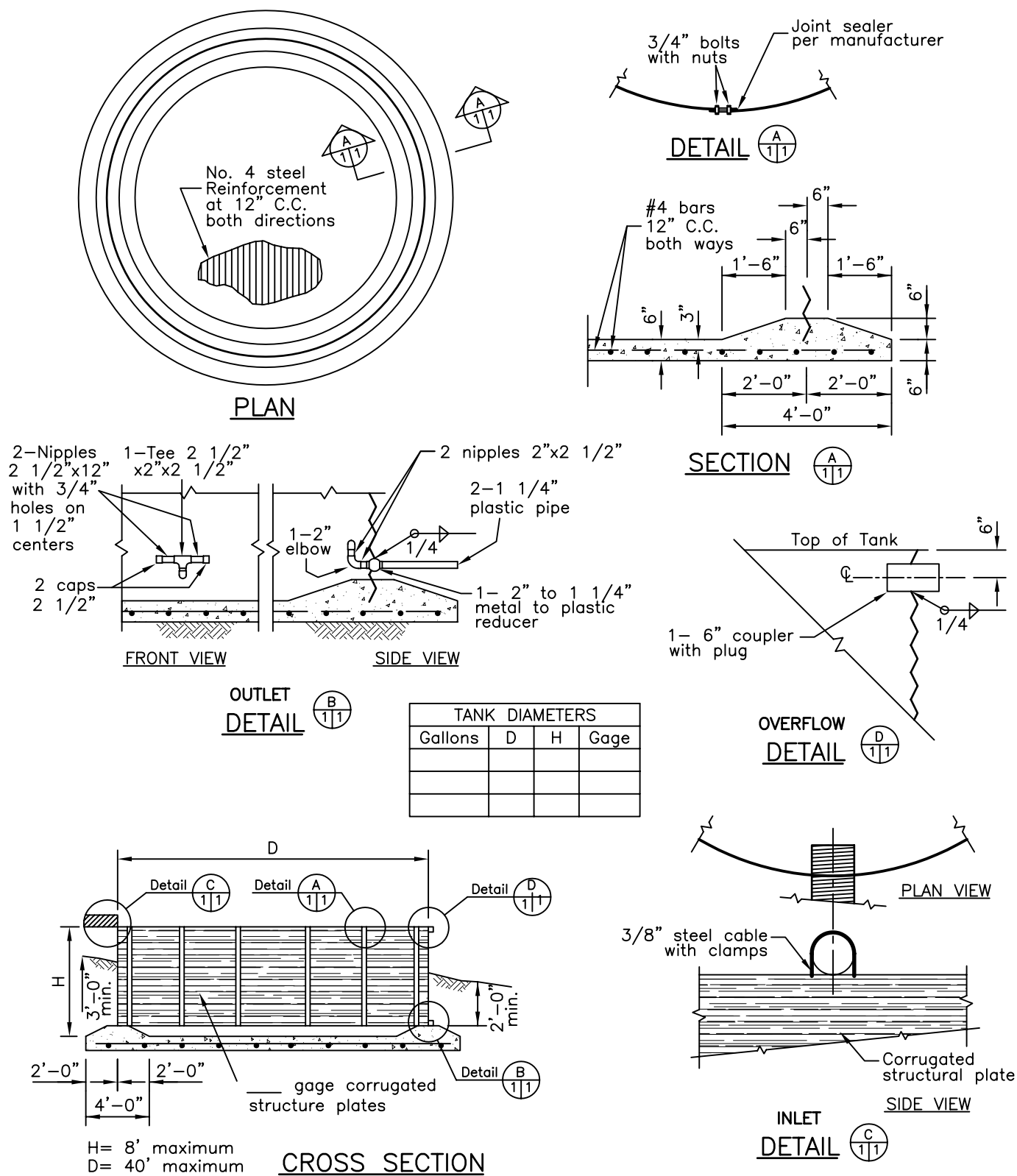


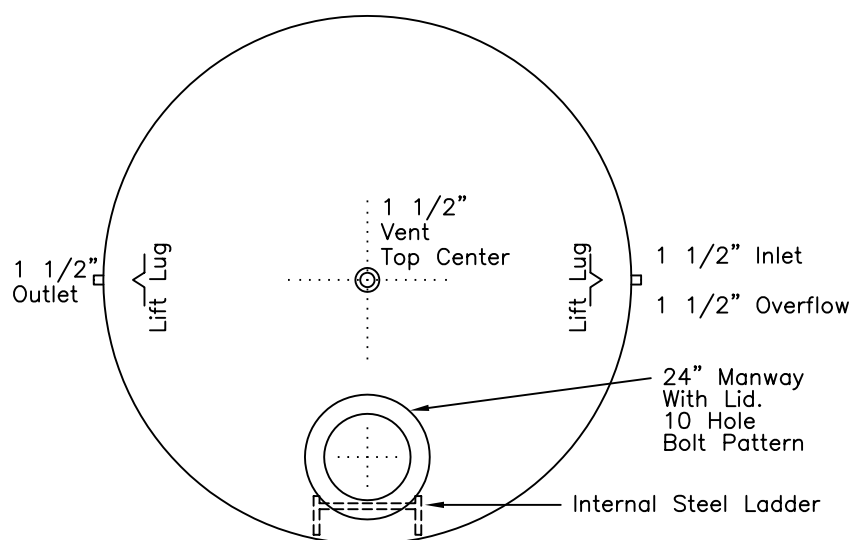
Figure 8.36
CONSTRUCTED CORRUGATED STEEL STORAGE TANK



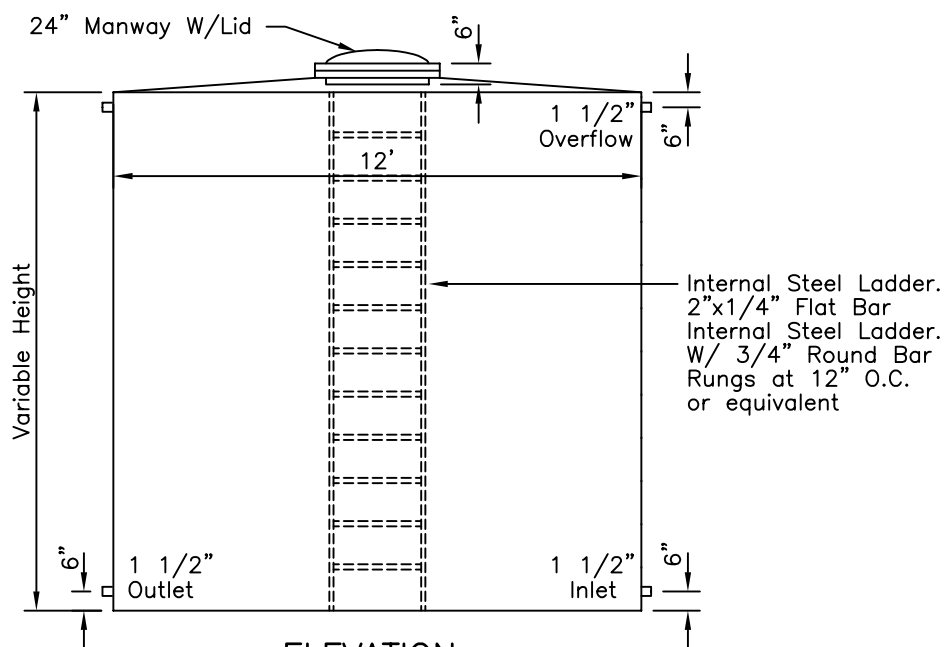
Notes:

1. Unless otherwise shown reinforcing steel shall be #4 bars at 12" C.C. in both directions.
2. Bar splices shall be 30 bar diameters (15 inches).
3. Steel shall not be closer than 3 inches from bottom floor slab or 2 inches from top of floor slab.

Figure 8.37
FIBERGLASS STORAGE TANK



PLAN VIEW



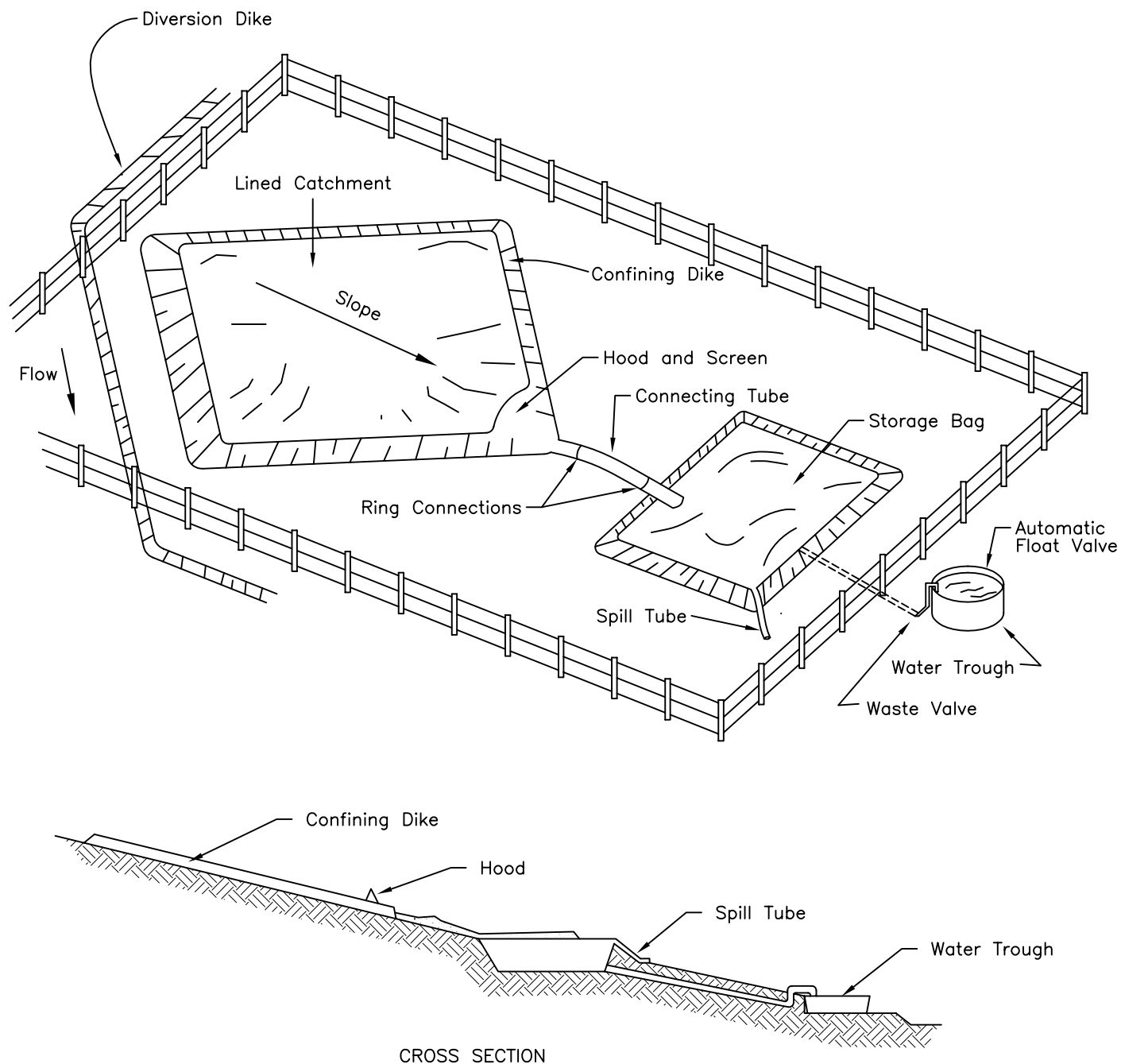
ELEVATION

Scale: 1/4"=1'-0"

WALL THICKNESS TABLE

Distance From Top in Feet	Tank Diameter in Feet															
	2	2 1/2	3	3 1/2	4	4 1/2	5	5 1/2	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	3/16	1/4	1/4	
8	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	1/4	1/4	
10	3/16	3/16	3/16	3/16	3/16	3/16	3/16	3/16	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	1/4	1/4	1/4	1/4	1/4	5/16	5/16	5/16	5/16	3/8	

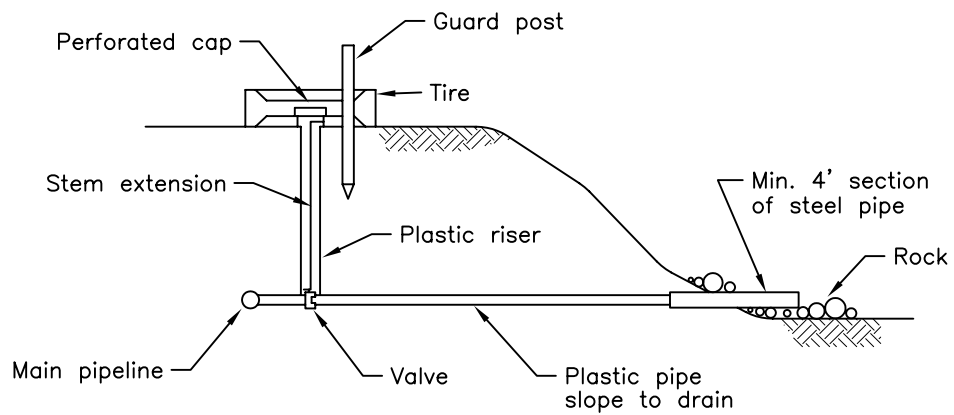
Figure 8.38
WATER HARVESTING SYSTEM USING
RUBBERIZED FABRIC STORAGE BAG



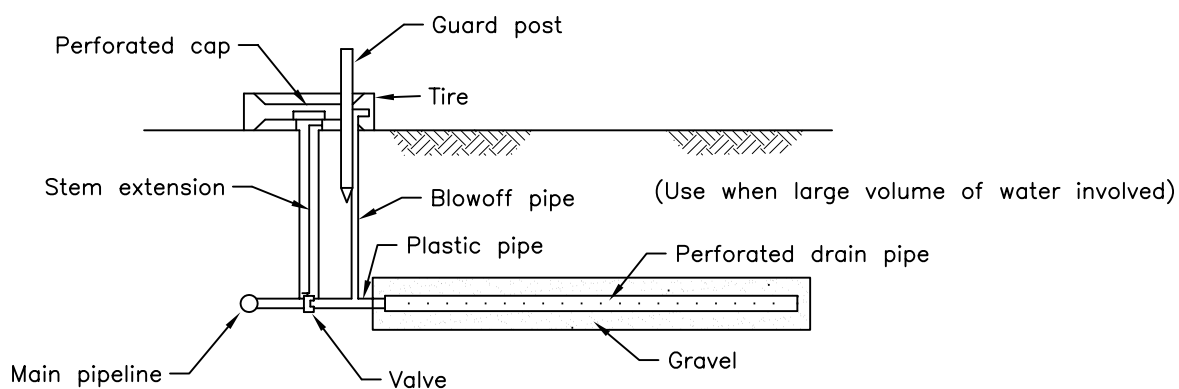
8.9 PIPELINE DRAINS

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 8.39 illustrates typical drain details.

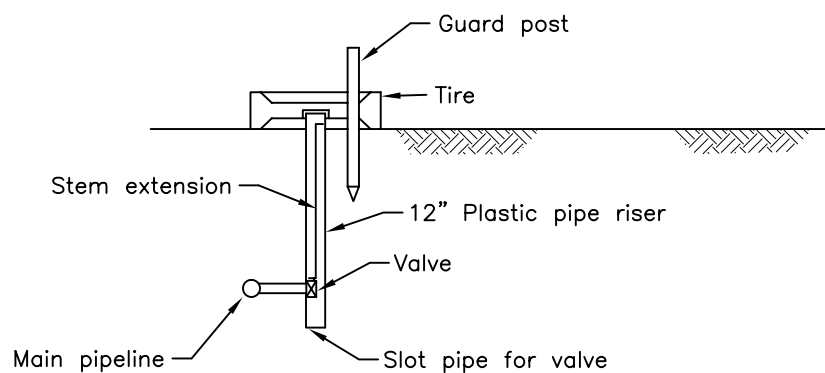
Figure 8.39
PIPELINE DRAINS



GRAVITY DRAIN



BLIND DRAIN



PUMPOUT

Chapter 9

System Design Procedures

CHAPTER 9 SYSTEM DESIGN PROCEDURES

TABLE OF CONTENTS

PART	9.1 GENERAL	9-1
PART	9.2 EXAMPLE 1, LOW PRESSURE GRAVITY SYSTEM	9-1
PART	9.3 EXAMPLE 2, PUMPED AUTOMATIC PRESSURE PIPELINE	9-4
	9.3.1 Pumped Automatic Pressure System Computations	9-4
	9.3.2 Lateral Computations	9-5
PART	9.4 EXAMPLE 3, TIMER OR MANUALLY OPERATED PRESSURE SYSTEM	9-11
	9.4.1 Timer or Manually Operated Pumped System Computations	9-11
	9.4.2 Gravity Line Computations	9-15
	9.4.3 Lateral Computations	9-16
PART	9.5 EXAMPLE 4, PRESSURE REDUCER	9-18

FIGURES

Figure	9.1 Low Pressure Gravity System	9-2
Figure	9.2 Low Gravity System Computations	9-3
Figure	9.3 Pumped Automatic Pressure System	9-6
Figure	9.4 Automatic Pressure Computations	9-7
Figure	9.5 Lateral Profile	9-9
Figure	9.6 Lateral Computation	9-10
Figure	9.7 Timer or Manually Operated System	9-12
Figure	9.8 Storage Tank Plumbing	9-13
Figure	9.9 Timer or Manually Operated Pump System Computations	9-14
Figure	9.10 Gravity Flow Computations	9-15
Figure	9.11 Gravity Flow Lateral Profile	9-16
Figure	9.12 Gravity Flow Lateral Computations	9-17
Figure	9.13 Pressure Reducer Valve Installation	9-18
Figure	9.14 Pressure Reducer Valve System Computations	9-19

CHAPTER 9

SYSTEM DESIGN PROCEDURES

9.1 GENERAL

There are three major categories of system 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 system design for a very simple, low pressure 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 PRESSURE GRAVITY SYSTEM

Figure 9.1 illustrates the profile for a very low Pressure 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 a 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 design involved in this installation. Size of pipe is the minimum dictated by the standards. Missouri 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 shows 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

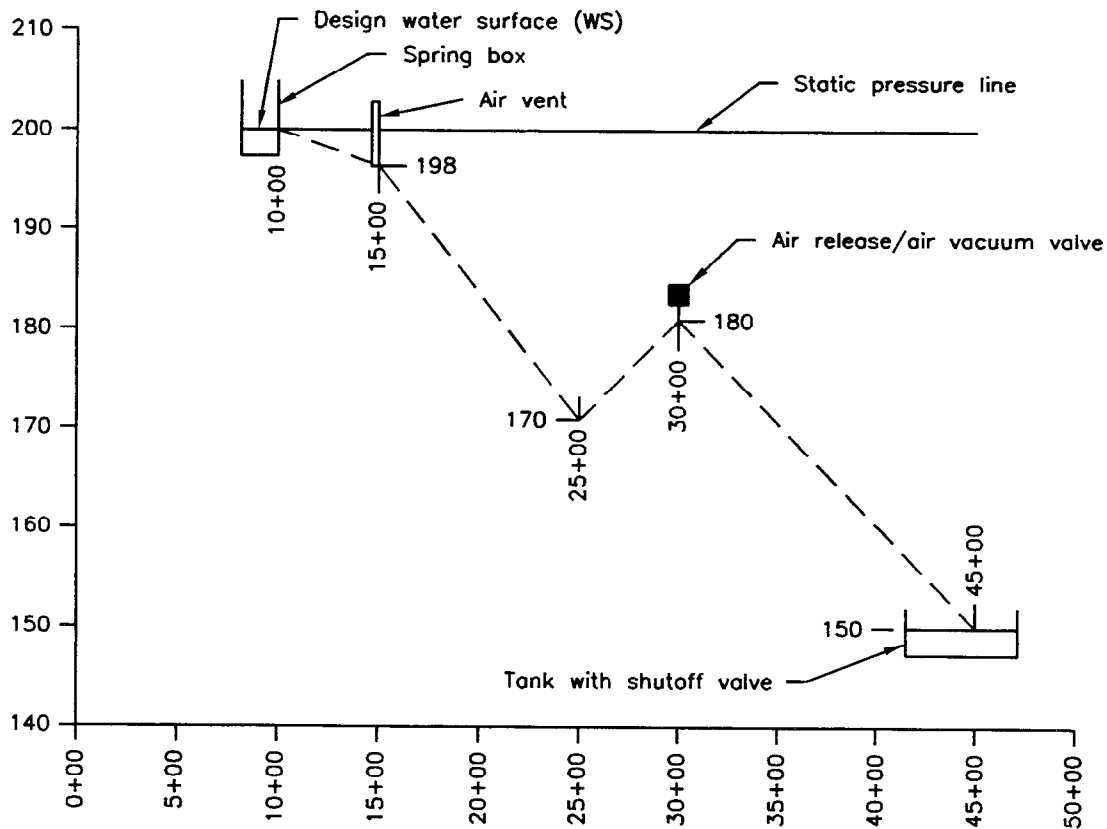


Figure 9.2

LOW PRESSURE GRAVITY SYSTEM COMPUTATIONS

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MO-ENG-106

07-97

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**GRAVITY STOCKWATER PIPELINE
HYDRAULIC COMPUTATION WORKSHEET**Land user Example No. 1Job description South Pasture PipelineFarm No. 532 Tract No. 3 Field No. 2 County GallatinDesigner V. Tech Date 11/8/90 Checked by JCD Date 11/10/90Water surface elevation (WS) 200Critical 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) = ----- ftStarting 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 $H_f/100\text{ft}$ (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)	Comments (slope %)
10+00		200			PVC						at source
	500			2	SDR 26						
15+00		198		1 1/4	PVC						0.40%
	1000				SDR 26						
25+00		170		1 1/4	PVC						2.80%
	500				SDR 26						
30+00		180		1 1/4	PVC						2.00%
	1500				SDR 26						
45+00		150								21.6	2.00%
											21.6 psi<
											160 psi
											∴ ok

9.3 EXAMPLE 2, PUMPED AUTOMATIC PRESSURE PIPELINE

Example number 2 covers the 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 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 Glossary for definition of terms. In this case a CH value of 25 feet was selected.

A 30 psi pressure range between pump cut-in and cut-out is used. 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 the 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 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 well. 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.

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 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

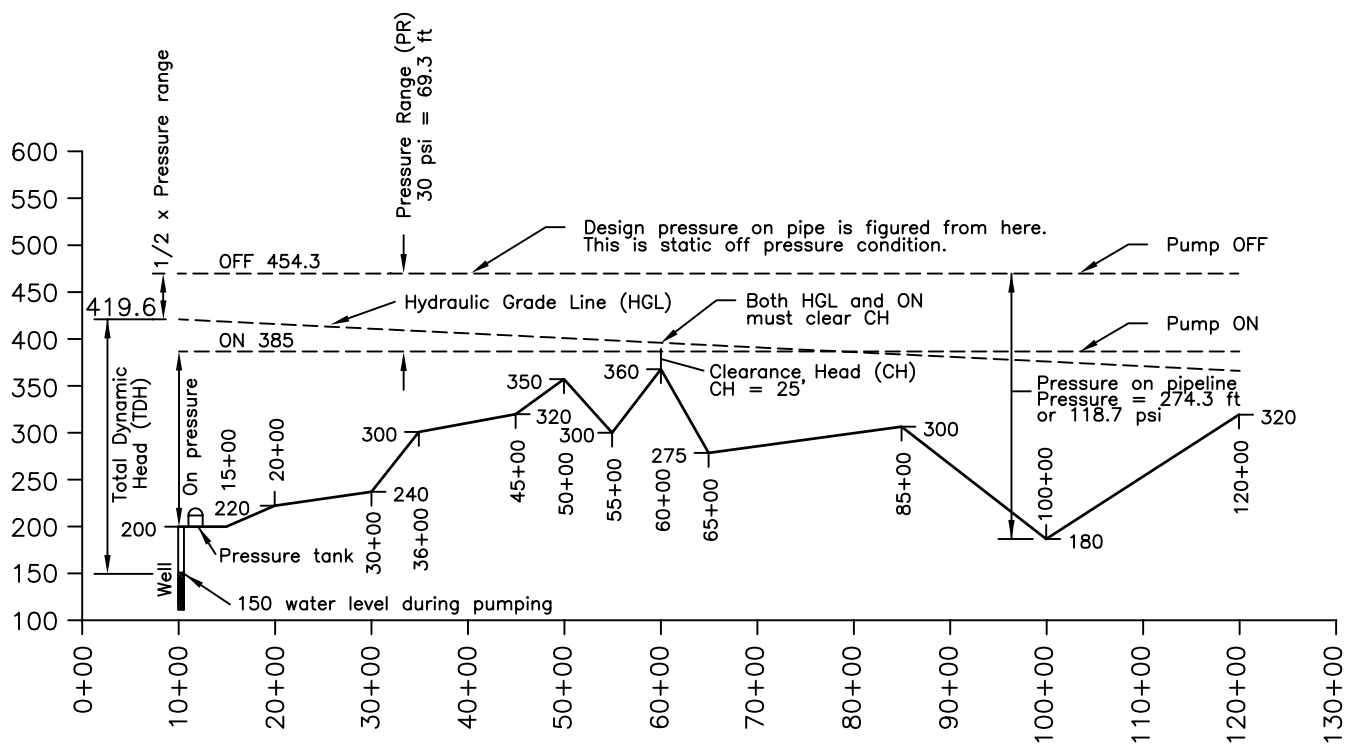


Figure 9.4
AUTOMATIC PRESSURE COMPUTATIONS

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**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 V. Tech Date 11/8/90 Checked by JCD 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 elevation 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 used = ON elevation + PR ft = 385 + 69.3 = 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 start HGL)	(11) Max Pressure on Pipe (psi) WS-(3)	Comments (slope %)
10+00		200			PVC				413.6	110.1	
	500		8	1.25	SDR 26	160	0.572	2.86			
15+00		200			PVC				410.7	110.1	
	500		8	1.25	SDR 26	160	0.572	2.86			
20+00		220			PVC				407.9	101.5	
	1000		8	1.25	SDR 26	160	0.572	5.72			
30+00		240			PVC				402.2	92.8	
	600		8	1.25	SDR 26	160	0.572	3.43			
36+00		300			PVC				348.7	66.8	
	900		8	1.25	SDR 26	160	0.572	5.15			
45+00		320			PVC				393.6	58.2	
	500		8	1.25	SDR 26	160	0.572	2.86			

continued on next page

(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 $H_f/100\text{ft}$ (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)	Comments (slope %)
50+00	500	350	8	1.25	PVC SDR 26	160	0.572	2.86	390.7	45.2	
55+00	500	300	8	1.25	PVC SDR 26	160	0.572	2.86	387.9	66.8	
											Critical
60+00	500	360	8	1.25	PVC SDR 26	160	0.336	2.86	385	40.8	Point
65+00	2000	275	6	1.25	PVC SDR 26	160	0.336	6.72	382.1	77.6	
85+00	1500	300	6	1.25	PVC SDR 26	160	0.336	5.04	376.4	66.8	
100+00	2000	180	6	1.25	PVC SDR 26	160	0.336	6.72	370.4	118.9	
120+00		320							363.7	58.2	

Figure 9.5
LATERAL PROFILE

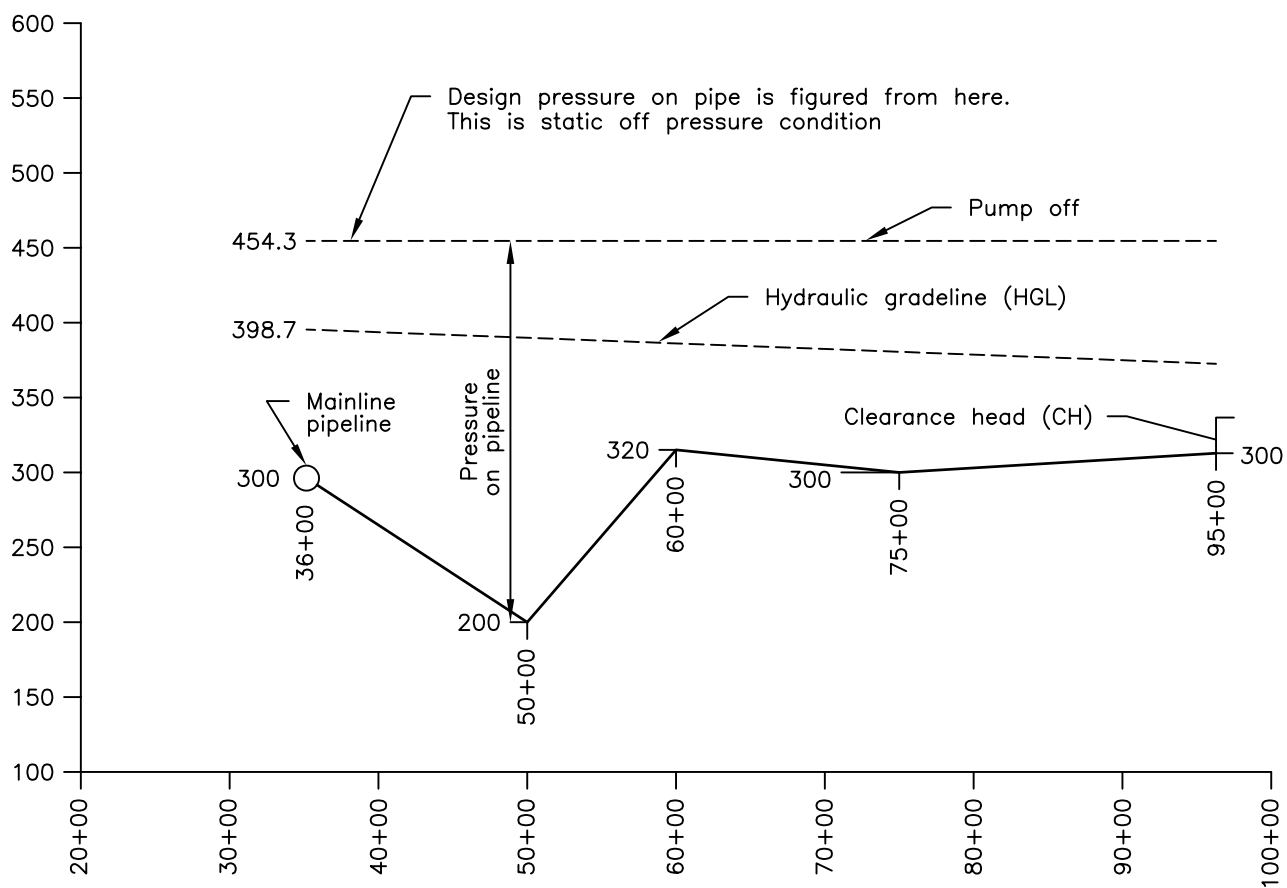


Figure 9.6
LATERAL COMPUTATIONS

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**LATERAL STOCKWATER PIPELINE
HYDRAULIC COMPUTATION WORKSHEET**

Land user Example No. 2 (Lateral A)Job Description West pastureFarm No. 532 Track No. 3 Field No. 3 County GallatinDesigner V. Tech Date 11/8/90 Checked by JCD Date 11/10/90HGL at mainline 398.7Pump OFF elevation (Automatic pressure sysem only) 454.3Flow in lateral - OFF elevation (manual, timed or gravity) -----Critical point along lateral (CP): Station 95+00 Elevation 310.0Clearance Head (CH) at critical point: 25 ft x .433 = 10.8 psiMinimum 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 $H_f/100\text{ft}$ (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)	Comments (slope %)
36+00		300			PVC				398.7	77.5	at main
	1400		8	1.25	SDR 26	160	0.572	8.01			
50+00		200			PVC				390.7	118.8	
	1000		8	1.25	SDR 26	160	0.572	5.72			
60+00		320			PVC				385	66.8	
	1500		6	1.25	SDR 26	160	0.336	5.04			
75+00		300			PVC				379.9	75.5	
	2000		6	1.25	SDR 26	160	0.336	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 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 gravity flow portion of the pipeline. Figure 9.11 contains 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 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

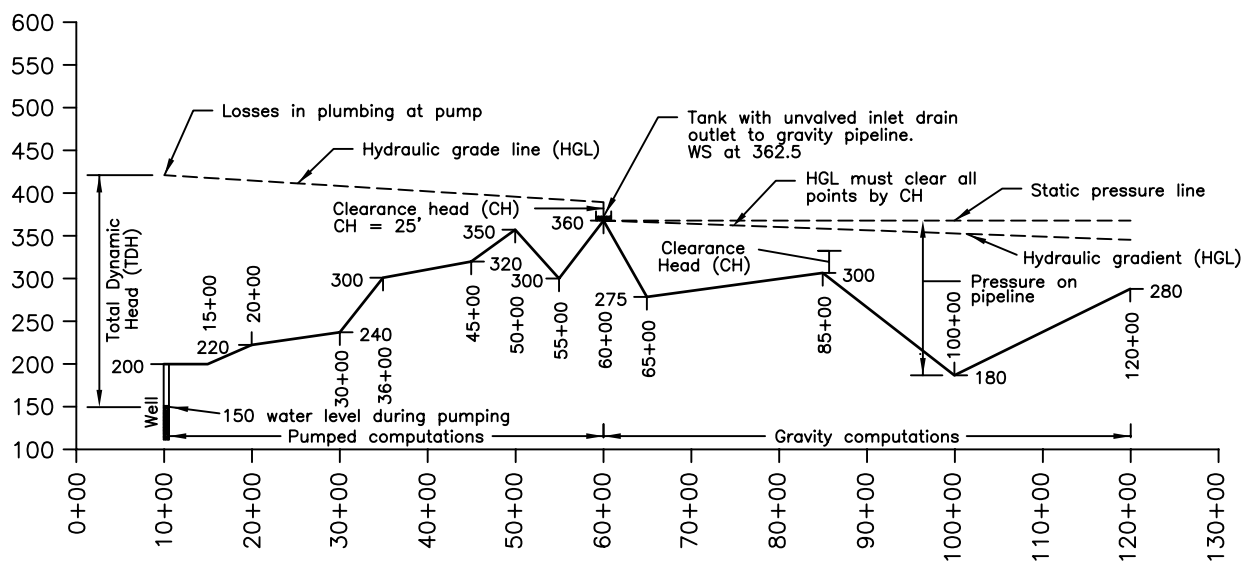


Figure 9.8
STORAGE TANK PLUMBING

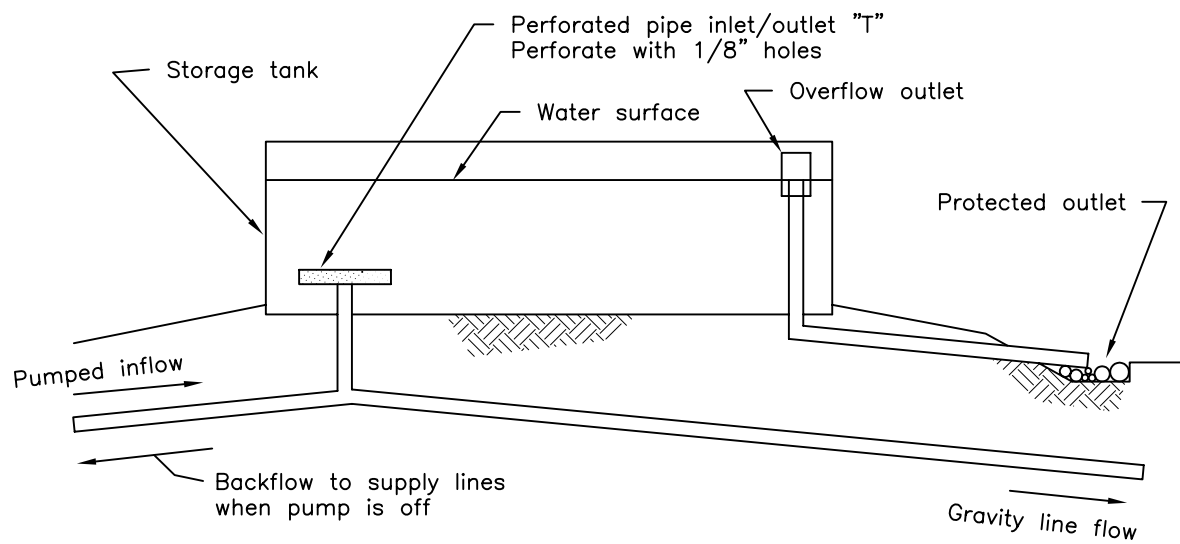


Figure 9.9
**TIMER OR MANUALLY OPERATED
 PUMP SYSTEM COMPUTATIONS**

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**MANUAL OR TIMER OPERATED STOCKWATER PIPELINE
 PUMPED SEGMENT HYDRAULIC COMPUTATION WORKSHEET**

Land user Example No. 3 (Sheet 1 of 3)Job description West pastureFarm No. 532 Tract No. 3 Field No. 3 County GallatinDesigner V. Tech Date 11/8/90 Checked by JCD Date 11/10/90Water surface elevation during pumping (WS) 150Pumped segment end station critical point (CP): Station 60+00 Elevation 360Clearance Head (CH) at critical point: 25 ft x .433 = 10.8 psiLosses in plumbing at pump (PL): 4 ftHGL at CP = CP elevation + CH ft = 360 + 25 = 385HGL_{pump} = HGL from profile = PL = 413.6 + 4 = 417.6Total 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 start HGL)	(11) Max Pressure on Pipe (psi) WS-(3)	Comments (slope %)
10+00		200			PVC				413.6	92.5	at pump
	500		8	1.25	SDR 26	160	0.572	2.86			
15+00		200			PVC				410.7	91.2	
	500		8	1.25	SDR 26	160	0.572	2.86			
20+00		220			PVC				407.9	81.4	
	1000		8	1.25	SDR 26	160	0.572	5.72			
30+00		240			PVC				402.2	70.2	
	600		8	1.25	SDR 26	160	0.572	3.43			
36+00		300			PVC				398.7	42.7	
	900		8	1.25	SDR 26	160	0.572	5.15			
45+00		320			PVC				383.6	31.9	
	500		8	1.25	SDR 26	160	0.572	2.86			
50+00		350			PVC				390.7	17.6	
	500		8	1.25	SDR 26	160	0.572	2.86			
55+00		300			PVC				387.9	38.1	
	500		8	1.25	SDR 26	160	0.572	2.86			
60+00		360							385	10.8	Critical Point
(1)											

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 hydraulic computations. Friction loss is subtracted from WS to compute HGL. Figure 9.10 shows computations that were preformed for this example.

Figure 9.10
GRAVITY FLOW COMPUTATIONS

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GRAVITY STOCKWATER PIPELINE HYDRAULIC COMPUTATION WORKSHEET

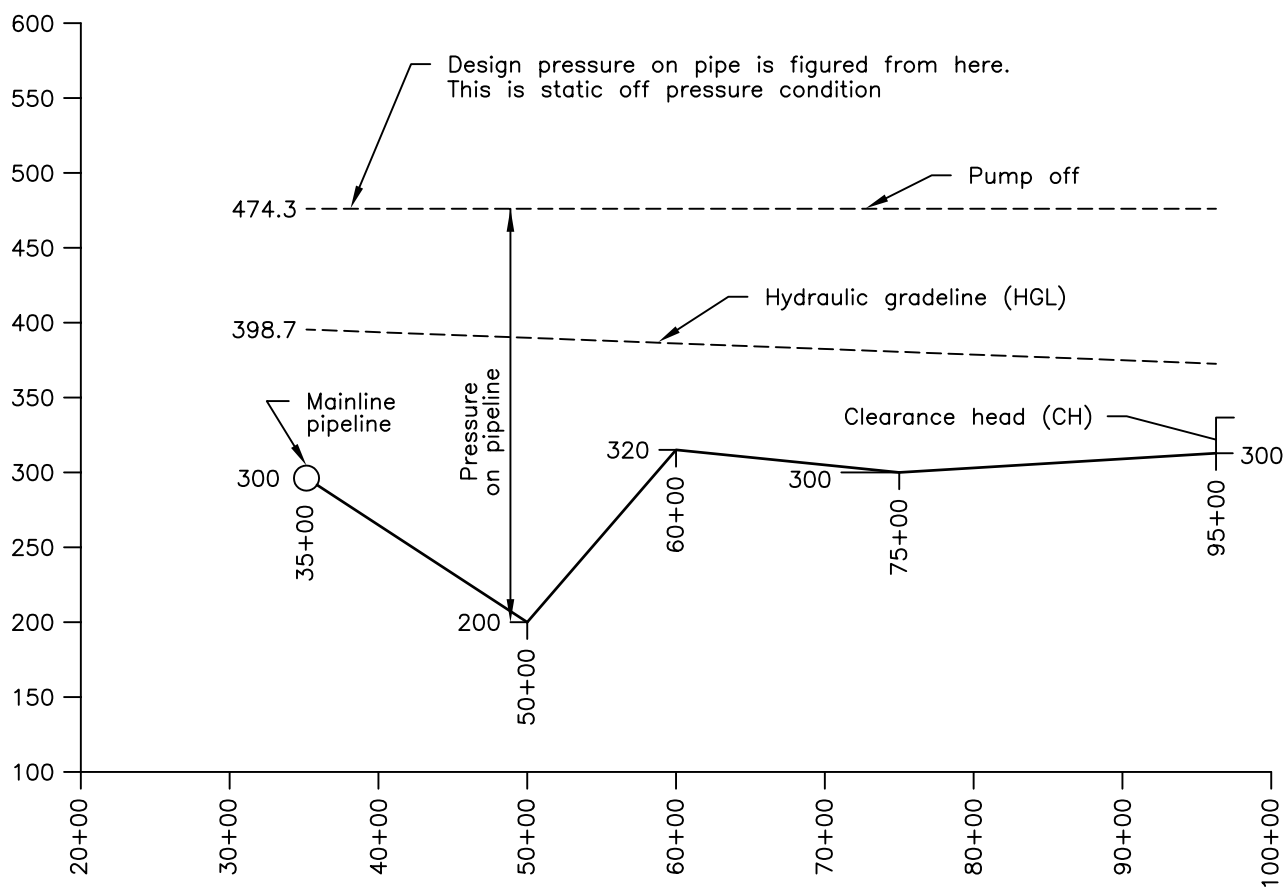
Land user Example No. 3 (Gravity Extension)

(Sheet 2 of 3)

Job description West pastureFarm No. 532 Tract No. 3 Field No. 3 County GallatinDesigner V. Tech Date 11/8/90 Checked by JCD Date 11/10/90Water surface elevation (WS) 362.5 (Intake at sta 60+00)Critical point along pipeline (CP): Station 85+00 Elevation 300Clearance Head(CH) at critical point: 25 ft x .433 = 10.8 psiMinimum required HGL at CP = CP elevation + CH ft = 300 + 25 = 325Estimated pipeline entrance losses (EL) = ftStarting HGL elevation = WS - EL = 362 - 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 $H_f/100\text{ft}$ (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)	Comments (slope %)
60+00	500	360	8	1.25	PVC	160	0.572	2.86	361.5	1.1	at source
65+00		275			PVC				358.6	37.9	
85+00	2000	275	6	1.25	SDR 26	160	0.336	6.72			Critical
	1500	300	6	1.25	PVC	160	0.336	5.04	351.9	27.1	Point
100+00		180			SDR 26				346.9	79	
120+00	2000	180	6	1.25	PVC	160	0.336	6.72			
		280			SDR 26				340.2	35.7	

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

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MO-ENG-107

07-97

File Code - Coop Folder

**LATERAL STOCKWATER PIPELINE
HYDRAULIC COMPUTATION WORKSHEET**

Land user Example No. 2 (Lateral A)

Job Description West pasture

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

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

HGL at mainline 398.7

Pump OFF elevation (Automatic pressure sysem only) _____

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 $H_f/100\text{ft}$ (ft/100)	(9) Reach Total H_t (ft) (2) x (8)	(10) HGL Elev (from start HGL)	(11) Max Pressure on Pipe (psi) WS-(3)	Comments (slope %)
36+00		300			PVC				398.7	77.5	at main
	1400		8	1.25	SDR 26	160	0.572	8.01			
50+00		200			PVC				390.7	118.8	
	1000		8	1.25	SDR 26	160	0.572	5.72			
60+00		320			PVC				385	66.8	
	1500		6	1.25	SDR 26	160	0.336	5.04			
75+00		300			PVC				379.9	75.5	
	2000		6	1.25	SDR 26	160	0.336	6.72			
95+00		310								71.1	373.2>
											335 ok

Figure 9.13
PRESSURE REDUCER VALVE INSTALLATION

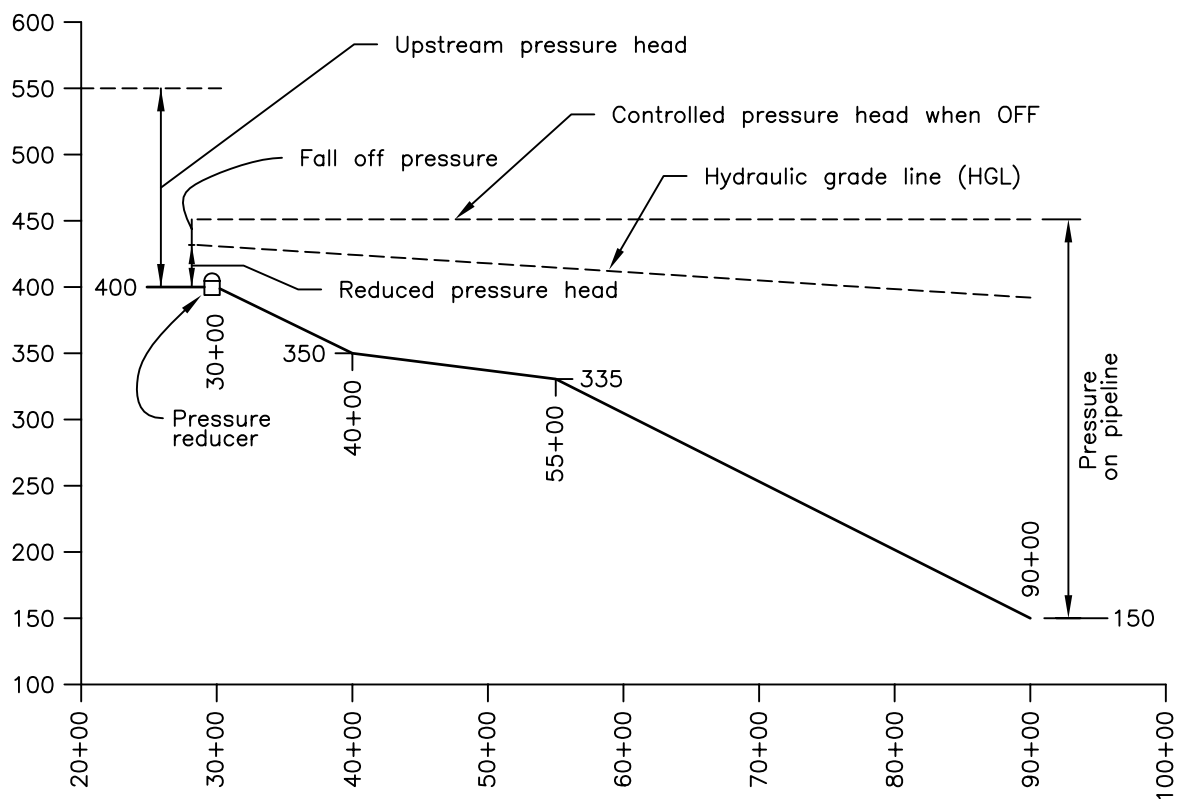


Figure 9.14
PRESSURE REDUCER VALVE SYSTEM COMPUTATIONS

USDA - NRCS

MO-ENG-107

07-97

File Code - Coop Folder

**LATERAL STOCKWATER PIPELINE
 HYDRAULIC COMPUTATION WORKSHEET**

Land user Example No. 4 (Pressure Reducer)Job Description North pastureFarm No. 532 Track No. 3 Field No. 4 County GallatinDesigner V. Tech Date 11/8/90 Checked by JCD Date 11/10/90HGL at mainline 450

Pump OFF elevation (Automatic pressure sysem 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 Manufacturer - Fall Off = 4.0 psi at receiving 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 $H_f/100\text{ft}$ (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)	Comments (Slope %)
30+00		400			PVC				440.8	21.7	at main
	1000		10	1 1/4	SDR 26	160	0.865	8.65			
40+00		350			PVC				432.2	43.3	
	1500		10	1 1/4	SDR 26	160	0.865	13			
55+00		335			PVC				419.2	49.8	
	4500		10	1 1/4	SDR 26	160	0.865	38.9			
90+00		150							380.3	129.9	
											129.9<
											160 ∴ ok

Chapter 10

Pipeline Installation

CHAPTER 10 STOCKWATER PIPELINE INSTALLATION

TABLE OF CONTENTS

PART 10.1	TRENCHING	10-1
	10.1.1 Backhoe Constructed Trench	10-1
	10.1.2 Trencher Constructed Trench	10-1
	10.1.3 Backfilling and Maintenance	10-1
	10.1.4 Road Crossings	10-3
	10.1.5 Stream Crossing	10-3
	10.1.6 Safety	10-3
PART 10.2	PIPE JOINTS	10-4
PART 10.3	INSPECTION DURING CONSTRUCTION	10-4
PART 10.4	MEASUREMENT FOR PAYMENT	10-4

FIGURES

Figures 10.1	Water Bar	10-2
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CHAPTER 10

PIPELINE INSTALLATION

10.1 TRENCHING

10.1.1 Backhoe Constructed Trench

Backhoe trenches are usually a minimum of 12 inches wide depending on depth. 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 material isn't available, then material such as sand or lime should be imported and placed around the pipe to a depth of 4 to 6 inches over the top of the pipe.

10.1.2 Trencher Constructed Trenches

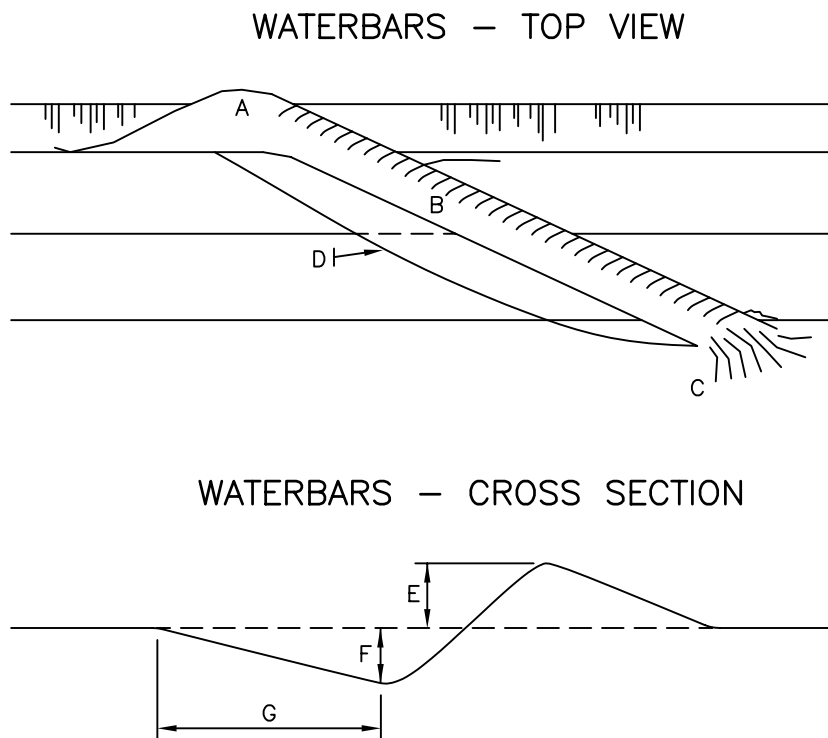
When conditions permit, trenching for pipelines which are buried from 2 to 3 feet are usually done with a narrow 4 to 6 inch wide chain trencher. Where there is little gravel or rocks and the ground is not too wet, these trenchers bring up well pulverized soil that makes good backfill material. The material 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.

10.1.3 Backfilling and Maintenance

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, out 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. D--Angle drain 30 to 45 degrees downgrade with road centerline.
6. E--Up to 2 feet in height.
7. F--Depth to 18 inches.
8. G--3 to 4 feet.
9. Remember energy dissipater, waterspreaders.

10.1.4 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. Stronger pipe or better backfilling requirements can be evaluated by Area Engineer using TR-77.

10.1.5 Stream Crossing

Crossing a stream with a pipeline may be relatively simple depending on several factors - width, depth, drainage area and especially composition of the bottom.

Selection of a stable portion of the stream will be important and alignment of the pipeline might need to be changed from a preferred location in order to accommodate this. Construct the stream crossing first then bring the rest of the pipeline to it.

Cross a gravel or earth bottom stream at a right angle and dig to the maximum depth possible. Freezing probably won't be a problem but the use of burst proof pipe should be considered if the possibility exists.

Crossing a solid rock bottom stream in the Ozarks is another proposition. A lot of thought should go into selection of site and method. One method, which has worked, is to jack hammer a trench across the rock bottom. A trench, a foot deep and as wide as the backhoe bucket, has been successful. Place the water pipe in a larger section of heavy, thick walled pipe, preferably steel, for protection and backfill with a mix of fines and larger material. Pouring some concrete over the larger pipe might be considered also. Again consider using burst proof pipe and shut off valves in case of problems.

Another consideration could be running that section (across the stream) above ground at a height well above the expected high water mark. Allowance would need to be made for drainage and shutting down during freezing weather and/or non-use periods.

Keep in mind some larger streams will need all necessary permits before construction is started.

10.1.6 Safety

It is very important to have some knowledge of the location of buried pipelines, electric cables and telephone lines. A landowner usually knows the approximate location of major buried lines but may or may not know of lines to out buildings, etc. A call to the utility company and/or Missouri One Call by the landowner even in the planning stage might save some problems later. Before construction starts it's a necessity if anything major is suspected. The Missouri One Call toll free number is 1-800-344-7483.

Another safety consideration should be the depth of trenches. If trenches are deep enough and/or soil conditions appear to be making the sides unstable, connecting pipe joints, hydrants, etc. together and then lowering into the trench should be considered. Allow time for glue joint to set prior to lowering into trench. OSHA requirements shall be followed when men are working in trenches.

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 may be used.

Polyvinyl chloride (PVC) and other rigid plastic pipes are usually joined using glued joints. Only solvents and glues designed for specific plastic type must be used. They also should be rated for temperature and conditions existing at the time of construction. Some appear to work better than others in colder than normal conditions, while others will also bond on damp pipe (used on gravity systems). A solvent cleaning and preparation process should always be done if recommended. Connections must be stabbed full depth into fittings. Pipe intended for pressure systems should have "pressure" joints, these are about 2 times as long as those for gravity systems thus allowing more surface for glue joint.

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 each side of joint or four per connection. Snaking the pipe in the trench helps keep the pipe from pulling apart.

Plastic pipe such as that used by ground source heat pump installers is usually welded by a special welder if a local installer is available.

Joints should be checked by pressure, either air or water. If the pressure tank is already installed on a pressure system, it should be left open at least 2 hours and longer if possible.

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 weather is significantly below freezing.

10.3 INSPECTION DURING CONSTRUCTION

Frequent inspection during construction of stockwater pipelines may not need to be performed by the field office. We should make a point 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 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. The laid length may be 1 to 2 percent shorter than the nominal length. 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, chain or string measurer 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 remeasured. 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, Maintenance and Replacement

CHAPTER 11 OPERATION MAINTENANCE AND REPLACEMENT

TABLE OF CONTENTS

PART 11.1	GENERAL	11-1
PART 11.2	WINTERIZING	11-1
PART 11.3	OPERATION AND MAINTENANCE PLAN	11-1
PART 11.4	REPLACEMENT	11-1

FIGURES

Form MO-ENG-108 Operation and Maintenance Guide (2 sheets)

CHAPTER 11

OPERATION, MAINTENANCE AND REPLACEMENT

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 freezeup. 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. Attached is Form MO-ENG-108. When there are unique or critical factors associated with a system, a supplemental or special operation and maintenance plan should be provided.

11.4 REPLACEMENT

As installed systems continue to operate, there will be deterioration of materials over time. Provisions must be made to replace materials, ie. pipe materials, couplings, valves and other appurtenances as needed to keep system operating.

**OPERATION AND MAINTENANCE GUIDE
FOR
STOCKWATER PIPELINE AND TANKS**

Operator: _____

Project: _____

Location: _____ Sec. _____, T. _____, R. _____

NRCS 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 numbers 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 _____

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 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.

Appendix A

WORKSHEETS

APPENDIX A

WORKSHEETS

- MO-ENG-100 Documentation Checklist
- MO-ENG-101 Livestock Watering Practice
- MO-ENG-102 Livestock Watering Practice Checkout
- MO-ENG-103 Stockwater Pipeline Resource Inventory Worksheet
- MO-ENG-104 Automatic Pressure Stockwater Pipeline Hydraulic Computation Worksheet
- MO-ENG-105 Manual or Timer Operated Stockwater Pipeline Pumped Segment Hydraulic Computation Worksheet
- MO-ENG-106 Gravity Stockwater Pipeline Hydraulic Computation Worksheet
- MO-ENG-107 Lateral Stockwater Pipeline Hydraulic Computation Worksheet
- MO-ENG-108 Operation and Maintenance Guide for Stockwater Pipeline and Tanks
(2 sheets)

DOCUMENTATION CHECKLIST

ITEMS THAT WILL BE DOCUMENTED ARE:

NRCS-CPA-52 completed _____

Survey Notes and Benchmark description completed _____

Profiles plotted _____

Data sheet completed _____

Computations checked _____

Engineering Job Class noted _____

Construction Plans and Specifications Completed _____

Conservation Practice Installation Check (MO-ENG-74) attached _____

ACP practices recorded on LTP-4 (if applicable) _____

AD-862 (or equivalent) and drawings and specifications attached _____

LTA work identified by agreement item number (if applicable) _____

Practices identified by job number _____

Completed practices recorded on plan map _____

Assistance Notes recorded (NRCS-CPA-6) _____

SCS-ENG-5 or Missouri One Call System, Inc. (if Needed) _____

FOCS progress entered _____

Name of Producer _____

Type of Practice _____

Date _____

Responsible Technician _____

Livestock Watering Practice

Landowner Name: _____

Address: _____ Field # _____

Completed by: _____ Checked by: _____ Approved by: _____

Date: _____ Date: _____ Date: _____

_____ Low PSI in pressure tank
_____ Average pressure tank outflow (gpm)
_____ Estimated springflow in gpm(or N/A)
_____ No. of Cattle
_____ Sketch of pipeline location attached

CALL BEFORE DIGGING
1-800-344-7484
MISSOURI ONE CALL SYSTEM, INC.

Sizing Pipe for pressure systems:

$$h_f = \frac{\text{Head}}{\text{Distance}} = \frac{\text{Well El.} + (\text{Low PSI} \times 2.31) - \text{Tank El.}}{\text{Distance in Feet}}$$

$$h_f = \frac{(\text{_____}) + ((\text{_____}) \times (2.31)) - (\text{_____})}{(\text{_____})}$$

$$h_f = \frac{\text{_____ Feet of Head}}{\text{_____ Feet of Pipe}}$$

Use h_f and MLWSH, Chapter 5 (or applicable charts) to determine size of pipe:

Use _____ inch diameter pipe

Flow through pipe is _____ gpm

Sizing Pipe for spring systems

Use maximum springflow (or provide overflow)

$$h_f = \frac{\text{feet of fall}}{\text{length of pipe}} = \text{_____}$$

Sizing Tank:

If enough water cannot be provided using a pipeline, size tank reservoir to provide adequate water:

A cow will drink about 5 gallons each trip to the water source. (Use the 5 gallons per drink even for calves and smaller animals). Size the tank for one "drink" for the whole herd:

Provide water at a rate of not less than 2 gpm times the number of cattle that can drink. For example, a two hole waterer needs at least 4 gpm. Don't exceed 12 gpm without checking output of well and planned tank.

Use _____ gpm delivery rate per drinking fountain.

Water Needed = (No. of Cattle) x (5 gallons/drink)

Water Needed = _____ x _____

Tank Size = Water Needed = _____ Gal.

Bill of Materials

_____ No. of Tanks
_____ Freezeproof Hydrants
_____ Ft. of _____ dia. Schedule 40 Pipe
_____ C.Y. of concrete in pad
_____ Ft. of Ultraviolet Stabilized Aboveground Pipe

Tank Description _____
_____ Ft. of Fencing
_____ Ft. of _____ dia. Schedule 40 Pipe
_____ Tons/C.Y. of gravel in pad and base
_____ Check valve for Rural Water

Plus plumbing and fitting requirements. Other miscellaneous items listed below or attached

Livestock Watering Practice Checkout

Landowner Name: _____ Practice Description: _____
Field #(s): _____ Acres Served: _____

Pipeline Components:

_____ Ft. of _____ inch diameter pipe	ASTM# _____
_____ Ft. of _____ inch diameter pipe	ASTM# _____
Installation of Ultraviolet Stabilized Aboveground Pipe(2% Carbon Black), ASTM # D2239 or AWWA C901:	
_____ Ft. of _____ inch dia., _____ psi pipe	
_____ Ft. of _____ inch dia., _____ psi pipe	
Pipe is buried 18 inches or more: yes no N/A	
Trench is backfilled, graded, and seeded: yes no N/A	
If pipe is hooked to rural water, has required check valve been installed: yes no N/A	

Tank Components: Concrete Freezeproof

_____ No. of Tanks(or N/A)	_____ No. of hydrants(or N/A)
Pad installed at least 2' out from all sides of tank: yes no N/A	
Pad is: gravel concrete (circle one) Is gravel retained by Ties or similar material: yes no	
Pad computations: _____ (L) x _____ (W) = _____ S. F. x _____ (D) = _____ C.Y. (Volume)	
or converting to tons: _____ C.Y. x 1.4 = _____ tons	
Retaining wall installed and buried portion fenced from cattle: yes no	
Is overflow pipe protected: yes no N/A	

Tank Components: Energy Free

_____ No. of Tanks(or N/A)	_____ No. of hydrants(or N/A)
Pad installed at least 2' out from all sides of tank: yes no N/A	
Pad is: gravel concrete (circle one) Is gravel retained by Ties or similar material? yes no	
Pad computations: _____ (L) x _____ (W) = _____ S. F. x _____ (Dpth) = _____ C.Y. (Volume)	
or: converting to tons: _____ C.Y. x 1.4 = _____ tons	

Miscellaneous:

Cross fencing has been installed to provide grazing distribution improvement: yes no N/A
If cost shared, has landowner supplied the field office the tickets for materials: yes no N/A

Pipeline and Tank Installation meet all NRCS Specifications

Completed by _____ Approved by: _____
Date: _____ Date _____

STOCKWATER PIPELINE RESOURCE INVENTORY WORKSHEET

Land user _____

Job description _____

Farm No. _____ Tract No. _____ Field No. _____ County _____

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. (See Pipeline Standard 516)

Total usage per day (T) = no x V = _____ x _____ = _____ gal/day..

Add 10% for evaporation and spillage: (GT) = T + 10% T (optional)

GT = _____ + .10 x _____ = _____ gal/day

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

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

TT = _____ hrs

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

[illegible]

Land user _____
Job description _____
Farm No. _____ Tract No. _____ Field No. _____ County _____
Designer _____ Date _____ Checked by _____ Date _____

[illegible]

[illegible]

Land user _____
 Job description _____
 Farm No. _____ Tract No. _____ Field No. _____ County _____
 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 = _____ + _____ = _____

[illegible]

**OPERATION AND MAINTENANCE GUIDE
FOR
STOCKWATER PIPELINE AND TANKS**

Operator: _____

Project: _____

Location: _____ Sec. _____, T. _____, R. _____

NRCS Office: _____ Phone: _____

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- ☐ 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:

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Date _____

MAINTENANCE CHECKLIST

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- ☐ 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.

Appendix B

COMPUTER PROGRAMS

PIPELINE DESIGN PROCEDUREInformation to collect

- 1) Type of Livestock _____
- 2) Number of Livestock _____
- 3) Water needed: gal / day / head: (1.5) (12) (25) (_____) **Circle one**
 Compute Minimum Flow Rate (item 2 x item 3) ÷ (60 x 8*) = _____ gal / min
- 4) Grazing months: From _____ To _____
- 5) Type of stock tank shut off: (Manual) (Float) **Circle one**
- 6) Stock tank Size: _____ gal
- 7) Sketch possible pipeline route on plan map or USGS topographic map.
- 8) Utilities Present (Yes) (No) **Circle one**
- 9) Existing Pressure Tank: (Yes) (No) **Circle one**
 Size _____ Gal
 On Pressure _____ PSI
 Off Pressure _____ PSI

- 10) Other information if new well will be constructed, a new pressure tank is installed, or expansion of herd is planned.

Pump capacity: _____ Gal / Min	<u>Source of Information</u>
Other uses of the well:	Landowner
household: _____ (35-50 gal/day/person)	AWMFH
farm: _____	Missouri Livestock Watering Systems Handbook
milkhouse: _____	Midwest Plan Service MWPS-14
other: _____	
Total Gal/Day: _____	

*8 hours used for calculation. Assumption is that cattle will place peak demand during these hours. Actual hours range between 8 and 12.

PROCEDURE FOR DETERMINING EXISTING PUMP CAPACITY OF SYSTEM

No water should be used by the operator during this process.

- 1) Open any faucet and run until the pump turns “on”.
- 2) Close the faucet and let the pump fill the pressure tank until it turns “off”.
- 3) Open the faucet closest to the pressure tank and collect all the water discharged until the pump turns “on”.
- 4) When the pump turns “on”, close the faucet and start timing the pump cycle. (Pump “on” to pump “off”)
- 5) Record the time for the pump cycle. _____ seconds
- 6) Measure the gallons collected in step 3. _____ gal
- 7) Average pumping capacity: $(\text{item 6} \div \text{item 5}) \times 60 =$ _____ gal / min

Example:

9 gals collected in 72 seconds (1 min 12 sec)

$(9 \div 72) \times 60 = 7.5$ gal / min (average)

MISSOURI LIVESTOCK WATERING SYSTEMS HANDBOOK

APPENDIX B

PROCEDURE FOR PIPELINE DESIGN

THIS PROCEDURE WAS ADAPTED FROM
WISCONSIN WITH VERY LITTLE CHANGE

The Missouri pipeline spreadsheet program can be used to design a pipeline system. Attached are design examples. Two options are available in the spreadsheet, **“Design”** and **“Pipe Q”**. The “Design” tab requires the user to input Q (gal / min), and the “Pipe Q” tab Q (gal / min) is solved for, based on the layout of the pipeline and a given pressure at the outlet.

Other design considerations

Check the pressure tank for size and cycling. The “Pressure Tank Design Procedure Example” is used.

The spreadsheet gives the pressure rating of the pipe at each station. A safety factor of 1.4 is included.

“Design” tab (example) Exhibits 1 and 2

This system will deliver 6 gal / min to the outlet at station 1200. The minimum pressure tank setting is 50 psi to push the 6 gal / min over the hill. A lesser pressure would push less gal/min over the hill.

“Pipe Q” tab (example) Exhibits 3, 4 and 5

These three exhibits show changes that occur in the same pipeline system as the pressure at the outlet is increased. Note the rise in the hydraulic grade line of the system at the critical station of 600. Exhibit 5 shows the maximum flow rate for this system with the given pressures. Lesser pressures will have flow but are not calculated by the spreadsheet. The same results can be achieved by changing the “design” tab numbers.

“Design” tab (example) Exhibit 6 and 7

This exhibit shows outlets at different locations. Some design changes will be required to make this work.

PRESSURE TANK DESIGN PROCEDURE EXAMPLE

The Desired Outcome

Provide a pressure tank which will cause the pump to recycle not more than 6 times per hour when pumping the average rate needed to supply the maximum daily use.

What pressure tank size is needed for an average pump rate of 14 gal / min and given pressure tank settings of: 50 psi on, 70 psi off?

Max daily use:

175 beef cows at (12 gal / day / head) = 2100 gal / day

House 360 gal / day

Total use = 2100 + 360 = 2460 gal / day

Average daily rate: $2460 \div (10^1 \times 60) = 4.1$ gal / min

Given:

In one cycle inflow = outflow

6 cycle / hour = 10 min / cycle

Then one cycle (10 min) yields 41 gal. (given by 10 min. x average daily rate of 4.1 gal.)

With an average pumping rate of 14 gal. / min, one cycle will have 2.9 minutes of pumping and 7.1 minutes of rest. During this 7.1 minutes, the pump rests but water is delivered.

$41 \text{ gal} / 14 \text{ gal} / \text{min} = 2.9 \text{ min}$

$10 \text{ min} - 2.9 \text{ min} = 7.1 \text{ min}$

Therefore:

$7.1 \text{ min} \times 4.1 \text{ gal} / \text{min} = 29.1 \text{ gal}$ usable storage in the pressure tank.

This needs to be increased by the efficiency of the tank at a given operating pressure range.

(See Figure 1) 50 psi on – 70 psi off gives 21.3 % efficiency

Tank size = $29.1 / .213 = 137$ gal pressure tank required.

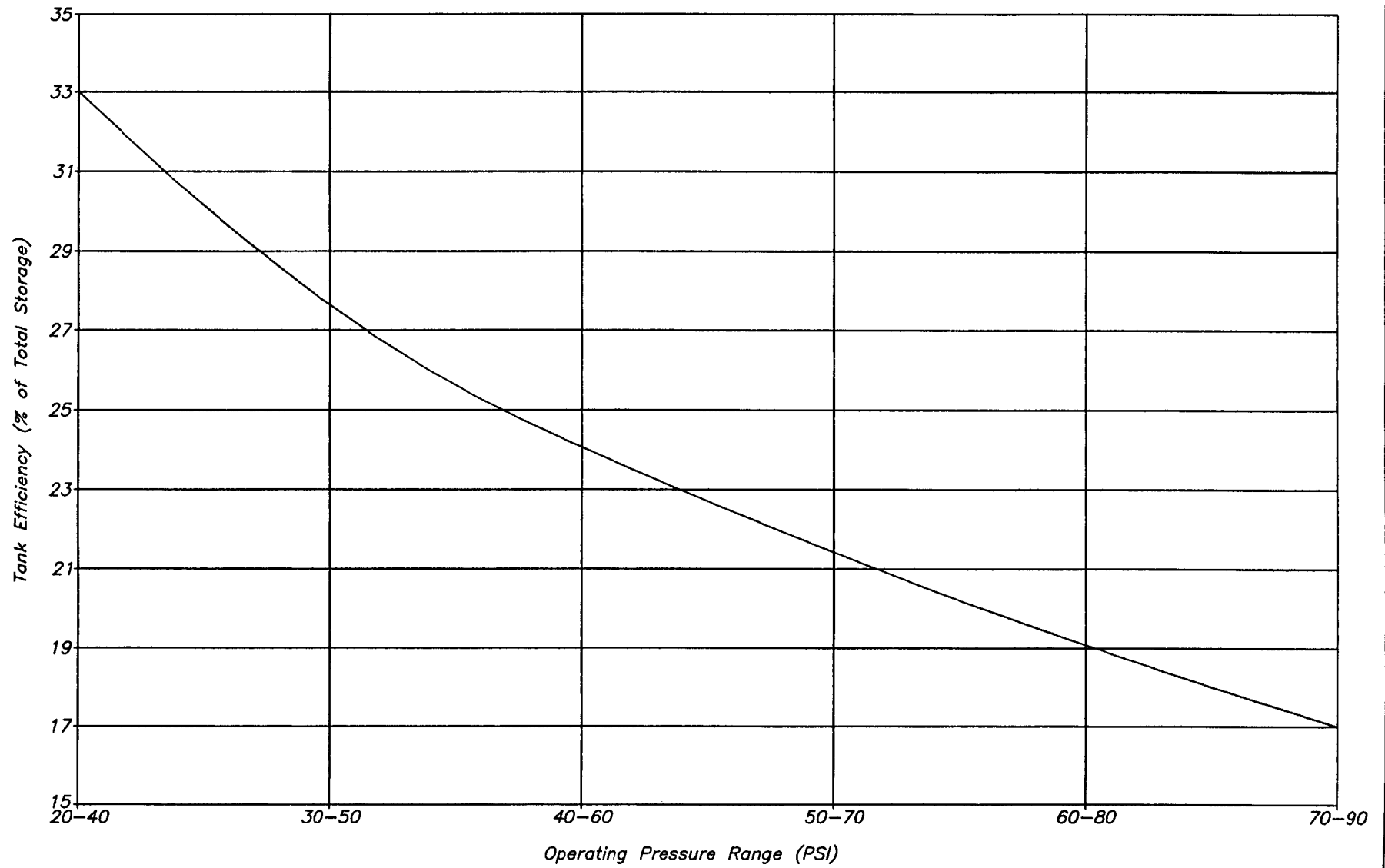
Other pressure tank sizing charts and graphs may also be used, like Midwest Plan Service Publications - 14.

Note:

Use a shorter cycle time if needed to keep pressure tank within a reasonable size and cost range. Pump supplier should be contacted on recommended size of pressure tank.

¹10 hours used for calculation. Assumption is that cattle will place peak demand during these hours. Actual hours range between 8 – 12.

Figure 1 – Pneumatic Pressure Tank Efficiency



INSTRUCTIONS

These are instructions for the use of the Pipeline Spreadsheet for EXCEL. The program is designed to calculate the friction loss through a pipeline system. There is a sheet labeled "Help" that gives an explanation of terms. You need to be familiar with how to design a pipeline system before you use this spreadsheet for designing a system. There are two methods of designing a pipeline system. The tab labeled "Design" allows you to vary the flow and the pipe size throughout the system. The tab labeled "Pipe Q" solves for the flow in a system where the water is taken out at the end only and five pipe sizes can be used. The instructions for both systems are below and to the right.

INPUT (for Design tab)

The first thing that needs to be done is to clear the worksheet. There is a macro button labeled "Reset Worksheet". You need to place the cursor on this button and click on it. This will reset the worksheet. If this isn't done you may get some erroneous data.

The input to the heading section is the Client, DSN by and any Comments. Data input is the elevation of the pressure tank or water source. The high and low pressure switch settings for the pressure tank and the mannings "n" value of the pipe being used. The next item to input is the station along the pipeline. Up to 15 stations can be entered. In the outlet column you only enter a value if water is being taken out at this location, otherwise enter a zero. Typically the last station entered would have a value for the design flow in gpm. The next column is the total system flow from the pressure tank. If flow was being taken out at different stations along the pipeline, the total gpm would be reduced by the amount entered in the previous column. If you are designing for only one flow at the last station then every station would have the design flow entered. The next column to be entered is the ground elevation at each station. The next column is the pipe id. There is a sheet labeled "Pipe ID" listing the common pipes used and there corresponding pipe id. The pipe diameter entered at a station is for the length from that station to the previous station. The pipe sizes can be changed for each reach.

OUTPUT

There is a column labeled "Velocity" at the far right of the input screen. The standard specifies that if the velocity is less than 8 fps some means must be provided to remove air from the high points in the system. This column gives the velocity for each reach of the system. If you page down, the next set of columns gives the results. If there are numbers all the way across for each station entered then the design will work. If there are some columns that show "no flow" then some changes will need to be made to make the system work. Usually the flow will have to be changed or the pipe size increased. To get a visual representation of what is happening click on the sheet labeled "Graph" at the bottom of the screen. This will give a graphical representation of the ground line and hydraulic grade line. To get back to the design section click on the sheet labeled "Design". The "Help" sheet gives the explanation for each column heading. The last column gives the design pressure required at each station of the pipeline.

PRINTING

There are two macro buttons on the spreadsheet labeled “Print Design” and “Print Graph”. Move the cursor to either one of these and click on it to print the desired output.

Pipe Q Tab Instructions

The Pipe Q tab is for the design of a system where there is only one outlet and up to five pipe sizes. Before starting the input data hit the “Reset Worksheet” button.

INPUT

The first input is how many pipe sizes you will be using (1-5). The next is pressure tank elevation (assumed), high and low pressure settings on the pressure tank, mannings “n” value of the pipe being used, head loss at the outlet (this is the friction loss through the control valve at the outlet) and the pipe ID. The manufacturer of the outlet valve should provide what the friction loss through; the valve for a range of flows is. If it is given in “psi” it needs to be converted to feet by multiplying it by 2.31. If you chose more than one pipe size you will be prompted for the pipe section lengths and diameters. The total of these should equal your total station length. The first pipe section is starting at the pressure tank. The profile of the pipeline is then entered using stationing starting at the pressure tank as station 0 and then entering the elevation at each station.

If you switch from one pipe size to two or more pipe sizes without resetting the worksheet you will need to erase the diameter you input for one pipe. If you go from two or more pipes to one you will need to erase the length and diameter for the sections and input the diameter in the line above.

OUTPUT

The spreadsheet will calculate the static elevation, the high and low HGL. In the upper right part of the spreadsheet, two boxes will show what the output is for the high and low pressure settings along with the velocity for each flow for each pipe diameter if more than one pipe size was used. If either HGL intersects the ground line a “No Flow” will appear in the boxes. The spreadsheet will not be able to calculate the flow for the input parameters. The input parameters will need to be changed or you will need to use the “Design” sheet if more than two pipe sizes are required. If you page down there will be a graph showing the ground profile, the high and low HGL and the static elevation. This graph will be printed when you hit the “Print Design” button.

HELP

Before starting to enter data the worksheet must be reset to work properly.

INPUTS

High and low pressure from pressure tank

Pressure tank elevation.

Mannings "n" value - This is 0.009 for PVC and Polyethylene pipe.

Station - Start stationing at pressure tank. Make sure to include lowest and highest points along the pipeline. Have a station for each outlet location.

Outlet GPM - Calculate how much water you will need per pasture. Most likely you will only be taking water out at one pasture. The outlet GPM for the other pastures will be 0. The program will handle water being removed at more than one location at a time.

Total GPM - This will be the GPM going through the system. Even though outlet GPM at a particular spigot may be 0, the total GPM will be what is required for the whole system.

Ground Elev. - This is the ground elevation corresponding to the stationing above. The lowest elevation will give the highest pressure in the pipe.

Pipe ID - This is the inside diameter of the pipe being used between the preceding station and the current station. For a given pipe size there are several inside diameters depending on pipe material and pressure rating.

OUTPUTS

Friction Loss - This is the energy loss due to pipe roughness. It depends on the GPM, pipe diameter and on Mannings "n" coefficient. It is the friction loss from the current station to the previous station.

HGL - Represents the hydraulic grade line at any location under the specified flow conditions. If the pipe elevation is greater than the HGL, then the system doesn't have enough pressure to get the water to that point or beyond. If this happens "no flow" will appear in the table. Even if the table shows flow beyond that point there will be none. Try putting in larger pipe size. This will decrease the friction loss and will give you a higher HGL.

Section psi - This is the pressure in the pipe at a particular point when the tank is at the specified pressure.

The HGL and Section psi have been provided for both the high and low settings on the pressure tank. You may not have enough pressure to deliver water at the low setting.

High Static - This is the pressure in the pipeline when there is no flow in the pipeline and the pressure tank is at the maximum setting. This is the maximum pressure the pipeline will have to withstand. Check this column to determine the minimum pressure rating for the pipe.

Design Pressure for Pipeline - This is the pressure that the given section of pipe has to be designed for. It includes a safety factor for waterhammer.

		Plastic Pipe Inside Diameters							
	PVC			SDR - PVC					PE
Size	SCH 40	SCH 80	SCH120	SDR 32.5	SDR 26	SDR 21	SDR 17	SDR 13.5	
3/4"	0.82	0.74	0.71	NA	NA	0.93	0.93	0.89	0.82
1"	1.05	0.96	0.92	NA	1.2	1.19	1.16	1.12	1.05
1 1/4"	1.38	1.28	1.23	1.54	1.54	1.5	1.46	1.41	1.38
1 1/2"	1.61	1.5	1.45	1.78	1.75	1.72	1.68	1.62	1.61
2"	2.07	1.94	1.88	2.23	2.19	2.15	2.1	2.02	2.07
2 1/2"	2.47	2.32	2.28	2.7	2.66	2.6	2.54	2.45	2.47

Note:

For further details see appropriate ASTM or AWWA Standards. Information is also included in Missouri Livestock Watering Systems Handbook, Chapter 5.

LIVESTOCK PIPELINE

Ver. 9.99

Client: Exhibit 1 Design Tab Example

Date: 3/31/00

DSN By: CHK By: _____

Date: _____

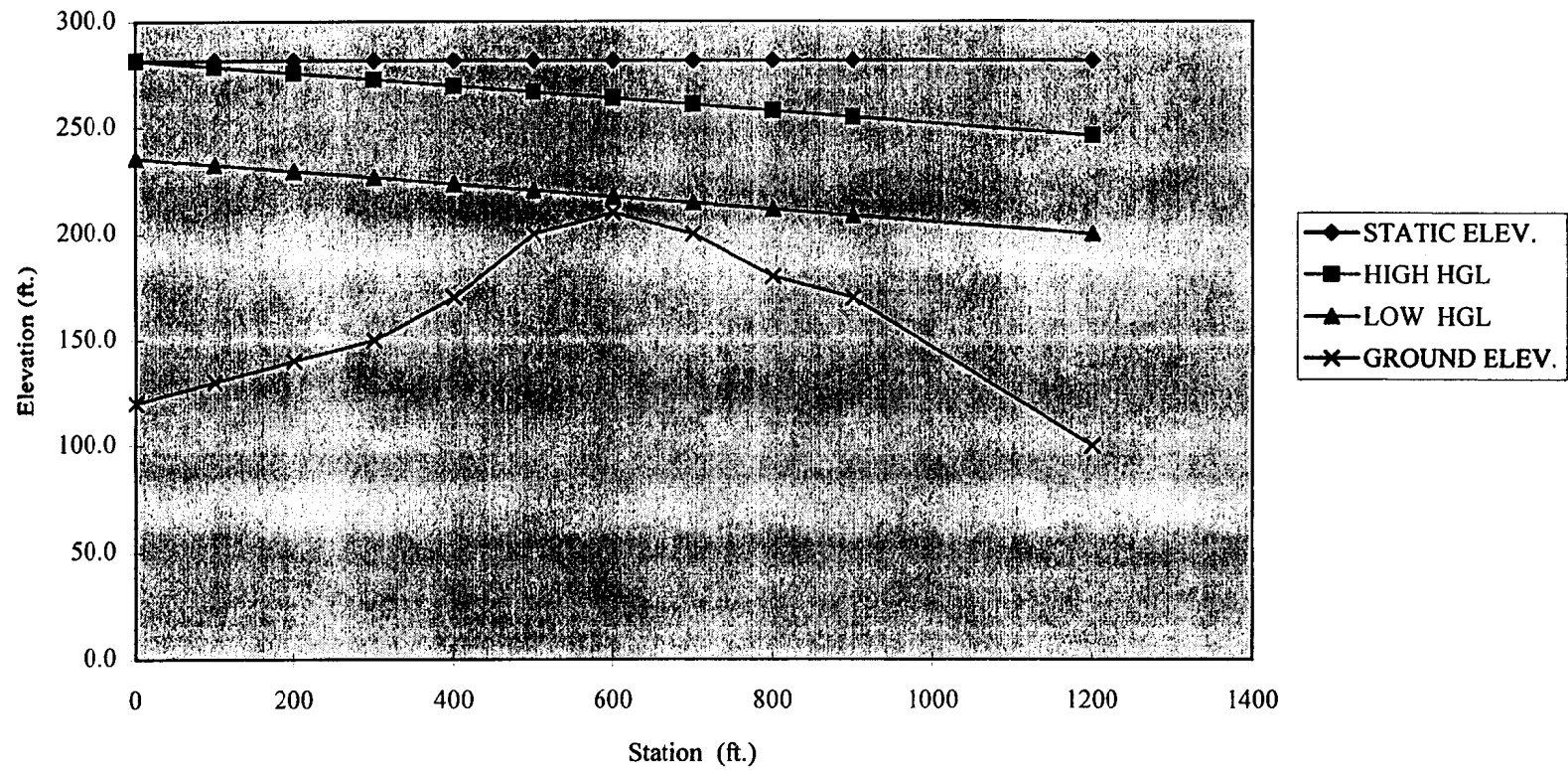
Comments:

Pressure Tank elevation (ft.) 120
 High pressure from tank (psi) 70
 Low pressure from tank (psi) 50
 Mannings "n" 0.009

Section Number (press. tank)	Station (ft.)	Outlet (gpm)	Total (gpm)	Ground Elev. (ft.)	Pipe ID (in.)	Design Pressure for Pipeline (psi)	Velocity (fps)
	0	No outlet	6	120	NA	100.0	
2	100	0	6	130	1.05	92.0	2.2
3	200	0	6	140	1.05	84.0	2.2
4	300	0	6	150	1.05	75.9	2.2
5	400	0	6	170	1.05	61.7	2.2
6	500	0	6	200	1.05	41.3	2.2
7	600	0	6	210	1.05	33.3	2.2
8	700	0	6	200	1.05	37.7	2.2
9	800	0	6	180	1.05	48.2	2.2
10	900	0	6	170	1.05	52.6	2.2
11	1200	6	6	100	1.05	90.4	2.2
12	0						
13	0						
14	0						
15	0						

Section Number	Friction Loss (ft.)	High HGL (ft.)	High Section (psi)	Low HGL (ft.)	Low Section (psi)	High Static (psi)
1	None	281.5	70.0	235.4	50.0	70.0
2	2.95	278.6	64.4	232.4	44.4	65.7
3	2.95	275.6	58.8	229.5	38.8	61.3
4	2.95	272.7	53.2	226.5	33.2	57.0
5	2.95	269.7	43.2	223.6	23.2	48.3
6	2.95	266.8	28.9	220.6	8.9	35.3
7	2.95	263.8	23.3	217.7	3.3	31.0
8	2.95	260.9	26.4	214.7	6.4	35.3
9	2.95	257.9	33.8	211.8	13.8	44.0
10	2.95	254.9	36.8	208.8	16.8	48.3
11	8.86	246.1	63.3	199.9	43.3	78.7
12						
13						
14						
15						

Pipeline HGL



Client: Exhibit 2 Design Tab Example
DSN By:

Date: 3/31/00

LIVESTOCK PIPELINE

Ver. 9.99

Client: Exhibit 3 Pipe Q Tab Example

Date: 3/31/00

DSN By:

CHK By: _____

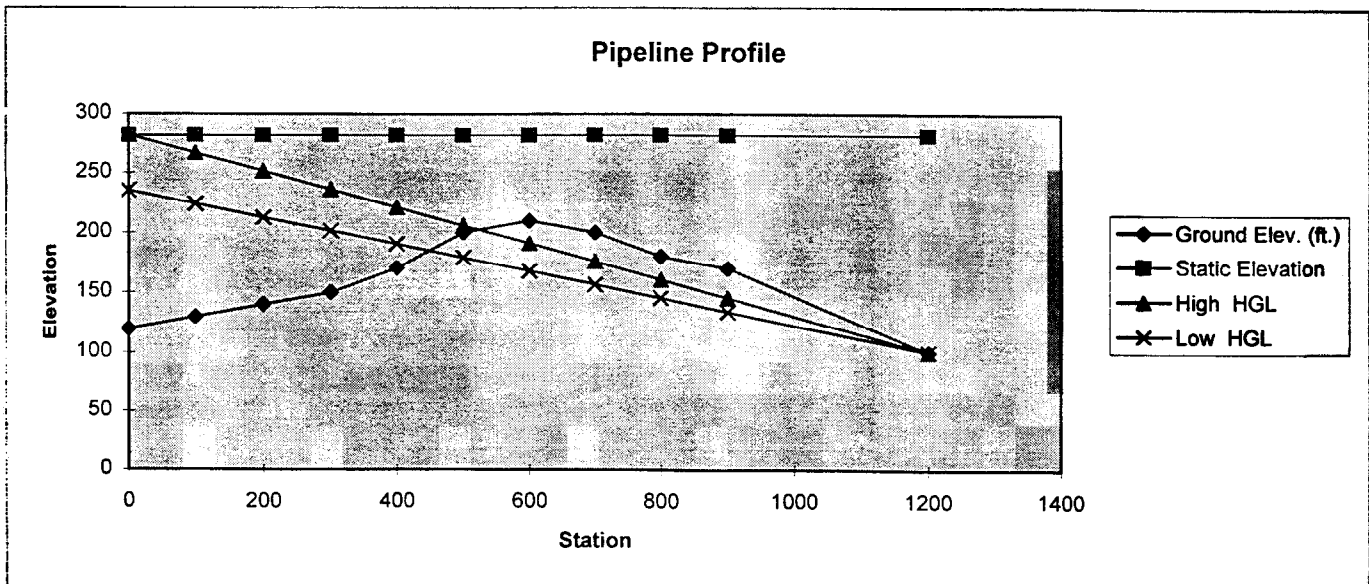
Date: _____

Comments:

		Flow (gpm)	Pipe Sec.	Velocity hi (fps)	Velocity lo (fps)
Number of pipe sizes (1-5)	1		1	NO FLOW	NO FLOW
Pressure Tank elevation (ft.)	120	No Flow		NO FLOW	NO FLOW
High pressure from tank (psi)	70	No Flow		NO FLOW	NO FLOW
Low pressure from tank (psi)	50	No Flow		NO FLOW	NO FLOW
Mannings "n"	0.009			NO FLOW	NO FLOW
Head loss at outlet (ft.)	0			NO FLOW	NO FLOW
Pipe ID (in.)	1.05				

Section Number	Station (ft.)	Ground Elev. (ft.)	Static Elevation	High HGL	Low HGL	Design Pressure for Pipeline (psi)
(press. tank)	0	120	281.7	281.7	235.5	100.1
2	100	130	281.7	266.6	224.2	84.5
3	200	140	281.7	251.4	212.9	69.0
4	300	150	281.7	236.3	201.6	57.1
5	400	170	281.7	221.1	190.3	48.4
6	500	200	281.7	206.0	179.0	35.4
7	600	210	281.7	190.9	167.8	31.1
8	700	200	281.7	175.7	156.5	35.4
9	800	180	281.7	160.6	145.2	44.1
10	900	170	281.7	145.4	133.9	48.4
11	1200	100	281.7	100.0	100.0	78.7
12	0					
13	0					
14	0					
15	0					

INPUT ERROR



LIVESTOCK PIPELINE

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Client: Exhibit 4 Pipe Q Tab Example

Date: 3/31/00

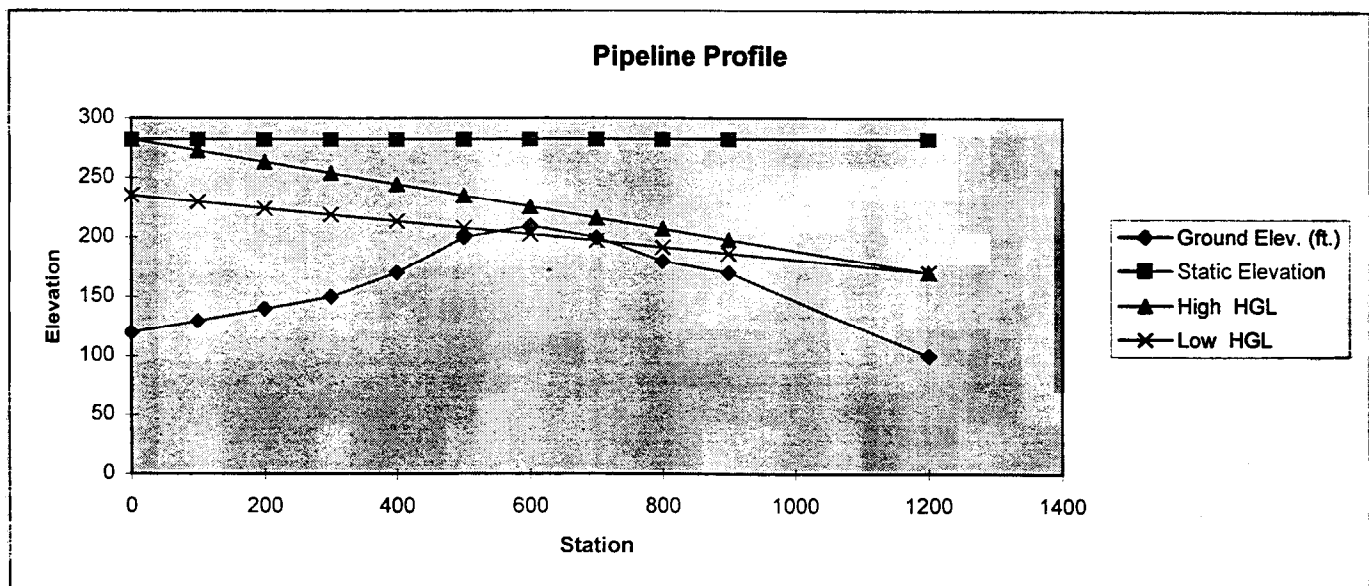
DSN By: _____ CHK By: _____

Date: _____

Comments:

		Flow	Pipe Sec.	Velocity hi	Velocity lo
Number of pipe sizes (1-5)	1	(gpm)	1	(fps)	(fps)
Pressure Tank elevation (ft.)	120	10.7		3.9	NO FLOW
High pressure from tank (psi)	70	No Flow			NO FLOW
Low pressure from tank (psi)	50				NO FLOW
Mannings "n"	0.009				NO FLOW
Head loss at outlet (ft.)	70				NO FLOW
Pipe ID (in.)	1.05				

Section Number	Station (ft.)	Ground Elev. (ft.)	Static Elevation	High HGL	Low HGL	Design Pressure for Pipeline (psi)
(press. tank)	0	120	281.7	281.7	235.5	100.1
2	100	130	281.7	272.4	230.0	88.1
3	200	140	281.7	263.1	224.6	76.2
4	300	150	281.7	253.8	219.1	64.2
5	400	170	281.7	244.5	213.7	48.4
6	500	200	281.7	235.2	208.2	35.4
7	600	210	281.7	225.9	202.8	31.1
8	700	200	281.7	216.5	197.3	35.4
9	800	180	281.7	207.2	191.8	44.1
10	900	170	281.7	197.9	186.4	48.4
11	1200	100	281.7	170.0	170.0	78.7
12	0					
13	0					
14	0					
15	0					



LIVESTOCK PIPELINE

Ver. 9.99

Client: Exhibit 5 Pipe Q Example

Date: 3/31/00

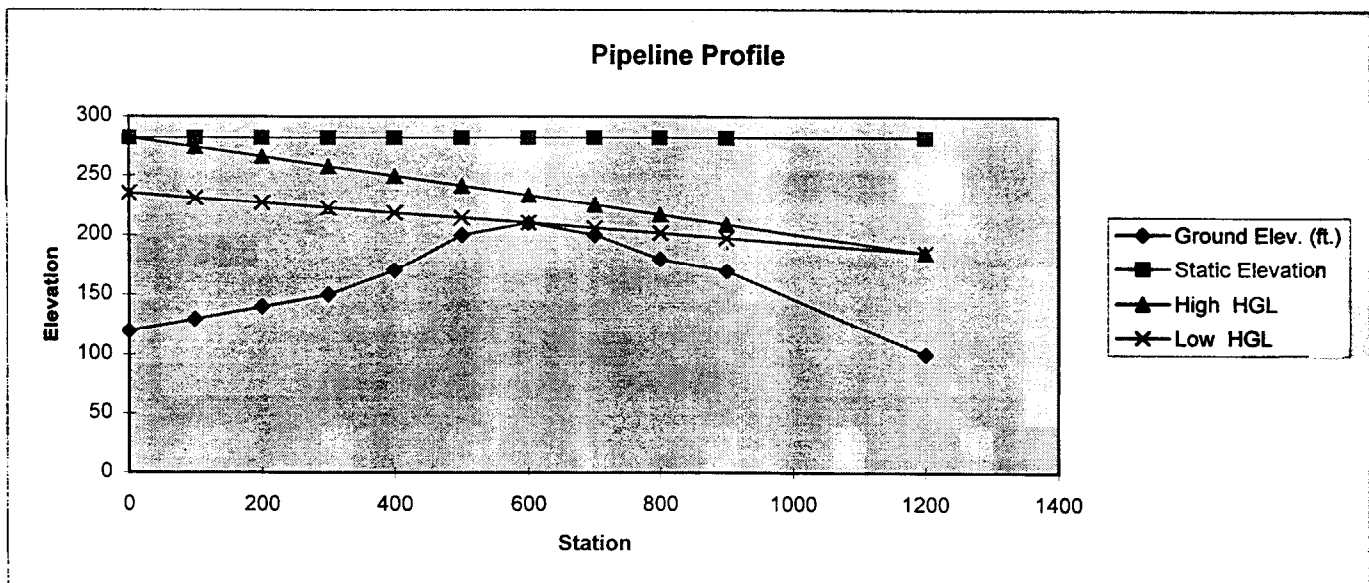
DSN By: _____

Date: _____

Comments:

		Flow	Pipe Sec.	Velocity hi	Velocity lo
Number of pipe sizes (1-5)	1	(gpm)	1	(fps)	(fps)
Pressure Tank elevation (ft.)	120	9.9		3.7	2.6
High pressure from tank (psi)	70	7.2			
Low pressure from tank (psi)	50				
Mannings "n"	0.009				
Head loss at outlet (ft.)	85				
Pipe ID (in.)	1.05				

Section Number	Station (ft.)	Ground Elev. (ft.)	Static Elevation	High HGL	Low HGL	Design Pressure for Pipeline (psi)
(press. tank)	0	120	281.7	281.7	235.5	100.1
2	100	130	281.7	273.6	231.3	88.9
3	200	140	281.7	265.6	227.1	77.7
4	300	150	281.7	257.5	222.9	66.6
5	400	170	281.7	249.5	218.7	49.2
6	500	200	281.7	241.4	214.5	35.4
7	600	210	281.7	233.4	210.3	31.1
8	700	200	281.7	225.3	206.0	35.4
9	800	180	281.7	217.2	201.8	44.1
10	900	170	281.7	209.2	197.6	48.4
11	1200	100	281.7	185.0	185.0	78.7
12	0					
13	0					
14	0					
15	0					



LIVESTOCK PIPELINE

Ver. 9.99

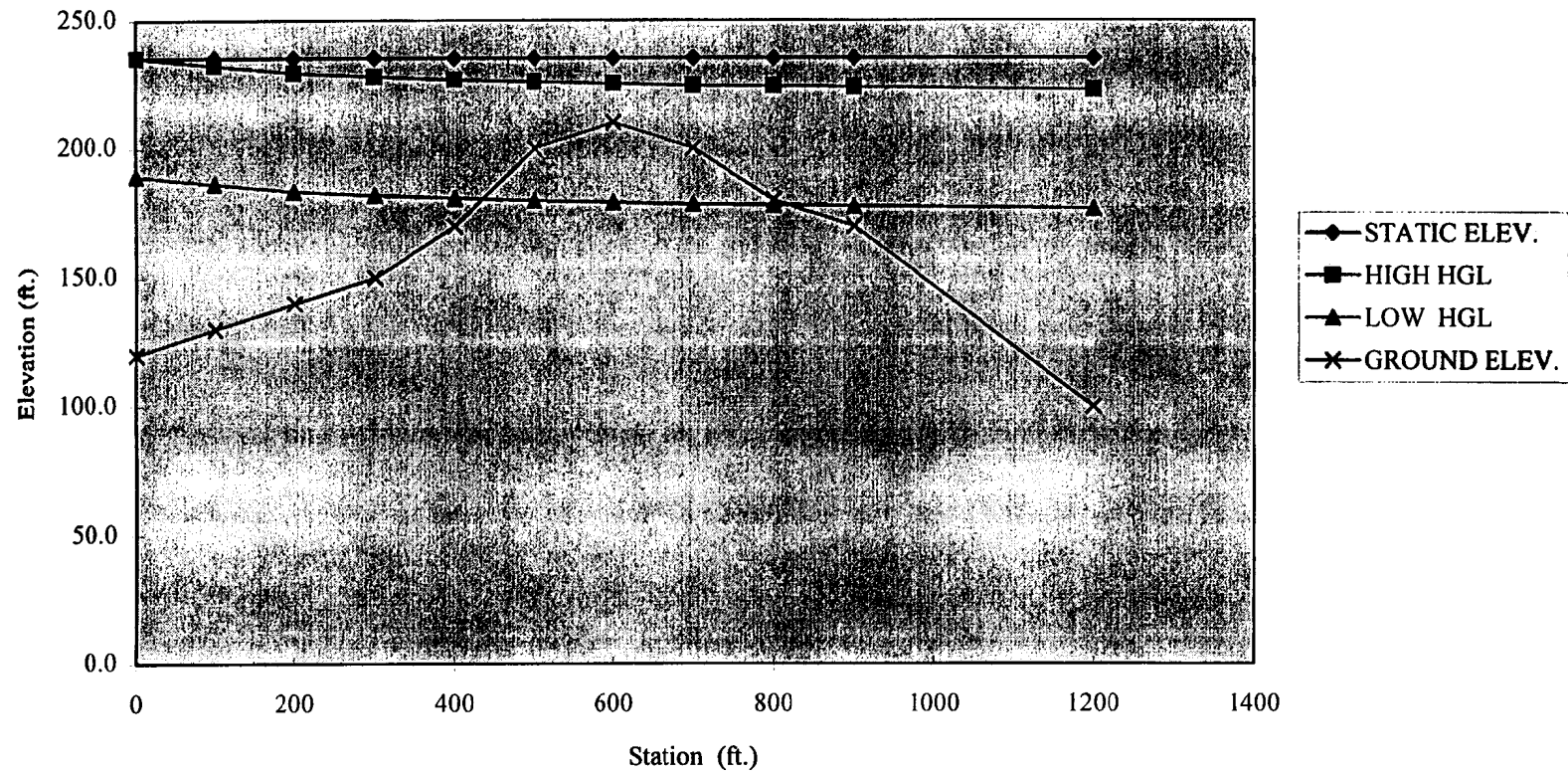
Client: Exhibit 6 Design Tab Example Date: 3/31/00
 DSN By: CHK By: _____ Date: _____
 Comments: This example will require some changes too make it work

Pressure Tank elevation (ft.) 120
 High pressure from tank (psi) 50
 Low pressure from tank (psi) 30
 Mannings "n" 0.009

Section Number	Station (ft.)	Outlet (gpm)	Total (gpm)	Ground Elev. (ft.)	Pipe ID (in.)	Design Pressure for Pipeline (psi)	Velocity (fps)
(press. tank)	0	No outlet	6	120	NA	71.4	
2	100	0	6	130	1.05	63.4	2.2
3	200	2	6	140	1.05	55.4	2.2
4	300	0	4	150	1.05	48.4	1.5
5	400	0	4	170	1.05	35.2	1.5
6	500	1	3	200	1.05	16.2	1.1
7	600	0	3	210	1.05	11.0	1.1
8	700	1	3	200	1.05	15.3	1.1
9	800	0	2	180	1.05	27.4	0.7
10	900	0	2	170	1.05	33.4	0.7
11	1200	2	2	100	1.05	76.1	0.7
12	0						
13	0						
14	0						
15	0						

Section Number	Friction Loss (ft.)	High HGL (ft.)	High Section (psi)	Low HGL (ft.)	Low Section (psi)	High Static (psi)
1	None	235.4	50.0	189.2	30.0	50.0
2	2.95	232.4	44.4	186.3	24.4	45.7
3	2.95	229.5	38.8	183.3	18.8	41.3
4	1.31	228.2	33.9	182.0	13.9	37.0
5	1.31	226.8	24.6	180.7	4.6	28.3
6	0.74	226.1	11.3	180.0	No Flow	15.3
7	0.74	225.4	6.7	179.2	No Flow	11.0
8	0.74	224.6	10.7	178.5	No Flow	15.3
9	0.33	224.3	19.2	178.2	No Flow	24.0
10	0.33	224.0	23.4	177.8	No Flow	28.3
11	0.98	223.0	53.3	176.8	33.3	58.7
12						
13						
14						
15						

Pipeline HGL



Client: Exhibit 7 Design Tab Example
DSN By:

Date: 3/31/00

Appendix D

PLANNING and DESIGN GUIDE

APPENDIX D**PLANNING AND DESIGN GUIDE**

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

MISSOURI

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.

RESOURCE INVENTORY

(May use Stockwater Pipeline Resource Inventory Worksheet, MO-ENG-103)

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.
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.

MLWSH Ch. 2

FOTG 556

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.
 - Is the site within a flood plain?
 - Will wetlands be modified or disturbed by installing the project?
 - Make archaeological and historical resource survey, if one is required.

NEH 503.03

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.
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.

DEVELOPING AND EVALUATING ALTERNATIVES

1. Determine minimum flow requirements during the period of peak stockwater use.
2. Determine desirable drinking tank locations. Standards set maximum distance between drinking locations.

FOTG 614
FOTG 516
MLWSH Ch. 2

FOTG 516

3.	Determine minimum water storage requirements.	FOTG 516 FOTG 614 MLWSH Ch. 8
4.	Determine drinking tank-type and capacity.	
5.	Determine storage tank-type and capacity.	MLWSH Ch. 8
6.	Based on all known factors, design the pipeline system alternative alignments.	MLWSH Ch. 9
7.	Type of system (automatic pressure, timed, gravity).	MLWSH 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.	MLWSH Ch. 8
9.	Preliminary design of drinking and storage tanks, including types, locations and preliminary sizes and elevations.	MLWSH Ch. 8
10.	Perform preliminary hydraulics to set size and grades. (SPIPE, IPIPE, or other approved computer programs may be used to aid with calculations.)	EFH Ch 3 MLWSH Ch 9 MSPM App B

MAKING DECISIONS AND DOCUMENTING

1. Present developed alternatives to the operator.
2. Make sure the operator has made a decision before proceeding.
3. Document decisions in SCS-CPA-6 planning notes and on the SCS-CPA-68 Record of Cooperator's Decisions.

IMPLEMENTING DECISIONS

Permits Make sure all required permits are obtained before proceeding with detailed design and layout.

1. Water right permits
2. Permits to cross State or Federal land and easements to cross private land.

Approval Authority

1. Determine approval authority for pipelines, tanks and other appurtenances.

NEM MO501.04
Individual

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
EFH Ch. 1
MLWSH Ch 4

System Design

1. Detailed hydraulics which were not done previously.
 - Pipeline hydraulics
(Can use SPIPE and IPIPE programs to aid in calc's)
2. Pressure tank size requirements
3. Pressure, surge and air control features
4. Pump size and pressure requirements
5. System accessory design
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

FOTG 516
MLWSH

EFH Ch 3
MLWSH Ch 9

MLWSH Ch 8

MLWSH Ch 6, 7

MLWSH Ch 8

MLWSH Ch. 8

Drawings and Specifications

1. Prepare drawings
 - Use standard drawings when possible.
 - Minimum drawings shall include:
 - Location map or enough description on plan view map to adequately locate job.
 - Plan view map showing location of all pipelines, tanks and water source.
 - Profiles along each pipeline. Show location of all appurtenances such as tanks, troughs, hydrants, valves, pressure reducers, etc.
 - Show elevations including water surface or starting pressure head, ground line, design hydraulic grade line, and static grade line.

EFH Ch 5

MO Std. Dwng.
& Spec. Handbook
NEM

- Table or drawing notes showing elevations, descriptions, dimensions and size of all structures, valves, special fittings and appurtenances.
- Standard details of tanks and pipeline.
- Special detail drawings of appurtenances not otherwise described.

2. Specifications

- Standard Missouri 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.

MO Std. Dwng
& Spec Handbook

Operation and Maintenance Plan

MLWSH 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.

Layout

NEM 540
EFH 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 Handbook.

NEM 540
TR62
EFM Ch. 1

Compliance Checking

1. Adequate periodic inspection shall be scheduled and performed during construction. Frequent inspection during construction of stockwater pipelines cannot usually be performed by 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.

NEM 512.50

Complete documentation

The following documentation shall be in the case file:

1. Complete planner notes on Conservation Assistance Notes Form SCS-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 specifications or list of specifications with copy of signature sheet and special provisions.
6. Copy of sheet showing review of drawings and specifications 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 SCS-ENG-5 and SCS-ENG-6 must be in the file.
9. Copy of water rights or signed statement by producer that they are adequate.
10. Completed Environmental notes.
10. Cultural Resources Survey, if one is required.

References:

FOTG	NRCS Field Office Technical Guide: Missouri Practice Standards in FOTG Section IV.
NPM	NRCS National Planning Manual
NEM	NRCS National Engineering Manual
EFH	NRCS Engineering Field Handbook, Part 650
MLWSH	NRCS Missouri Livestock Watering Systems Handbook
NEH	NRCS National Engineering Handbook
TR62	NRCS Technical Release--Engineering Layout, Notes, Staking and Calculations
MSD&SH	NRCS Missouri Standard Drawings and Specifications Handbook



United
States
Department of
Agriculture

Natural
Resources
Conservation
Service

Parkade Center, Suite 250
601 Business Loop 70 West
Columbia, Missouri 65203

American Society of Agricultural Engineers
2950 Niles Road
St. Joseph, MI 49085-9659

December 3, 1997

Dear ASAE:

I am Neil Pellmann, Agricultural Engineer with the Natural Resources Conservation Service, an agency of the United States Department of Agriculture. I am also a member of ASAE (0002534).

Our agency in Missouri is developing a technical handbook entitled "Missouri Livestock Watering Systems Handbook". We ask your permission to reproduce Technical Paper No. 962097 -- OFF-STREAM WATER SOURCES FOR GRAZING CATTLE AS A STREAM STABILIZATION AND WATER QUALITY BMP to be a reference to the previously mentioned handbook.

The information provided in the paper will add to the successful use of the handbook. The material will be our county offices across the State and also will be available to others we are assisting. Approximately 400 copies will be printed.

If you have any questions, I can be reached at (573) 876-0908 and FAX (573) 876-0913.

I look forward to hearing from you.

Sincerely,

Neil Pellmann

NEIL F. PELLMANN P.E.
Agricultural Engineer

*Neil,
We are pleased to
grant permission.*

*Don Hull
ASAE 12/9/97*

OFF-STREAM WATER SOURCES FOR GRAZING CATTLE AS A STREAM STABILIZATION AND WATER QUALITY BMP

by

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Summary: A multi disciplinary study was conducted to evaluate the effectiveness of providing cattle with an off-stream water source (i.e., water trough) in reducing stream bank erosion and fostering water quality improvements. This study was conducted on two commercial cow-calf operations in southwest Virginia which utilized rotational stocking. Observations of cattle behavior, measurements of stream bank erosion and the analysis of fecal bacteria and water quality parameters showed that off-stream water sources were effective in reducing the time which cattle spent in the stream area, stream bank loss, and concentrations of fecal bacteria and sediment-bound nutrients.

Keywords: Water Quality, Erosion, Animal Behavior, BMP, Off-Stream Water Source

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INTRODUCTION

Cattle watering and standing in streams have long been seen as an eyesore by people both inside and outside of the agricultural community. This traditional agricultural practice has also been identified as a source of nonpoint source pollution (Smolen et al., 1990). Fencing of stream banks to deny cattle access to streams has been proposed (Skovlin, 1984 & Davis et al., 1991) to minimize pollution from pasture and rangelands. Debate over the economic consequences (Platts and Wagstaff, 1984), the resulting management issues and possible regulatory involvement (Swan, 1979) have escalated concerning stream bank fencing as a general management strategy. Unfortunately, few cost-effective alternatives to stream bank fencing have been proposed.

Off-stream water sources, suggested by Smith et al.(1992) and Marlow and Pogacnik (1986), is a water quality management practice which has been noted by some farmers and conservationists to be quite effective in reducing cattle impact upon stream environments. However little field data is available for evaluation of the impact of this practice on water quality. Water developments have traditionally been viewed solely as a farm improvement. Greene (1994), observed that when water troughs were installed, large stream bank vegetation such as speckled alders (*Alnus rugosa*) and willows (*Salix* sp.), were established after a few years in southwest Virginia because cattle would spend less time in the stream.

Miner et al. (1992) observed that hay-fed cattle in Oregon preferred to drink from a trough rather than from a stream during an eight-day observation period. Cattle preference resulted in a 90% reduction in the amount of time they spent in the stream area, if a stream was their sole source of drinking water. Miner et al. (1992) hypothesized that this 90% reduction in time spent in stream would correlate to a reduction in fecal and nutrient loadings to the stream.

Clawson (1993) observed that the installation of a water trough had a significant impact on cattle use in stream side areas. Use of a stream within a pasture dropped from 4.7 to 0.9 minutes per cow per day, and use of a wide streamside area dropped from 8.3 to 3.9 minutes per cow per day after the trough was installed. This correlated to an 81% reduction in the time cattle spent drinking from the stream and a 53% reduction in the time cattle spent in an adjacent stream side area. Clawson (1993) concluded that cattle preferred to drink from a water trough over drinking from a stream, 75% of the time.

OBJECTIVES

The overall goal of this study was to evaluate the feasibility of using water troughs as a Best Management Practice (BMP) to reduce the losses of soil, nutrients and bacteria from pasture lands. Specific objectives were: a) to compare the behavior of cattle using streams as a primary water source to those which had access to streams as well as to off-stream water sources; b) to estimate and compare stream bank erosion in pasture systems using rotational stocking where streams were and were not utilized as the primary water source; and c) to estimate and compare nutrients, fecal bacteria

and mineral concentrations from pasture systems where streams were and were not utilized as the primary water source.

THE STUDY SITES

This study was conducted on two commercial cow-calf operations in the Ridge and Valley region of southwest Virginia which utilized rotational stocking. One study pasture (14.2 ha) was located on the River Ridge Farm in Independence, Virginia (Figure 1) and two additional study pastures (16.6 and 22.3 ha) were located on the Bender Farm in Floyd, Virginia (Figure 2). The River Ridge Farm produces Brahma-Angus calves utilizing high stocking density and stocking rates of 200 cows and 170 calves on eight pastures totaling 136 ha. The Bender Farm produces Angus-Hereford calves utilizing first-last grazing in the spring and fall at a stocking rate of 150 cows and 60 calves on eight pastures totaling 187 ha.

The three study pastures were chosen for several reasons. First, a spring-fed first-order stream originates in each pasture. Second, spring-developments provide water to a three-trough system on the River Ridge Farm, and a single-trough system provides water for cattle on each of the pastures on the Bender Farm. Lastly, tall fescue (*Festuca arundinacea* L.) was the dominant grass on both farms among a mix of orchardgrass (*Dactylis glomerata*), Kentucky bluegrass (*Poa pratensis*), red clover (*Trifolium pratense*) and white clover (*Trifolium repens*). A more detailed description of the study sites is given by Sheffield (1996).

The tall fescue present in the River Ridge and two Bender pastures was found to be highly infected (77%, 72% & 78%, respectively) by the fungal endophyte (*Acremonium coenophialum* Morgan, James and Gams). The endophyte has long been identified with three syndromes among cattle (Ball et al., 1991). Cattle grazing toxic tall fescue and suffering from the effects of fescue toxicosis or "summer slump" have been observed to have a tendency to wallow in mud (Boman et al., 1973) or stand in ponds or creeks during hot portions of the day. Fescue toxicosis causes the body temperature of cattle to elevate and subsequently the cattle spend more time within the stream areas. Therefore, it can be expected that the level of impact (erosion, degraded water quality) upon these areas would increase in pastures where high levels of the endophyte are present.

METHODOLOGY

During the first seven months of the study (pre-BMP period: Aug., 1994 - Apr., 1995), cattle had access to only one stream in the observed pasture as their source of water. After the first seven months, water troughs were installed in the pastures and cattle had continued access to streams (post-BMP period: Apr., 1995 - Oct., 1996). To provide water for the troughs, springs were developed according to design specifications of the Natural Resources Conservation Service (1992). At no time during the study were cattle excluded from the stream by fencing.

Prior to the study, various monitoring equipment was installed on the River Ridge Farm, and surveys were conducted in preparation of this project. A weighing raingauge and a standard raingauge were installed. The standard and weighing raingauges were read by the farm operator. Stream flow data were obtained by measuring the time to collect a known volume of water (3.785 L or 18.925 L.) at the pond outlet (QRR 6, Figure 1).

Three day-long observations of cattle behavior were conducted during the pre-and post-BMP treatment periods on both the River Ridge and Bender farms. Cow-day observations (daybreak to dark) were made at 5-minute intervals from the cab or rear of a pick-up truck parked either off pasture, if possible, or within the pasture at a distance which would not disturb the cattle. The number of cattle drinking from the stream or trough, cattle within the stream or trough areas, and the percentage of herd grazing were recorded during each time interval. Observations were also made between the 5-minute intervals to describe the behavior of the herd or of individual animals. Notes were made pertaining to the extent of the area along the stream used by the cattle, size of groups watering together, distance the cattle traveled to water in relation to grazing area, closest stream or trough location, and the behavior of age/sex groups within the herd.

The stream and trough area was defined in this study as the distance of two adult cow lengths (approximately 4.6 m) from the center of the stream or the edge of the water trough. The number of animals (cows, calves, and bulls) on the observed pasture was obtained from the farm managers prior to the day of observation. Each animal was treated as an individual unit.

Comparisons between the pre- and post-BMP treatment observation periods were made by averaging the three observations which were conducted during both treatment periods. The observation period with the largest number of 5-minute intervals (i.e., observations) was used as the reference observation period in order to have a common time scale for subsequent comparisons. The time intervals of the remaining observation periods were weighted in order to create a common time scale. The cumulative time per animal and the percentage of herd participation in each activity and observation period were averaged among the pre- and post-BMP treatment observation phases. Lastly, the percentage difference in cumulative time per animal and the percentage of herd participation were calculated by comparing the mean and standard deviations for each activity during the pre- and post-BMP treatment periods.

Estimates of stream bank erosion in terms of sloughing or mass wasting were made before and after providing cattle with an off-stream water source. These estimates were made by installing 19 pairs of 30-cm (1-foot) long, 13-mm (½-inch) wall thickness steel pipes (stakes) along the stream on the River Ridge Farm. Stakes were placed across straight as well as meandering portions of the stream channel.

The side of the stream which was closest to the primary grazing area was denoted as the inside side of the stream, and the opposite side of the stream was denoted as the outside of the stream (Figure 3). The free end of a 100 ft (32.8 m) tape measure was placed on a pipe on the outside bank of the stream, referred to as the reference stake, and was stretched across the stream to the back of a stake

located on the inside bank of the stream. The tape was then stretched to a predetermined known distance before measurements along the cross section were made. The distance from the reference stake to the outside edge of the stream bank was measured to the outside edge of the stream, inside edge of the stream and the inside edge of the stream bank, using a plumb bob. All measurements of the cross section were made on the upstream side of the stretched tape. This procedure was conducted prior to the study, and every two months during the pre- and post-BMP periods.

Differences in the distance from each reference cross section stake to the stream bank and to the stream edge were calculated from the most recent measurement compared to the previous measurement. Changes in distances were also calculated using the difference between the most recent measurement, to the beginning of the treatment period and to the beginning of the study period, for post-BMP measurements. The location of the edge of the stream bank was allowed only to increase through time. If the most recent measurement of the location of the stream bank was closer to the stream than the previous measurement, then the previous value was substituted for the most recent value. No adjustments were made to the edge of stream measurements. The average and standard deviations of loss of stream bank for all of the stream cross-sections during the pre- and post-BMP treatment periods were calculated. A Wilcoxon sign-rank test ($\alpha = 0.05$) was used to detect whether a significant difference existed between the amount of stream bank loss during the pre- and post-BMP treatment periods.

Variations in water quality were evaluated prior to and after the BMP was installed. Five stations were located along the stream at the River Ridge Farm (Figure 1). Water quality samples were also taken from the Bender Farm but are not presented here. The following water quality parameters were measured from semimonthly water quality samples: total suspended solids (TSS), nitrate-nitrogen ($\text{NO}_3\text{-N}$), ammonium ($\text{NH}_4\text{-N}$), total nitrogen (TN), sediment-bound nitrogen (SBN), ortho-phosphorus (PO_4), total phosphorus (TP), sediment-bound phosphorus (SBP), fecal coliform (FC), fecal streptococci (FS), and total coliform (TC).

The concentrations of all parameters, expressed in mg/L, were evaluated at each sampling station. The concentration of TN was calculated by summing the concentrations of nitrate and total Kjeldahl nitrogen. SBN was calculated by subtracting the total Kjeldahl nitrogen and filtered total Kjeldahl nitrogen concentrations. The sediment-bound phosphorus concentration (SBP) was calculated by subtracting the filtered total phosphorus from total phosphorus. The concentrations of the three fecal bacteria were also evaluated in terms of colonies per 100 mL of water. Due to the skewness of the data, the non-parametric Wilcoxon sign-rank sum test was used to evaluate each parameter.

The nutrient samples collected from the outlet of the stream (QRR-5) on the River Ridge Farm were also evaluated in terms of their loading and flow-weighted concentration. Pollutant loading (kg) at the stream outlet was calculated by multiplying the concentration by the flow volume measured at the time of sampling and the number of days since the last sampling date. The pollutant loadings were then divided by the amount of rainfall (cm) recorded since the last sampling date in order to remove the effect of variations in rainfall amounts during the pre-and post-BMP periods. If no rain had occurred since the last sampling date, the mass was carried over to the next sampling time where

rainfall was recorded. The pollutant loadings for each outlet and treatment period were then evaluated using the non-parametric Wilcoxon sign-rank sum test. Flow-weighted concentrations (mg/L) for each treatment period were calculated by summing the mass of each pollutant (kg) and dividing it by the total stream flow volume observed during the study period (m^3). The percent of difference, in loading and flow weighted concentration, which occurred due to installation of the BMPs was then calculated for each pollutant.

RESULTS

Cattle Behavior

The average cumulative time each cow spent within the stream drinking, and being in the stream area are depicted in Figures 4 and 5, respectively. These values are also listed for each observation period in Table 1. The average length of time spent by each cow drinking from the stream was 6.7 and 0.7 minutes for the pre- and post-BMP periods, respectively, an 89% reduction. These reductions are similar to those reported by Clawson (1993) who observed a drop from 4.7 to 0.9 minutes per cow when cattle were drinking only from a stream and when an off-stream water source was available, respectively. The average length of time spent by each cow within the stream area was reduced from 12.7 minutes to 6.2 minutes during the pre- and post-BMP treatment periods, respectively. This corresponds to a reduction of 51% in the average cumulative time spent by each cow within the stream area due to the availability of an off-stream water source for grazing cattle.

The pre-BMP values for cumulative time spent by each cow drinking from the stream and being in the stream area were less variable than those observed for the post-BMP period. The differences in variability can be largely explained by the pasture conditions in the South Bender Farm on the August 22, 1995 observation. During this post-BMP observation, the majority of the pasture was cut and baled for hay prior to cattle entering the pasture. It can be construed that the decreased amount of forage available within the main grazing area forced the cattle to seek vegetation within the stream corridor. Thus, the large value obtained for cumulative time each cow spent in the stream area on August 22 mainly reflects the effect of the farm forage management practices rather than the BMP. The moderately increased values in cumulative time each cow spent drinking from the stream on the South Bender Farm reflects increased use of the stream as a drinking water source when the adjacent stream area was used for forage, as compared to the other post-BMP observations. It is believed that with better cattle/forage management, the average cumulative time per cow spent in the stream area or drinking from the stream would be reduced. This should enhance the effectiveness of off-stream water sources in reducing the cumulative time spent within the stream area and reduce the use of the stream for drinking.

The presence of an off-stream water source for grazing cattle reduced the time spent by the cattle in the stream for drinking by an average of 91.7% (Table 2), assuming the time which cattle spend drinking remains constant regardless of the source. This assumption seems to be reasonable since the average cumulative time each cow spent drinking from the stream and drinking from a water trough are comparable with mean values of 6.8 minutes and 7.2 minutes, respectively. Godwin (1994) also reported no significant difference between the cumulative time cattle or horses spent drinking from

a stream when an off-stream water source was not provided, and the time spent drinking from an off-stream water source when it was made available. The data on the use of streams for drinking when an off-stream water source is available for grazing cattle is shown in Figure 6.

Stream Bank Erosion

The results of measurements taken from randomly placed cross sections along two streams on the River Ridge Farm are presented in Table 3. Measurements were taken three times during each treatment period in order to estimate the amount of stream bank erosion which took place due to the influence of grazing cattle and the presence of an off-stream water source.

Stream bank losses which occurred during the post-BMP period were less ($\alpha = 0.05$) than those measured during the pre-BMP treatment period. Average stream bank loss was 0.62 m and 0.15 m on the River Ridge Farm for the pre-BMP and post-BMP periods, respectively. This resulted in a 77% reduction in the amount of stream bank loss due to the effect of sloughing by cattle during the post-BMP treatment period.

Water Quality

Water quality samples were taken every two weeks from the River Ridge Farm stream. Additional samples were also taken before, after and during some of the cattle rotation activities in order to coordinate water quality sampling with cattle movement. A total of 193 samples were taken from the six water quality stations (Figure 1), of which 83 were taken during the pre-BMP treatment period (8/17/94 - 3/17/95) and 110 were taken during the post-BMP (3/18/95 - 10/15/95) phase.

The average concentrations of water quality parameters from all stations reflected the significant reductions in stream bank erosion discussed earlier. Significant reductions were detected in the concentration of TSS in the River Ridge stream after BMP installation (Figure 7). The reduction in TSS concentrations reflects the reduction in stream bank erosion due to providing the off-stream water source. An 89% reduction in the flow-weighted concentration of TSS was found at the watershed outlet (QRR-5) on the River Ridge Farm due to installation of the off-stream water source (Table 4). At the same station, the loading of TSS per cm of rainfall during the post-BMP treatment period was reduced by 96% compared to the pre-BMP period. These results further support the earlier findings that, when cattle have access to an off-stream water source, the total amount of suspended solids in a stream could be substantially reduced.

Concentrations of total nitrogen, ammonium and sediment bound nitrogen on the River Ridge Farm were generally reduced due to the installation of the BMP (Figure 8). Concentrations of TN and SBN increased during the post-BMP period at station QRR-1. Nitrate concentrations also increased significantly after BMP installation at QRR-1 (Figure 1). It is not surprising to find increased NO_3 levels at this station. Due to the source area up-slope of QRR-1 and the increased mean air temperatures, concentrations of the soluble nutrient (NO_3) would be expected to increase at the headwater station during the primarily summertime post-BMP period, as compared to the wintertime pre-BMP period. The greater soil temperature during the post-BMP period may have increased the nitrification process, thereby increasing nitrate levels. The flow-weighted concentrations and loadings

of TN, NH₄, NO₃ and SBN are shown in Table 4. The percent of change which occurred during the post-BMP treatment period, as compared to the pre-BMP period, is also reported in Table 4.

The concentrations of sediment-bound phosphorus were reduced due to the installation of the off-stream water sources on the River Ridge Farm (Figure 9). Significant reductions in the concentration of TP were obtained at QRR-1, QRR-3, QRR-4, and QRR-5 during the post-BMP treatment period. These reductions also correspond with the significant reductions reported for TSS concentrations. The reductions in TP at QRR-2 were not statistically significant because of the insufficient number of samples collected during the post-BMP period due to the lack of sufficient flow at the station. Significant reductions in the concentration of SBP were found at QRR-1, QRR-3, and QRR-4. A 71% reduction in the average concentration of SBP found at QRR-5 was not statistically significant at $\alpha = 0.05$ (P-value of 0.06). Concentrations of soluble phosphorus, in the form of orthophosphates (PO₄), increased or remained relatively unchanged due to the installation of the off-stream water source. However, no statistically significant differences in PO₄ concentrations were detected for the samples collected from the River Ridge stream. The concentrations of PO₄ followed the same trend as those reported for NO₃.

The installation of the off-stream water source reduced the flow-weighted concentration and loading of TP and SBP on the River Ridge Farm (Table 3). Reductions of 65% and 43% were found in the flow-weighted concentration of total phosphorus and sediment bound phosphorus, respectively. The loading of TP and SBP were also significantly reduced by 98% and 92%, respectively, during the post-BMP treatment period. The flow-weighted concentration of PO₄ increased by 98% while its respective loading decreased by 75% during the post-BMP treatment period. However, the loading of SBP increased by 18% (from 0.11 kg/cm-rain to 0.13 kg/cm-rain) during the post-BMP treatment period.

Figure 10 presents the concentration of total coliform, fecal coliform, and fecal streptococci for all stations on the River Ridge Farm. The total coliform, fecal coliform and fecal streptococci bacteria are used as indicators of NPS pollution, especially those directly deposited by grazing cattle. However, since the total coliform group consists of species of bacteria from soil, vegetative matter, and animals, a direct relationship between its occurrence and the presence of cattle cannot be justified (Stephenson and Street, 1978.). Since the fecal coliform and fecal streptococci groups are directly related to the feces of warm-blooded animals, they are considered a more reliable indicator of pollution from grazing cattle. Significant reductions in TC, FC and FS were observed on the River Ridge stream due to the installation of the off-stream water sources. Significant reductions of 88%, 78% and 86% in total coliform were found at sampling stations QRR-3, QRR-4 and QRR-5, respectively. A significant increase (61%) in TC was also observed at QRR-1. However, the increase in TC (Figure 10) can be attributed to the significant increase in TSS also found at the headwaters of this station, as discussed previously. Significant reductions of 99%, 87% and 57% in FC were also found at stations QRR-3, QRR-4 and QRR-5, respectively. A 53% increase in total coliform was not statistically significant at the headwater station, QRR-1. Significant reductions in FS were observed at all stations on the River Ridge stream due to the installation of the off-stream water sources. Statistically significant reductions in FS of 99%, 77%, 70% and 84% resulted at the water monitoring stations of QRR-3, QRR-4, QRR-5 and QRR-6, respectively.

The reductions in TC, FC and FS concentrations are directly related to the dramatic changes in cattle behavior due to the presence of the off-stream water source. It can be construed that, with the 51% reduction in cumulative time each cow spent in the stream, the amount of fecal matter deposited by each cow was also reduced. Thus, as the water trough drew cattle away from the stream (92 % of the time), manure which would have been deposited in the stream was deposited near the off-stream water source. This study has shown that the installation of off-stream water sources was an effective BMP for reducing the concentration of sediment-bound pollutants and bacteria, while cattle access to streams remained unchanged.

CONCLUSIONS

The presence of an off-stream water source for grazing cattle reduced the time which cattle spent in the stream area as well as the time which they spent drinking from the stream. When given the choice, cattle were observed to drink from a spring-fed water trough 92% of the time, as compared to the time which they spent drinking from the stream. Cattle use of the stream area for all activities, including drinking, was reduced by 58% when an off-stream water source was made available. These results were observed on study pastures that were predominately tall fescue with a high percentage of endophyte infection.

Due to the dramatic reductions in time which cattle spent within the stream area, stream bank erosion and the losses of sediment and sediment bound pollutants were also significantly reduced. Stream bank erosion was reduced by 77% on the River Ridge Farm in Independence, Virginia. The presence of an off-stream water source significantly reduced the loading of sediment, sediment-bound nutrients and fecal bacteria in a first-order stream on the River Ridge Farm. Concentrations of total suspended solids, total nitrogen, ammonium, sediment-bound nitrogen, total phosphorus and sediment-bound phosphorus were reduced by 90%, 54%, 70%, 68%, 81% and 75%, respectively, due to the installation of an off-stream water source. Concentrations of dissolved nutrients such as nitrate and orthophosphates, however, were adversely affected by the implementation of the BMP.

The installation of off-stream water sources was also effective in reducing the concentration of fecal bacteria as hypothesized by Miner et al. (1992). Concentrations of fecal coliform and fecal streptococci were reduced by an average of 51% and 77%, respectively, on all the River Ridge Farm sampling stations due to the use of off-stream water sources. The presence of an off-stream water source for grazing cattle greatly reduced the impact which grazing cattle had upon stream bank erosion and water quality. The results of this study indicate that the development of off-stream water sources for grazing cattle would be effective in reducing stream bank erosion as well as sediment-bound pollutants and fecal bacteria production from smaller order streams.

The implementation of the conclusions drawn from this study are limited by several factors. First, the study was conducted for a relatively short time of about 14 months. Seasonal variation of cattle behavior, rainfall patterns and runoff nutrient concentrations may significantly alter the conclusions drawn from this study if data were taken for longer durations. However, it must be noted that the post-BMP treatment period of this study was conducted during the warmer summer months of the year, during which greater sediment, nutrient and bacteria concentrations are expected, thus, BMP

impacts reported in this study are conservative. Had the post-BMP treatment period been conducted during the winter months, greater BMP impacts (more reductions in water quality concentrations and loadings) would have been resulted. In spite of these limitations, this study has clearly shown that off-stream water sources for grazing cattle are quite effective in reducing the amount of sediment bound and fecal bacteria contributed to streams without resorting to stream bank fencing.

Future studies should compare the economic costs and environmental benefits of off-stream water sources, as a stream bank erosion and water quality BMP, to those of stream bank fencing. Water quality and stream bank erosion results of this study should be compared to those which fenced cattle from streams. Also, the scale of BMP implementation, either farm, watershed or regional, should be a major component of such an analysis. Such an analysis should address the economic feasibility of providing off-stream water sources compared with mandatory stream bank fencing in order to protect water resources.

REFERENCES

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Table 1. Comparison of length of time spent by each cow drinking from the stream and being in the stream area.

Date	Farm	Cumulative time per cow drinking from the stream	Cumulative time per cow being in the stream area
Pre-BMP[†]			
11-22-94	South Bender	6.20	13.33
12-03-94	River Ridge	6.62	12.71
1-10-95	North Bender	7.35	12.02
Mean		6.72	12.69
Post-BMP[‡]			
6-29-95	River Ridge	0.62	3.55
8-22-95	South Bender	1.31	12.33
9-26-95	River Ridge	0.24	2.80
Mean		0.72	6.19
% Reduction in Mean		89.4	51.2

All values expressed in minutes. †: without water trough. ‡: with water trough.

Table 2. Off-stream water source preference during the post-BMP treatment period.

Date	Farm	Reduction in % of time spent drinking in stream due to trough installation
6-29-95	River Ridge	92
8-22-95	South Bender	90
9-26-95	North Bender	93
Average		91.7

Table 3. Results of stream cross-sectional surveys on the River Ridge Farm

	Pre-BMP	Post-BMP	D ¹
P -value			0.747
Mean	1.84	1.81	0.03
st. dev.	0.51	0.80	0.87
% Reduction		1.6	

Means and standard deviations area expressed in terms of feet of stream bank erosion. (*) significant at 0.05 level. D¹ = Difference between pre- and post BMP values.

Table 4. Flow-weighted concentrations and loadings of water quality nutrients for the outlet of the River Ridge stream.

Parameter	Flow-Weighted Concentration (mg/L)			Loading (kg/cm rain)		
	Pre-BMP	Post-BMP	% Change	Pre-BMP	Post-BMP	% Change
Total Suspended Solids (TSS)	132.35	14.28	-89.21	292.84	11.06	-96.22‡*
Total Nitrogen (TN)	1.340	1.237	-7.72	3.02	1.34	-55.63‡
Ammonium (NH ₄)	0.321	0.090	-72.06	0.52	0.12	-76.92‡
Nitrate (NO ₃)	0.167	0.229	37.05	0.31	0.35	12.90
Sediment Bound Nitrogen (SBN)	0.472	0.468	-0.66	1.05	0.55	-47.62
Total Phosphorus (TP)	0.203	0.072	-64.56	3.25	0.08	-97.54‡
Orthophosphates (PO ₄)	0.004	0.007	98.47	0.04	0.01	-75.00
Sediment Bound Phosphorus (SBP)	0.120	0.068	-42.87	0.93	0.07	-92.47‡

‡ = Significant difference between means at $\alpha = 0.05$ level. * = A negative value (-) indicates a reduction due to the installation of the BMP.

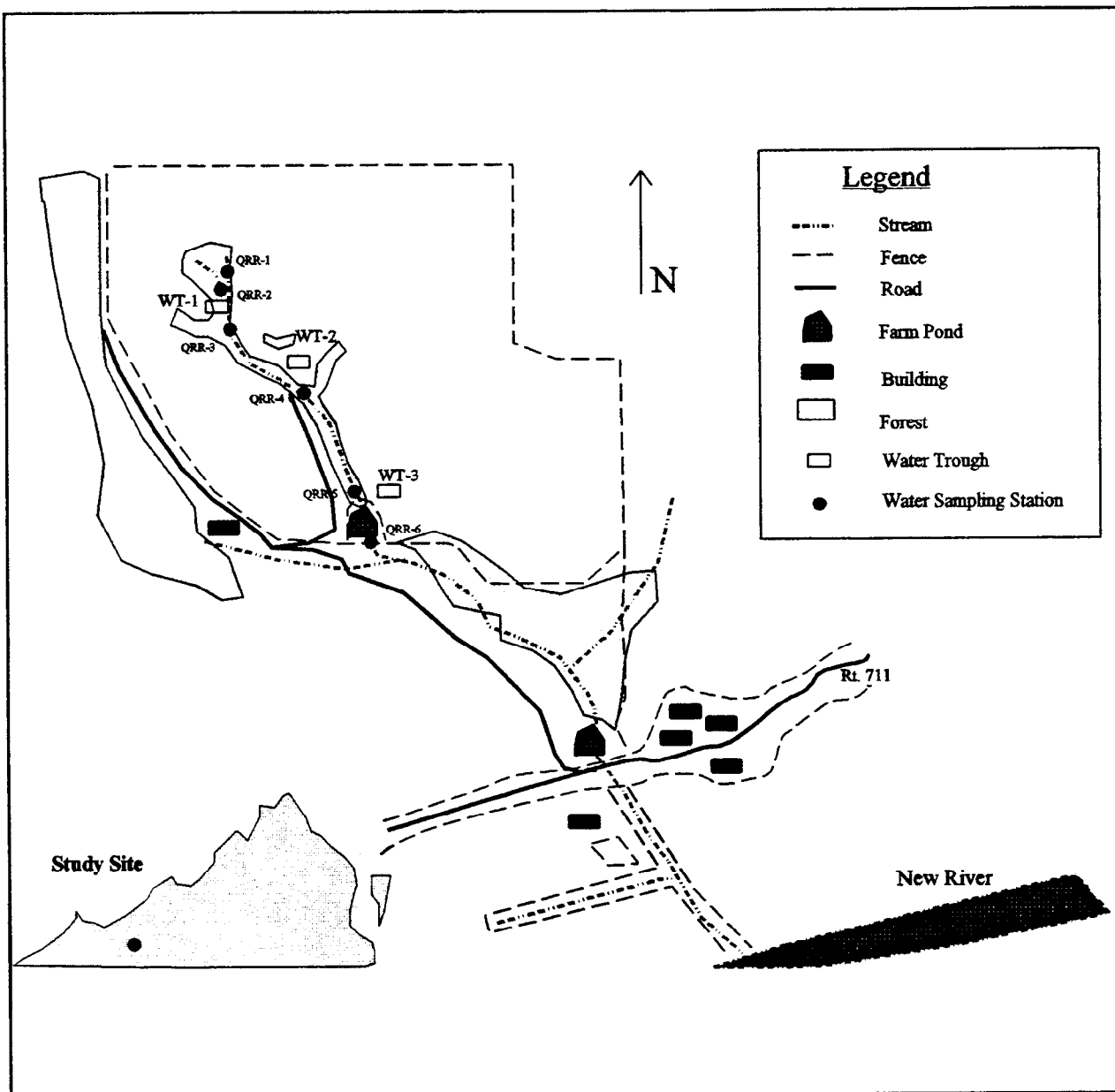


Figure 1. Location of study site at the River Ridge Farm in Independence, Virginia.

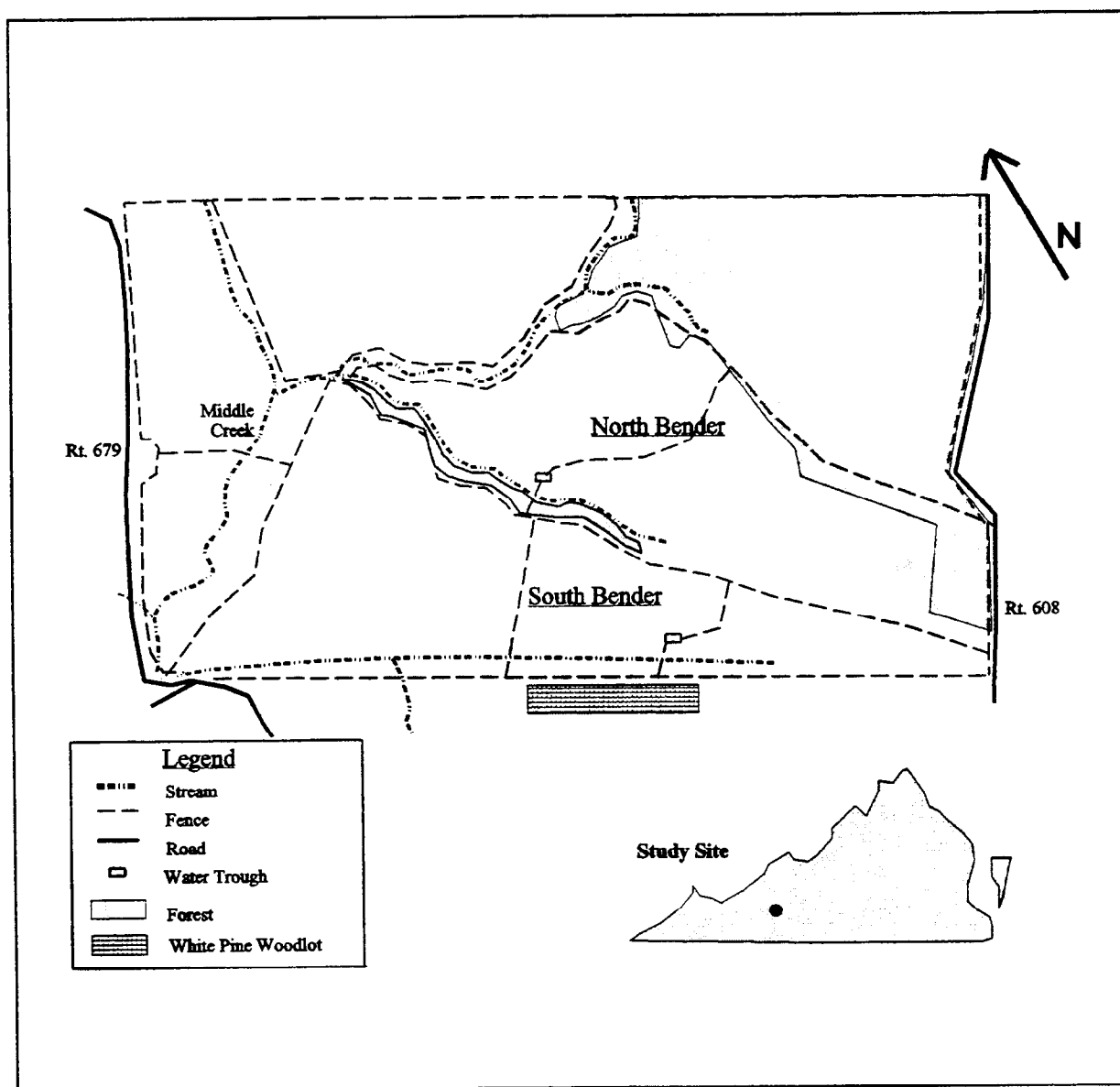


Figure 2. Location of study site at the Bender Farm in Floyd, Virginia.

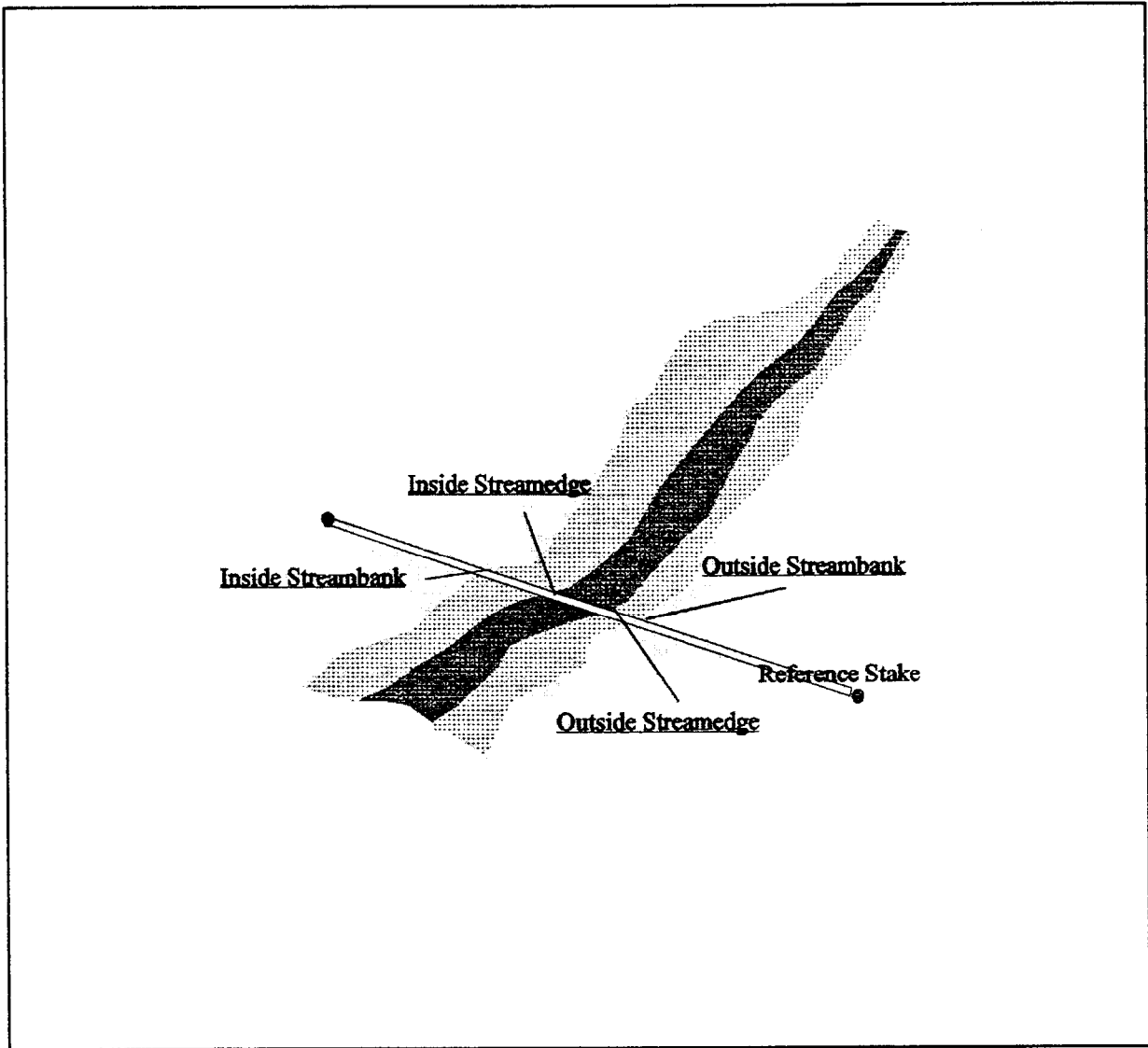


Figure 3. Schematic the methodology used for measuring a stream cross section to estimate stream bank erosion.

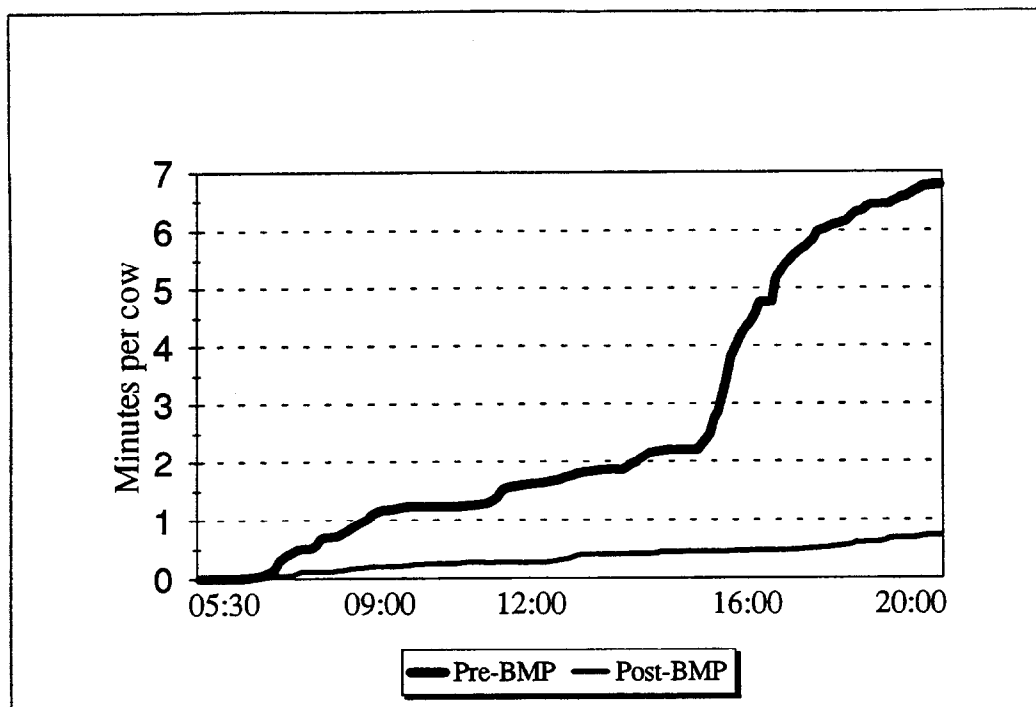


Figure 4. Cumulative time per cow spent in the stream drinking for an average cow-day.

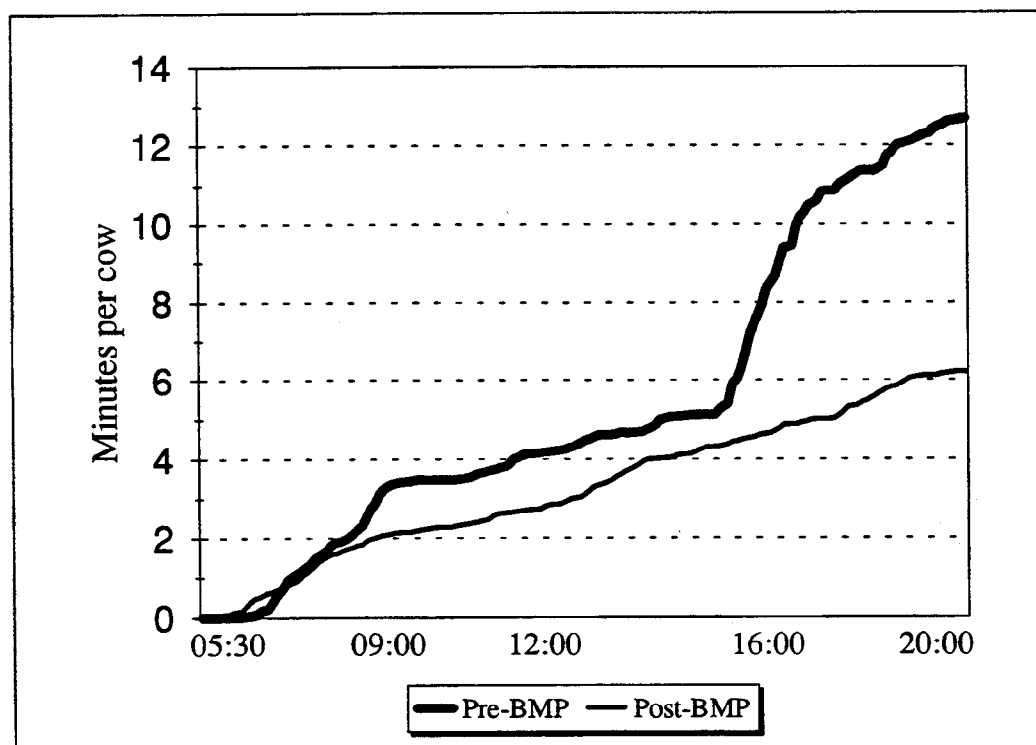


Figure 5. Cumulative time per cow spent in the stream area for an average cow-day.

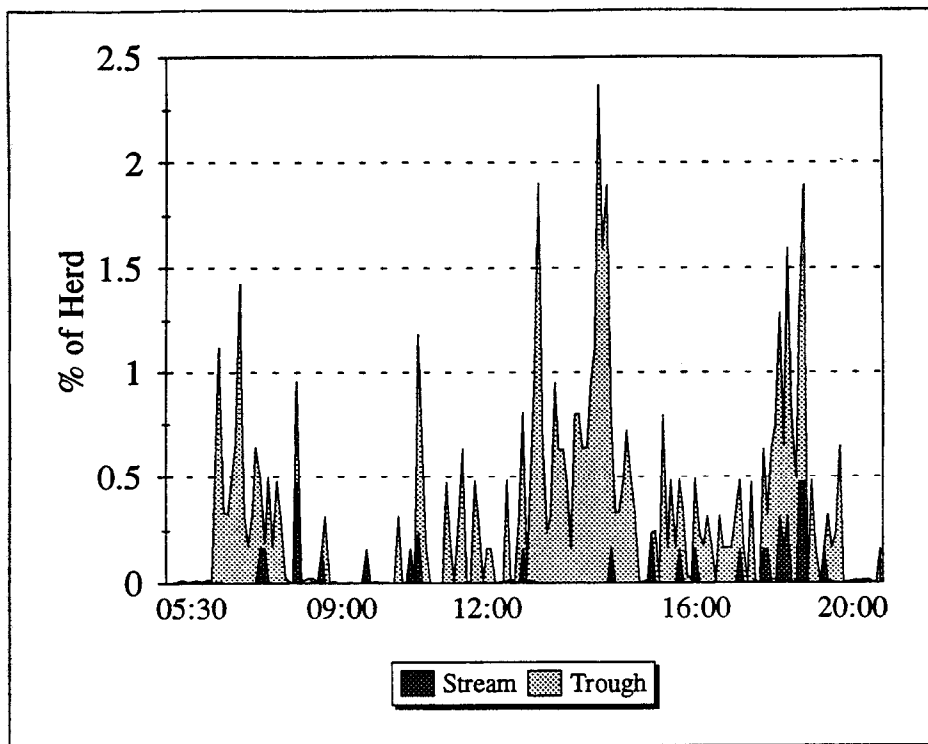


Figure 6. Cattle water source preference during the post-BMP treatment period.

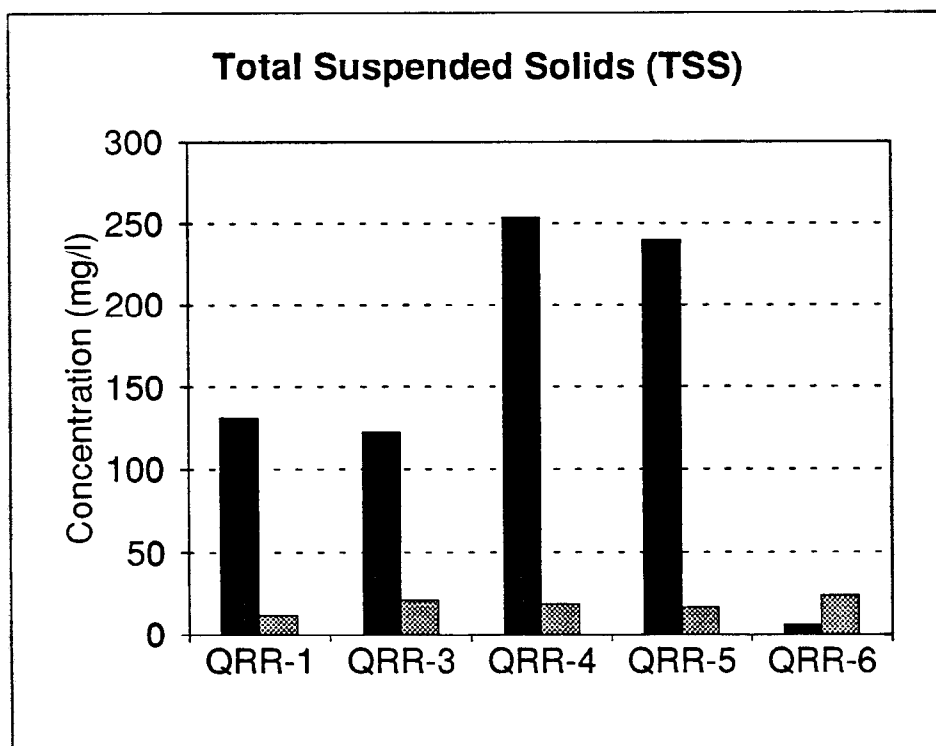


Figure 7. Average concentration of total suspended solids for all stations on the River Ridge Farm.

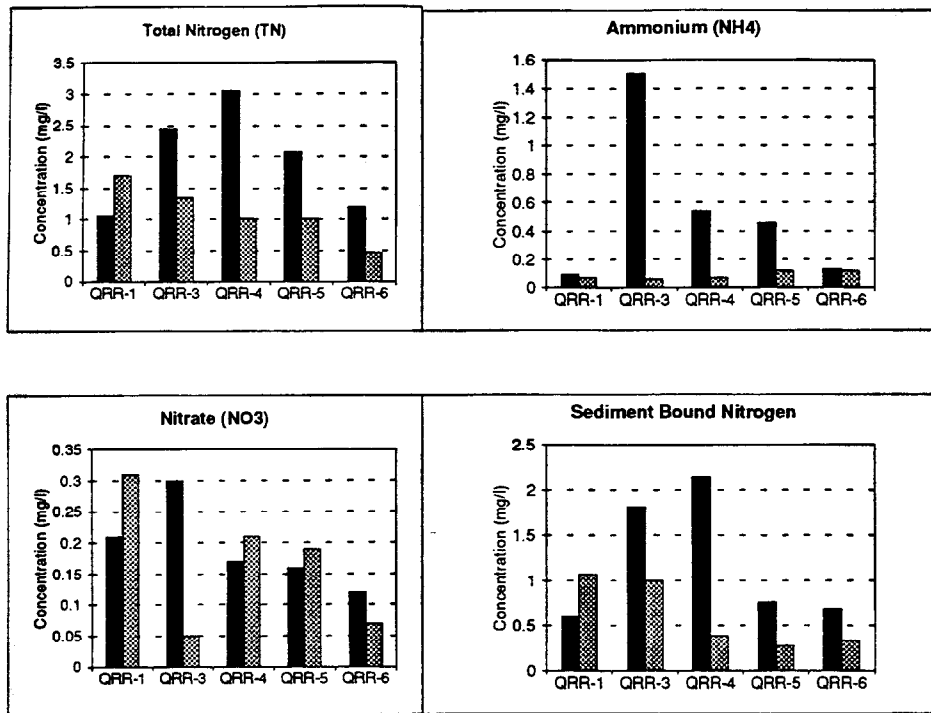


Figure 8. Average concentration of total nitrogen, ammonium, nitrate and sediment-bound nitrogen for all stations on the River Ridge Farm.

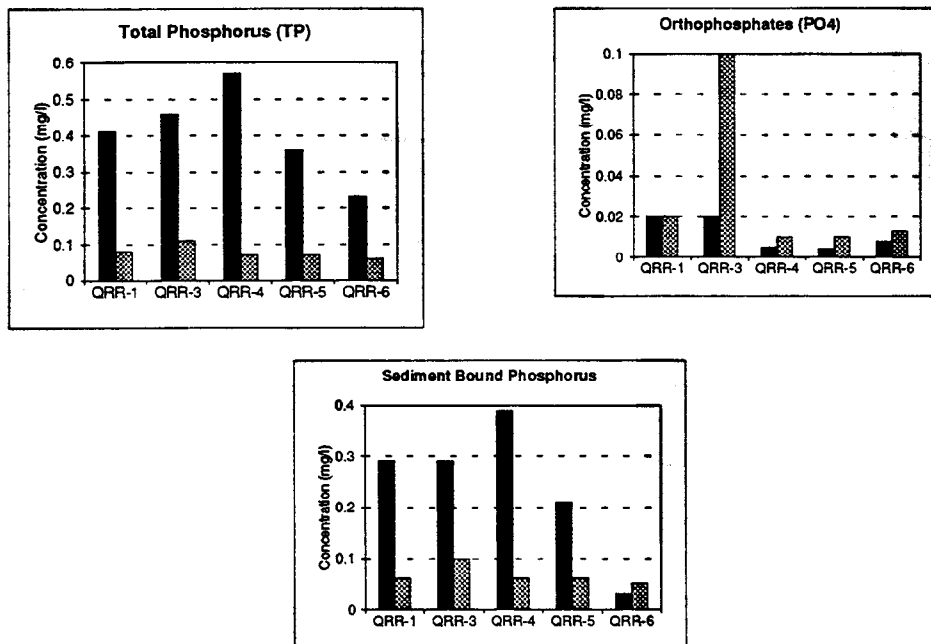


Figure 9. Average concentration of total phosphorus, orthophosphates and sediment-bound phosphorus for all stations on the River Ridge Farm.

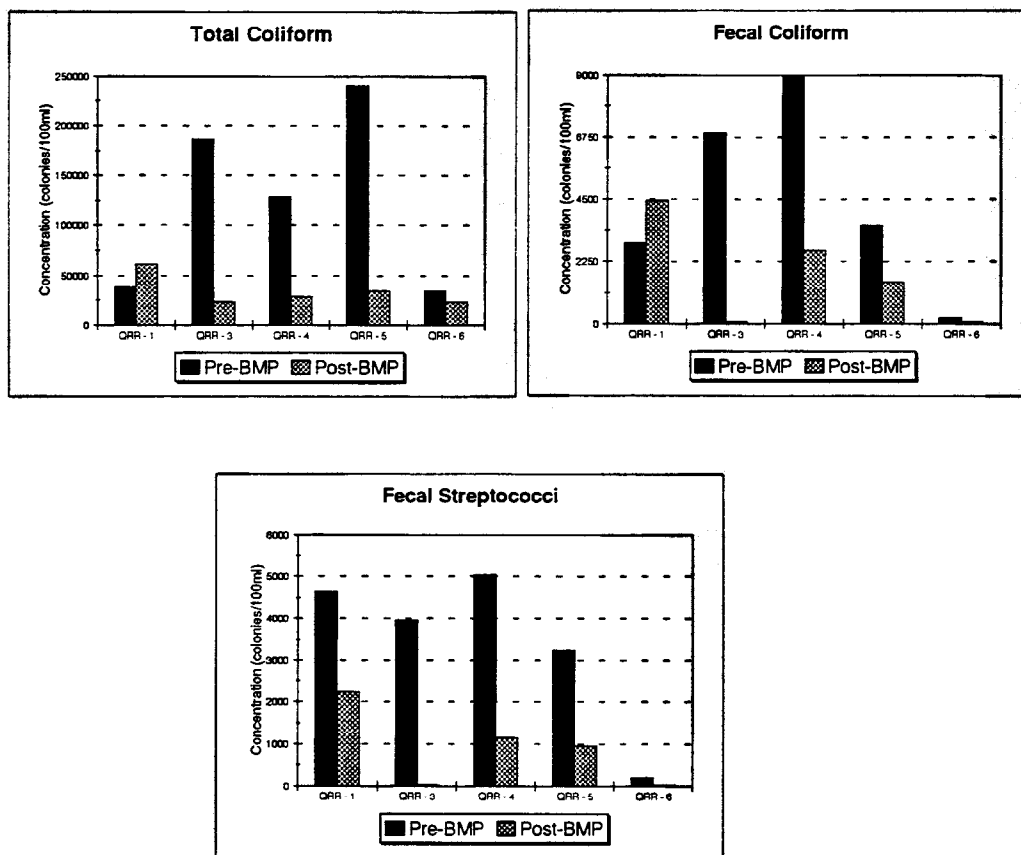


Figure 10. Average concentration for total coliform, fecal coliform and fecal streptococci for all stations on the River Ridge Farm.

STATE OF MISSOURI
DEPARTMENT OF NATURAL RESOURCES

Mel Carnahan, Governor • David A. Shorr, Director

DIVISION OF ENVIRONMENTAL QUALITY
P.O. Box 176 Jefferson City, MO 65102-0176

September 15, 1997

Mr. Hugh A. Curry, P.E.
State Conservation Engineer
Natural Resources Conservation Service
Parkade Center, Suite 250
601 Business Loop 70 West
Columbia, Missouri 65203

Dear Mr. Curry:

First, let me apologize for not responding sooner to your letter of June 2, 1997. In regard to livestock watering systems, specifically those served by public water systems, our department does have certain concerns for the safety of the public water supply. In situations involving a direct connection between the public water system and a livestock watering system, there exists the potential to introduce contaminants when water pressures fluctuate due to high usage or water main breaks. These conditions provide the means for backflow to occur. Backflow is defined as the unwanted reversal of flow in a water distribution system.

Enclosed is a copy of our state regulation, 10 CSR 60-11.010, Prevention of Backflow. This regulation establishes the requirements for protection of public water supplies from the introduction of contaminants due to backflow. Although livestock watering systems are not specifically listed as an actual or potential hazard, Section (3)(E) provides a means for their identification and designation as a potential hazard.

For the majority of livestock watering systems, an air gap separation between the water supply piping and the receiving vessel would constitute adequate protection for essentially no cost. However, there may be extenuating circumstances where a mechanical backflow prevention assembly would be necessary. In either case, an inspection by a qualified person to verify proper installation would be required. If you have details of or recommendations for specific installations, I would appreciate receiving that information.

If you have any additional questions after reviewing the referenced regulation, please feel free to contact me at (573) 751-4594.

Sincerely,

PUBLIC DRINKING WATER PROGRAM



Michael Logston, P.E.
Environmental Engineer

ML:cb

Enclosure



United
States
Department of
Agriculture

Natural
Resources
Conservation
Service

Parkade Center, Suite 250
601 Business Loop 70 West
Columbia, Missouri 65203

Mr. Jerry L. Lane
Missouri Department of Natural Resources
Division of Environmental Quality
Public Drinking Water Program
P.O. Box 176
Jefferson City, MO 65102-0176

June 2, 1997

Dear Mr. Lane:

The Natural Resources Conservation Service, formerly Soil Conservation Service, is a U. S. Department of Agricultural agency which provides assistance to landowners in addressing natural resource concerns. This involves assisting livestock producers with livestock watering systems. Many times the source of water is from existing or planned ponds or impoundment structures. But sometimes the use of public water supplies is a more economical alternative.

As our employees work with landowners to plan and install livestock watering systems, what health and safety rules and regulations should be followed? We recognize that the requirements may vary from one water district to another.

Would you please provide a copy of any State safety and health regulations that pertain to rural public water supplies?

If you or a member of your staff has any questions for us, feel free to contact Richard Koenig or Neil Pellmann in Columbia. Our telephone number is (573) 876-0910 and FAX (573) 876-0913.

Thank you in advance for your assistance.

HUGH A. CURRY P.E.
State Conservation Engineer

cc: Richard Koenig, Head, Design Section
Neil Pellmann, Agricultural Engineer

**Title 10—DEPARTMENT OF
NATURAL RESOURCES**
Division 60—Public Drinking Water
Program
Chapter 11—Backflow Prevention

10 CSR 60-11.010 Prevention of Backflow

PURPOSE: This rule establishes requirements for protection of public water systems from introduction of contaminants by backflow.

(1) Applicability, Exemptions and Compliance Dates.

(A) Applicability. This rule applies to all community water systems.

(B) Exemptions.

1. This rule does not apply to customer facilities used solely for residential purposes unless a cross-connection is specifically identified or the rule indicates otherwise.

2. The department may issue an exemption from the requirements of paragraphs (3)(A)1. and (3)(B)1. of this rule if the customer can demonstrate to the department, the local governmental authority (if one exists) and the supplier of water that the activities taking place at the customer's facility and the materials used in connection with these activities or stored on the premises cannot endanger the health of customers or degrade the water quality of the public water system should backflow occur, or that any potential risk posed by these materials or activities is isolated from the public water system. Those customers granted an exemption in accordance with this paragraph shall report to the supplier of water any proposed change in process, plumbing or materials used or stored at the exempted facility at least fourteen (14) days prior to making the change.

3. Any exemption granted under paragraph (1)(B)2. of this rule shall be void if the supplier of water, local governmental authority (if one exists) or the department determines that the customer facility has become an actual or potential backflow hazard, or if the customer fails to provide notice at least fourteen (14) days prior to making any change in process, plumbing or materials used or stored at the facility.

(2) Cross-Connections. No customer shall cause or allow the construction or maintenance of an unprotected cross-connection.

(3) Backflow Control by Containment.

(A) Class I Backflow Hazards.

1. A Class I backflow hazard presents an actual or potential health hazard to customers of the public water system should backflow occur. The customer or the customer's authorized representative shall construct a department-approved air-gap separation or install a reduced pressure principle backflow prevention assembly on the customer service line, in accordance with section (4) of this rule, when—

A. The supplier of water or local governmental agency (if one exists) requires protection from an actual or potential Class I backflow hazard at any facility;

B. Modification is made to the customer water system at an existing facility which is designated an actual or potential backflow hazard in paragraph (3)(A)2. of this rule. If an addition or modification requiring a separate customer service line is made to an existing facility, the new service line as well as the existing customer service line shall be equipped with department-approved backflow prevention assemblies;

C. A new customer service line connection is made to a facility listed in paragraph (3)(A)2. of this rule; or

D. A backflow incident occurs which introduces a contaminant into the public or customer water system which may create a health hazard.

2. Following is a list, not all inclusive, of actual or potential Class I backflow hazards:

A. Aircraft and missile manufacturing plants;

B. Automotive plants including, but not limited to, those plants which manufacture motorcycles, automobiles, trucks, recreational vehicles and construction and agricultural equipment;

C. Potable water dispensing stations which are served by a public water system;

D. Beverage bottling plants including, but not limited to, dairies, soft drink bottlers, and breweries;

E. Canneries, packing houses and reduction plants;

F. Car washes;

G. Chemical, biological and radiological laboratories including, but not limited to, those in high schools, trade schools, colleges, universities and research institutions;

H. Hospitals, clinics, medical buildings, autopsy facilities, morgues, mortuaries, veterinary facilities, dental clinics, and other medical facilities;

I. Metal or plastic manufacturing, fabrication, cleaning, plating or processing facilities;

J. Plants manufacturing paper and paper products;

K. Plants manufacturing, refining, compounding or processing fertilizer, film, herbicides, natural or synthetic rubber, pesticides, petroleum or petroleum products,

pharmaceuticals, radiological materials or any chemical which would be a contaminant to the public water system;

L. Commercial facilities that use herbicides, pesticides, fertilizers or any chemical which would be a contaminant to the public water system;

M. Plants processing, blending or refining animal, vegetable or mineral oils;

N. Commercial laundries and dye works;

O. Sewage, storm water and industrial waste treatment plants and pumping stations;

P. Waterfront facilities including piers, docks, marinas and shipyards;

Q. Industrial facilities which recycle water;

R. Restricted or classified facilities or other facilities closed to the supplier of water or the department;

S. Fire sprinkler systems using any chemical additives;

T. Auxiliary water systems, including but not limited to alternative water sources;

U. Irrigation systems with facilities for injection of pesticides, herbicides or other chemicals or with provisions for creating back pressure. The backflow assembly may be installed between the customer service line and the irrigation system;

V. Portable tanks for transporting water taken from a public water system;

W. Facilities which have pumped or repressurized cooling or heating systems that are served by a public water system; and

X. Facilities which contain any boiler system and are served by a public water system. The backflow assembly may be installed on the water service line to the boiler.

(B) Class II Backflow Hazards.

1. A Class II backflow hazard threatens to degrade the water quality of the public water system should backflow occur. The customer or the customer's authorized representative shall install, as minimum protection for Class II backflow hazards, a department-approved double check valve assembly on the customer service line in accordance with section (5) of this rule when—

A. The supplier of water or local governmental agency (if one exists) requires protection from an actual or potential Class II backflow hazard at any facility;

B. Modification is made to the customer water system at an existing facility which is designated an actual or potential backflow hazard in paragraph (3)(B)2. If an addition or modification requiring a separate customer service line is made to an existing facility, the new service line, as well as the existing customer service line, shall be

equipped with department-approved backflow prevention assemblies;

C. A new customer service line connection is made to a new facility listed in paragraph (3)(B)2.; or

D. A backflow incident occurs in any situation described in paragraph (3)(B)2. or subsection (3)(C).

2. Following is a list, not all inclusive, of actual or potential Class II backflow hazards:

A. Tanks to store water from the public water system for fire fighting only, unless the tanks meet the requirements of the department for construction to maintain bacteriological quality of the water;

B. Fire sprinkler systems not using chemical additives. This only applies to new fire sprinkler systems or fire sprinkler systems scheduled for modifications;

C. Irrigation systems without facilities for injection of pesticides, herbicides or other chemicals. The backflow assembly may be installed between the customer service line and the irrigation system; and

D. Cross-connections that could permit introduction of contaminants into the public or customer water system and create a nuisance, be aesthetically objectionable or cause minor damage to the public water system or its appurtenances.

(C) Customer facilities not designated a backflow hazard by subsection (3)(A) or (B) may be designated a Class I or Class II backflow hazard by written notification from the supplier of water or the department to the customer. The notice shall specify the nature of the customer activity which necessitates designation of the facility as a backflow hazard, the type of backflow protection required and the date by which the customer shall install or construct this assembly on the customer service line to the facility.

(D) Following is a list of facilities, not all inclusive, considered to be actual or potential Class II backflow hazards:

1. Tanks to store water from the public water system for fire fighting only, unless the tanks meet the requirements of the department for construction to maintain bacteriological quality of the water;

2. Fire sprinkler systems not using chemical additives;

3. Irrigation systems without facilities for injection of pesticides, herbicides or other chemicals and without provisions for creating back pressure. The backflow assembly may be installed between the customer service line and the irrigation system; or

4. Cross-connections that could permit introduction of contaminants into the public or customer water system and create a nuisance,

be aesthetically objectionable or cause minor damage to the public water system or its appurtenances.

(E) Customer facilities not designated a backflow hazard by subsection (3)(B) or (C) may be designated a backflow hazard by written notification from the supplier of water or the department to the customer. The notice shall specify the nature of the customer activity which necessitates designation of the facility as a backflow hazard, the type of backflow protection required and the date by which the customer shall install or construct this assembly on the customer service line to the facility.

(4) Department-Approved Backflow Prevention Assemblies.

(A) The department shall maintain a current list of approved backflow prevention assemblies and shall make this list available to the public upon request.

(B) The discharge pipe of an approved air-gap shall terminate a minimum of two (2) pipe diameters of the discharge pipe above the flood level rim of the receiving vessel; in no case shall the distance be less than one inch (1").

(C) Only those models of double check valve assemblies and reduced pressure principle backflow prevention assemblies which are approved by the Foundation for Cross Connection Control and Hydraulic Research of the University of Southern California and are on the approved list maintained by the department are acceptable.

(5) Standards of Construction and Installation.

(A) Reduced pressure principle backflow prevention assemblies shall be installed with no plug or additional piping affixed to the pressure differential relief valve port (except for specifically-designed funnel apparatus available from the manufacturer) and with the pressure differential relief valve port a minimum of twelve inches (12") above floor level. Additionally, the assembly shall be installed at a location where any leakage from the pressure differential relief valve port will be noticed, that allows easy access to the assembly for maintenance and testing, and that will not subject the assembly to flooding, excessive heat or freezing.

(B) All double check valve assemblies shall be installed at a location that allows easy access to the assembly for maintenance and testing and that will not subject the assembly to excessive heat or freezing.

(C) Backflow prevention assemblies shall be installed on the customer water system as close as possible to the point of service connection and prior to any other connection or branch line. If it is not possible to install the backflow prevention assembly as described, then installation shall be at the approval of the department.

(D) No bypass piping shall be allowed around a backflow prevention assembly unless the bypass is equipped with the same degree of backflow prevention protection.

(6) Backflow Prevention Assembly Testing and Inspection.

(A) All backflow prevention assemblies shall be inspected and tested by testers certified in accordance with the requirements and procedures in 10 CSR 60-11.030.

(B) Air-gaps shall be inspected each year by a date which is no later than thirty (30) days past the anniversary date established by the supplier of water to ensure that they continue to meet the requirements of subsection (4)(A).

(C) Reduced pressure principle backflow prevention assemblies shall be tested by a certified backflow prevention assembly tester each year by a date which is no later than thirty (30) days past the anniversary date established by the supplier of water to ensure that—

1. The pressure differential relief valve operates to maintain the zone between the two (2) check valves at least two pounds per square inch (2.0 psi) less than the supply pressure;

2. The #2 check valve is leak tight against reverse flow under all pressure differentials; and

3. The static pressure drop across the #1 check valve is at least three pounds per square inch (3.0 psi) greater than the pressure differential between the supply pressure and the pressure in the zone required to open the pressure differential relief valve.

(D) Double check valve assemblies shall be tested each year by a certified backflow prevention assembly tester by a date which is no later than thirty (30) days past the anniversary date established by the supplier of water to ensure that both the #1 and #2 check valves maintain at least one pound per square inch (1.0 psi) differential in the direction of flow and are leak tight against reverse flow under all pressure differentials.

(E) All certified backflow prevention assembly testers shall report to the appropriate governmental authority (if one exists), the supplier of water, the customer, and, if requested, the department the results of inspections or tests conducted in compliance with this section (6). Reports of tests shall contain the signature of the certified backflow prevention assembly tester attesting to the

compliance (or noncompliance) of the assembly with established operational requirements. Routine reports shall be submitted within thirty (30) days after making the inspection or test. Falsification of testing or inspection information shall be grounds for removing the tester from the list of testers authorized to operate in Missouri.

(7) Customer Responsibilities.

(A) The customer shall furnish, install and maintain in working order at all times any backflow prevention assembly required by this rule.

(B) To ensure that each backflow prevention assembly required by this rule is in working order, the customer shall have each assembly inspected and tested by a certified backflow prevention assembly tester at the time of construction or installation and at the frequency specified in section (6).

(C) The customer shall permit access to the premises by the certified backflow prevention assembly tester, supplier of water and department representatives, at reasonable times and upon presentation of identification, for inspection of the customer water system or testing of backflow prevention assemblies installed in accordance with this rule.

(8) Responsibilities of the Supplier of Water.

(A) Because backflow may cause a health hazard through transmission of contaminants via the public water system, the supplier of water shall remove the water meter or otherwise sever the public water system from the customer service line serving a facility when the supplier of water—

1. Has knowledge that the customer is causing or maintaining an unprotected cross-connection;

2. Has knowledge that the customer is failing or refusing to proceed without delay to correct any violation of the provisions of this rule after having been notified to do so;

3. Is so ordered by the appropriate local governmental authority (if one exists); or

4. Is so ordered by the department because of violation of any provision of this rule by the customer.

(B) The supplier of water shall retain records of the reports of inspections, tests and repairs on backflow prevention assemblies for a period of five (5) years.

(C) The supplier of water may develop, for use within his/her service area, written procedures to implement the provisions of this rule. In developing the procedures, the supplier of water will be permitted to take into account existing backflow prevention programs and incorporate ordinances, regulations or requirements of appropriate local

governmental authorities. However, the written procedures shall be no less stringent than the provisions of this rule. The department will prepare and make available on request the appropriate forms needed to assist the supplier of water in implementing the provisions of this rule. The supplier of water may submit the procedures to the department for approval.

(D) The supplier of water shall record the date of the initial inspection or test of backflow prevention assemblies required under subsections (3)(A) and (3)(B) and shall require that an annual inspection or test report be submitted by a certified backflow prevention assembly tester. The supplier of water shall establish an annual anniversary date for these inspection or test reports. If these reports are not received by the supplier of water on or before sixty (60) days following this anniversary date, the supplier of water promptly shall notify the customer, the local governmental agency (if one exists) and the department.

(E) The supplier of water shall notify the department within forty-eight (48) hours whenever a cross-connection problem has occurred which resulted in contamination of the public water system.

*AUTHORITY: section 640.100, RSMo (Cum. Supp. 1996). * Original rule filed May 4, 1979, effective Sept. 14, 1979. Rescinded and readopted: Filed July 11, 1986, effective Jan. 1, 1987. Amended: Filed Dec. 4, 1990, effective July 8, 1991. Amended: Filed Jan. 2, 1997, effective Sept. 30, 1997.*

**Original authority 1939, amended 1978, 1981, 1982, 1988, 1989, 1992, 1993, 1995, 1996.*

10 CSR 60-11.030 Backflow Prevention Assembly Tester Certification

PURPOSE: This rule establishes certification and recertification requirements for backflow prevention assembly tester training programs.

(1) Applicability. This rule applies to all persons seeking certification or recertification as backflow prevention assembly testers. A certified backflow prevention assembly tester shall inspect, test and report on backflow prevention assemblies in accordance with applicable requirements in 10 CSR 60-11.010.

(2) Certification Requirements.

(A) Any person seeking to be a certified backflow prevention assembly tester shall—

1. Satisfactorily complete written and performance (hands on) examinations (including questions specific to Missouri

backflow prevention rules) provided by the American Backflow Prevention Association (ABPA) Tester Certification Program or the American Society of Sanitary Engineering (ASSE); and

2. Ensure that ABPA or ASSE notifies the department that the tester has passed the examinations. The department shall not be held liable for any failure of ABPA or ASSE to notify the department that a person has passed the written and performance examinations.

(B) Certification shall be valid for three (3) years. Certification may be renewed in accordance with section (4) of this rule.

(C) Submittal of false information shall be grounds for denying or revoking certification.

(3) Examination Schedule. The department shall, in consultation with training providers, prepare an annual schedule of dates and locations of backflow prevention assembly tester examinations. The department shall make this schedule available to backflow prevention assembly tester training providers and to any interested person upon request. (Training providers may offer additional examinations, at their discretion.)

(4) Recertification Requirements.

(A) Any certified tester seeking to be recertified shall—

1. Satisfactorily complete ABPA's or ASSE's recertification requirements, including examination questions on Missouri backflow prevention rules; and

2. Ensure that ABPA or ASSE notifies the department that the tester has satisfactorily completed the requirements. The department shall not be held liable for any failure of ABPA or ASSE to notify the department that a tester has satisfactorily completed the recertification requirements.

(B) Recertification shall be valid for three (3) years.

(C) Submittal of false information shall be grounds for denying or revoking recertification.

(D) Any certified tester who fails the ABPA or ASSE examination within three (3) years of the effective date of this rule shall, upon request and submission of proof having taken and failed the examination, be granted a one (1)-time one hundred twenty (120)-day extension of his/her certification. The tester shall submit, or ensure that the instructor or testing organization submits, to the department a copy of the course roster and test results or other documentation which in the opinion of the department are equivalent.



(5) Reciprocity. Any backflow prevention assembly tester listed with ABPA or ASSE may be certified by the department upon notification from ABPA or ASSE that the tester has satisfactorily completed an examination on Missouri backflow prevention rules.

*AUTHORITY: section 640.100, RSMo (Cum. Supp. 1996). * Original rule filed Jan. 2, 1997, effective Sept. 30, 1997.*

**Original authority 1939, amended 1978, 1981, 1982, 1988, 1989, 1992, 1993, 1945, 1996.*



United States
Department of
Agriculture

Natural
Resources
Conservation
Service

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REC'D SEP 12 1997

September 5, 1997

SUBJECT: ECS - Range, Research Article on Performance
and Economic Comparison of a Mechanical
Windmill to a Wind-Electric Water Pumping System

FILE CODE: 190-19-

TO: State Grazing Lands Specialists

Tom Spoffard of the Water Climate Center, Portland, Oregon, recently sent me the attached research article comparing wind-electric windmills and mechanical windmills. I found it very interesting and I think it could have potential in many of your areas where windmills are used.

The bottom line is that an electric windmill is 25 percent cheaper to install and pumps more water than the mechanical windmill. Maintenance required for the electric windmill should be less also. Read on for more information. It might be the way of the future or now.

Rhett H. Johnson
Director

Attachment

cc:
GLTI staff
Jim Robinson, Agroforester, NAC, NRCS, Ft. Worth, TX

PERFORMANCE AND ECONOMIC COMPARISON OF A
MECHANICAL WINDMILL TO A WIND-ELECTRIC WATER PUMPING SYSTEM

by

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Minneapolis, Minnesota
August 10-13, 1997

Summary:

At a simulated 30-m (98.4ft) pumping depth, the water pumping performance of a mechanical windmill using two different size piston pumps was compared to two wind-electric water pumping systems. If the wind turbine of a wind-electric system was on a 20 m tower, it would average more daily water volume than a mechanical windmill on a 10 m tower for every month of the year at a 25% reduction in total system cost (assuming Bushland wind regime).

Keywords:

Water pumping, windmill, wind power, wind-electric

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PERFORMANCE AND ECONOMIC COMPARISON OF A MECHANICAL WINDMILL TO A WIND-ELECTRIC WATER PUMPING SYSTEM¹

B. D. Vick and R. N. Clark²

ABSTRACT

At a simulated 30m(98.4ft) pumping depth, the water pumping performance of a mechanical windmill using two different size piston pumps was compared to two wind-electric water pumping systems. The mechanical windmill had a rotor diameter of 2.44m(8ft) and reached a maximum of 32 strokes/minute at a 9m/s(20.1mph) wind speed. The inside diameters of the piston pumps tested on the mechanical windmill were 4.8cm(1.875in) and 7cm(2.75in) -- the stroke length on both was 19cm(7.5in). The wind turbine on one of the wind-electric systems had a rotor diameter of 2.44m(8ft) and was connected to a 0.38kW 3-phase 230V AC submersible motor via a USDA-ARS designed wind turbine smart controller. The wind turbine on the other wind-electric system had a rotor diameter of 2.74m(9ft) and was connected to a 0.75kW 3-phase 230V AC submersible motor via a controller supplied by the manufacturer. Both wind-electric systems used a 0.38kW 9-stage centrifugal pump. At a hub height of 10m, the wind-electric systems pumped more water than the mechanical systems in the winter and spring(highest average wind speed months), but pumped less water in the summer and fall(lowest average wind speed months). However, if the wind turbines were on 20m towers and the windmills were on 10m towers, then the wind-electric systems would pump as much or more water than the mechanical systems during every month of the year if the wind regime was similar to that of Bushland, TX. Even when the cost of a 20m tower for a wind-electric system was included, the total system cost for a wind-electric system was \$1282 to \$1414 cheaper than it would be for a new mechanical windmill system(a 25% cost reduction). The maintenance required on a wind-electric system should also be less than that for a mechanical windmill.

INTRODUCTION

A safe drinking water supply continues to be a major problem in the world. In parts of the world where there is no utility supplied electricity, the most economical solution is to use mechanical windmills, solar-PV systems, or wind-electric systems for pumping water. Which system is used depends on the pumping depth, solar radiation, wind speed, and amount of water needed. Many farmers and ranchers in this country are looking to replace their aging windmills with either another mechanical system, a solar-PV system, or a wind-electric system. Because of the high

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diameter pumps will also increase flow rate, maintenance is also likely to increase with using a larger size pump. As the pump diameter gets larger the drop pipe also should be increased which means higher cost and a much heavier system to try to do maintenance on. The total weight of the Aermotor 2.44m windmill is 161.4kg(355lb).

DESCRIPTION OF WIND-ELECTRIC SYSTEMS

The two wind-electric systems selected in this study were a Bergey Windpower³ 850 and a World Power Technologies³ Whisper 1000. The Bergey 850 is currently being sold for battery charging, but the manufacturer made a new winding for the stator so we could test it for powering a 3-phase AC submersible motor and centrifugal water pump. Since this is a prototype, the final Bergey 850 water pumping system that is sold will perform better than this one. The Bergey 850 has a rotor diameter of 2.44m(8ft) and reaches 850W at a 12.5m/s wind speed. There currently is no controller commercially available for using this wind turbine for water pumping, but a smart controller was designed for the Bergey 850 by USDA-ARS (Ling and Clark, 1997). The controller uses a 6V, 5A-hr rechargeable battery and has the usual high/low frequency cut-in/cut-out capability of a wind turbine pump controller. In addition, this controller also has:

- 1) solid state instead of mechanical relays for shorter response time and longer life.
- 2) a dump load cut-in and cut-out frequency which can be used for adding a resistive or a capacitive load for improving the performance at higher wind speeds.
- 3) a battery charging circuit which can limit the maximum charging current to protect a fuse from being blown due to low battery voltage. Low battery voltage can be caused by low wind days or wind turbine being braked for long periods.
- 4) CPU logic that will protect the turbine if it begins to get too hot.
- 5) CPU logic that determines the proper dump load cut-in/cut-out frequencies if the turbine goes offline repetitively due to gusty winds.

The wind turbine uses 3 pultruded fiberglass blades which have an airfoil developed by Karl Bergey. The blade's chord and twist are constant in a static condition, but a pitch weight will alter the twist at higher wind speeds. The generator is a permanent magnet alternator with 18 poles and has increased stator insulation(compared to the battery charging stator) to reduce the risk of the stator shorting due to high voltage. This wind turbine uses horizontal furling for overspeed protection. This wind-electric system used a Grundfos³ 0.38kW(0.5hp) 9-stage pump driven by a Franklin Electric³ 0.38kW(0.5hp) 3-phase, 230V submersible motor. The variable voltage and frequency from the generator was connected to the controller which in turn was connected to the submersible motor. No inverter was needed because additional capacitance is added in parallel(via controller) with the inductive motor which keeps the voltage-to-frequency ratio around 3 to 4 and keeps the voltage and current waveforms in phase (i.e. improvement in power factor). The capacitance used is 35 μ F until the dump load frequency is reached whereupon an additional 20 μ F is added. The total weight of the Bergey 850 wind turbine is 38.6kg(85lb).

The Whisper 1000 has been sold for about four years for water pumping. The Whisper 1000 has a rotor diameter of 2.74m(9ft) and reaches 1000W at a wind speed of 11m/s. Its controller is

energized by power from the wind turbine and therefore doesn't require a battery. This controller has a low frequency cut-in/cut-out, but no high frequency cut-in/cut-out. The wind turbine used 2 epoxy fiberglass blades which were made using a hand layup. A Wortmann airfoil with a variable chord and twist distribution were used in the blade design. The generator is a permanent magnet alternator with 10 poles. The wind turbine furls vertically for overspeed protection. This wind-electric system used a McDonald³ 0.38kW(0.5hp) 9-stage pump driven by a Franklin Electric³ 0.75 kW(1hp) 3-phase 230V submersible motor. As was true for the Bergey 850, the Whisper alternator generates 3-phase AC variable voltage and frequency electricity and was connected to a controller which in turn was connected to a submersible motor without the use of an inverter. A capacitance of 35 μ F was used to improve the power factor. The total weight of the Whisper 1000 wind turbine is 31kg(68.2lb).

RESULTS

The windmill and wind-electric systems were evaluated at a simulated pumping depth of 30m. The pumping depth was simulated by using a back pressure valve. For further discussion on the experimental apparatus see (Clark and Vick, 1994). The flow rate for both the windmill and wind-electric systems is shown in Figure 1. This graph shows that the windmill systems cut-in at a lower wind speed (2.5 to 3m/s) than the wind-electric systems (5 to 5.5m/s). This is due to the high solidity of the windmill with its 18 blades compared to the low solidity of the wind-electric systems with two or three blades. If the wind speeds always stayed between 3 and 5m/s the windmills would pump water, but the wind-electric systems would not. However, the wind-electric systems substantially outperform the windmill systems at higher wind speeds. From this graph it is evident that the windmill systems are beginning to furl at a windspeed of 9 m/s(20.1mph). While it appears the wind-electric systems are beginning to furl at 13m/s (because of the decrease in flow rate with increasing wind speed), in actuality the wind turbines are losing synchronization with the motors at these wind speeds and therefore running offline part of the time -- especially when there are gusty winds.

System Efficiency can be defined by the following equation:

$$\text{System Efficiency} = \text{Water Power} / \text{Wind Power}$$

Water Power is the change in potential energy of the pumped water with respect to time (the kinetic energy of the water pumped with respect to time is negligible). Wind power is the change in kinetic energy with respect to time of the air passing through a stream tube with the diameter of the wind turbine/windmill rotor and at the wind turbine/windmill hub height. The system efficiency for all the water pumping systems is shown in Figure 2. As was seen with the flow rate, the windmill systems are better at low wind speeds while the wind-electric systems do better at higher wind speeds. The maximum system efficiency is higher (15 to 20%) for the windmill systems but occurs at a lower wind speed (3.5 to 4.5 m/s). Besides the solidity, another reason for the windmill's high efficiency at low wind speeds is the chord and twist of the blades are optimized at these low wind speeds while the wind turbine blades are optimized at wind speeds around 7 to 8 m/s. Another advantage for the windmill is the wind power is directly converted to mechanical power while the wind turbines convert the mechanical power to electrical power and then the electrical power is converted back to mechanical power. The wind-electric maximum

system efficiency (5.5 to 7.5%) occurs over a broader band of wind speeds (7 to 11 m/s) than the mechanical windmill because the change in rotor speed with wind speed results in maintaining a constant angle-of-attack close to the maximum lift-to-drag ratio of the airfoil.

In Figure 3 the stroke rate is shown for both windmill systems. The maximum stroke rate for both systems is about 32 strokes/minute and occurs at a wind speed of 9m/s. As expected, the stroke rate for a given wind speed is less for the bigger diameter pump. If the furling wind speed is adjusted so the maximum stroke rate is increased, the flow rate will increase, but this will increase the wear on the pumping system and is not recommended by the manufacturer.

The monthly average wind speed at Bushland, TX at a 10m height over a 14 year period can be observed in Figure 4. This graph shows that the windspeeds are normally highest in the spring and winter and lowest in the summer and fall -- this is typical of the wind pattern in much of the Great Plains. March and April are usually the highest wind months, and August is usually the lowest.

Using the flow rate data in Figure 1 and the monthly average wind speed distribution data gathered at Bushland, TX from 1983 to 1996 at a 10m height, the monthly daily water volume for all the windmill and wind-electric systems can be calculated (Figure 5). At a constant hub height (10m), the water pumping performance of the Aermotor windmill system with the 48mm pump is about the same as the Bergey 850 wind-electric system, and the water pumping performance of the Aermotor windmill system with the 70mm pump is about the same as the Whisper 1000 system. The wind-electric systems pump more water than their Aermotor windmill/pump counterparts in the spring and winter (when the winds are highest) and less in the summer and the fall (when the winds are lowest). Since August (besides being the calmest month) is also usually very hot, water for cattle or domestic use is most critical during this month. Therefore it is imperative that the wind-electric system be as good as the mechanical system which it is to replace. The size of the wind turbine could be increased, but this would result in a substantial increase in cost. However, for a relatively small increase in cost the wind turbine height can be increased by using a taller tower which will result in higher wind speeds and a higher daily water volume.

The monthly average windspeeds at Bushland, TX during 1996 at 10 and 20m heights are shown in Figure 6. Only one year of data is shown because only a few years of 20m height data have been consistently collected at Bushland, TX. Although the wind speeds in this graph vary much more than in Figure 4, it is still evident that spring has the highest wind speeds and late summer has the lowest wind speeds. The 20m height average wind speed is between 0.4 and 0.9m/s higher than the 10m height average wind speed. Since the power in the wind goes up as the cube of the wind speed, this increase in wind speed will result in a large increase in wind power and correspondingly a large increase in daily water volume.

The monthly daily water volume during 1996 of the Aermotor windmill (48mm pump) system at a 10m height and the Bergey 850 wind-electric system at 10 and 20m heights is shown in Figure 7. When comparing the Aermotor (48mm pump) to the Bergey 850 at a 10m height, the results are similar to those seen in Figure 5 (average wind speed distribution over 14 years). But when

the Bergey 850 at the 20m height is compared to the Aermotor(48mm pump) at the 10m height, the Bergey 850 pumps more water than the Aermotor(48mm pump) for every month.

The same results as Figure 7(wind-electric systems pump more water than windmill systems if the wind turbines are at a higher height), can be seen in Figure 8, but this time the Aermotor windmill(70mm pump) system at the 10m height is compared to the Whisper 1000 wind-electric system at 10 and 20m heights. The only difference is this time the daily water volume in August for the wind-electric system is below the windmill system but only by about 5%. Table 1 shows the system cost for the windmill and wind-electric pumping systems. The system costs have been estimated for a 30m pumping depth, but as the pumping depth increases, the windmill systems will become even more expensive when compared to the wind-electric systems due to the high cost of sucker rod and drop pipe for windmill systems. The total cost of the wind-electric systems was \$1282 to \$1414 cheaper than the windmill systems.

CONCLUSIONS

Two wind-electric water pumping systems were compared to two windmill water pumping systems for a 30m pumping depth. The windmill systems had lower cut-in windspeeds(2.5 to 3m/s) compared to the cut-in wind speeds(5 to 5.5m/s) of the wind-electric systems. However, the wind-electric systems pumped more water at higher wind speeds than the windmill systems. For the same hub height, the average daily water volume of the wind-electric systems was higher than that of the windmill systems during the spring and winter but usually was less for summer and fall. However, if the wind turbines were set on towers giving them a 20m height compared to the windmills' 10m height, then the daily water volume of the wind-electric systems was higher than that of the windmill systems for every month. It should be mentioned that using 20m towers for windmills is too expensive. When comparing the total system cost of the wind-electric systems to that of the windmill systems, the wind-electric systems were found to be 25% cheaper than the windmill systems even when the cost of the taller wind-electric towers was included. For deeper pumping depths the wind-electric systems would be even more economical than the windmill systems(due to high cost of sucker rod and drop pipe for windmill systems). The above statements imply the Bergey 850 would be a good replacement for an Aermotor 2.44m(8ft) windmill with a 48mm(1.875in) pump if the wind regime is comparable to that at Bushland, TX. Similarly, the Whisper 1000 would be a good replacement for the Aermotor 2.44m(8ft) windmill with a 70mm(2.75in) pump if the wind regime is comparable to that at Bushland, TX. If pumping too much water in the spring and winter by the wind-electric systems is a problem, then a float switch could be installed that the controller can operate.

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ACKNOWLEDGMENTS

We would like to thank Ron Davis (USDA-ARS) and Shitao Ling (WTAMU-AEI) for their invaluable help in this research.

Table 1. SYSTEM COST OF WIND PUMPING SYSTEMS
30 METER PUMPING DEPTH
Estimated by USDA-ARS

<u>Component</u>	<u>Aermotor 2.44m</u>	<u>Aermotor 2.44m</u>	<u>Bergey 850</u>	<u>Whisper 1000</u>
Wind Turbine/Mill	\$2,400.00	\$2,400.00	\$1,825.00	\$1,950.00
Tower ^a	\$1,820.00	\$1,820.00	\$1,210.00	\$1,210.00
Pump Controller	-----	-----	\$ 300.00	\$ 200.00
Pump ^b	\$ 227.00	\$ 403.00	\$ 255.00	\$ 255.00
Motor ^c	-----	-----	\$ 301.00	\$ 320.00
Pump Rod ^d	\$ 50.00	\$ 50.00	-----	-----
Sucker Rod ^e	\$ 335.00	\$ 335.00	-----	-----
Packer Head	\$ 76.00	\$ 76.00	-----	-----
Pipe ^f	\$ 313.00	\$ 313.00	\$ 48.00	\$ 48.00
Total	\$5,221.00	\$5,397.00	\$3,939.00	\$3,983.00

^a Assuming 10m tower height for mechanical windmills & 20m tower height for wind turbines.

^b Assuming 5cm piston pump on first Aermotor & 7cm piston pump on second Aermotor.

Assuming 9-stage 0.38kW centrifugal pumps on both Bergey 850 & Whisper 1000.

^c Assuming 0.38kW 3 ϕ 230V motor on Bergey 850 & 0.75kW 3 ϕ 230V motor on Whisper 1000

^d Assuming 2.54cm square steel pipe

^e Assuming 1.59cm fiberglass rod

^f Assuming 5cm galvanized steel drop pipe for mechanical windmills and 2.5cm polyethylene pipe for wind turbines.

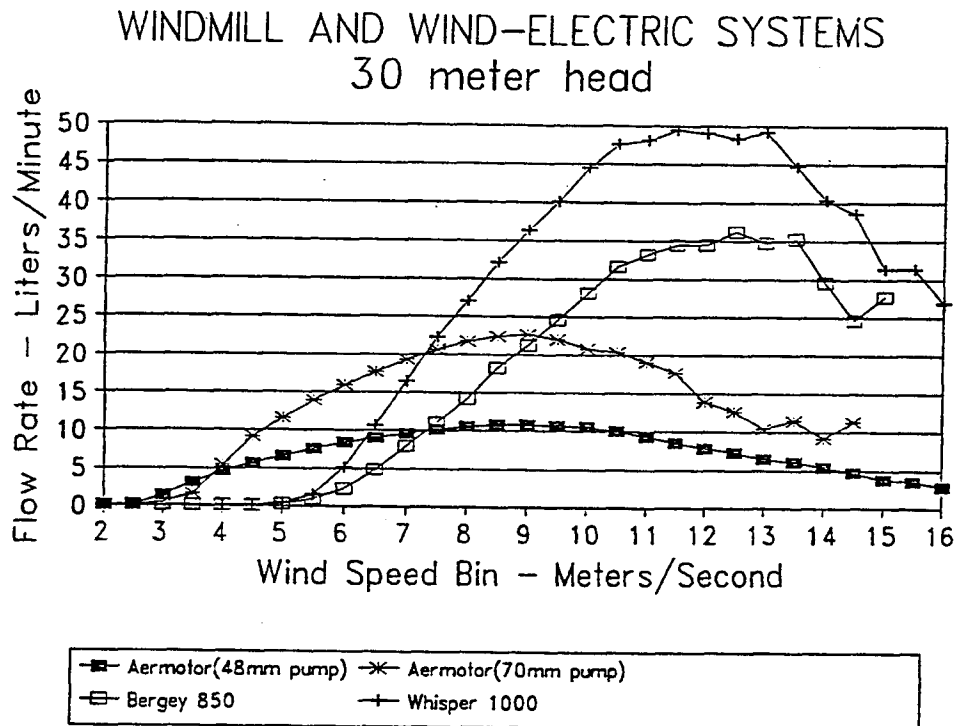


Figure 1. Flow rate at a 30 meter head for windmill and wind-electric systems.

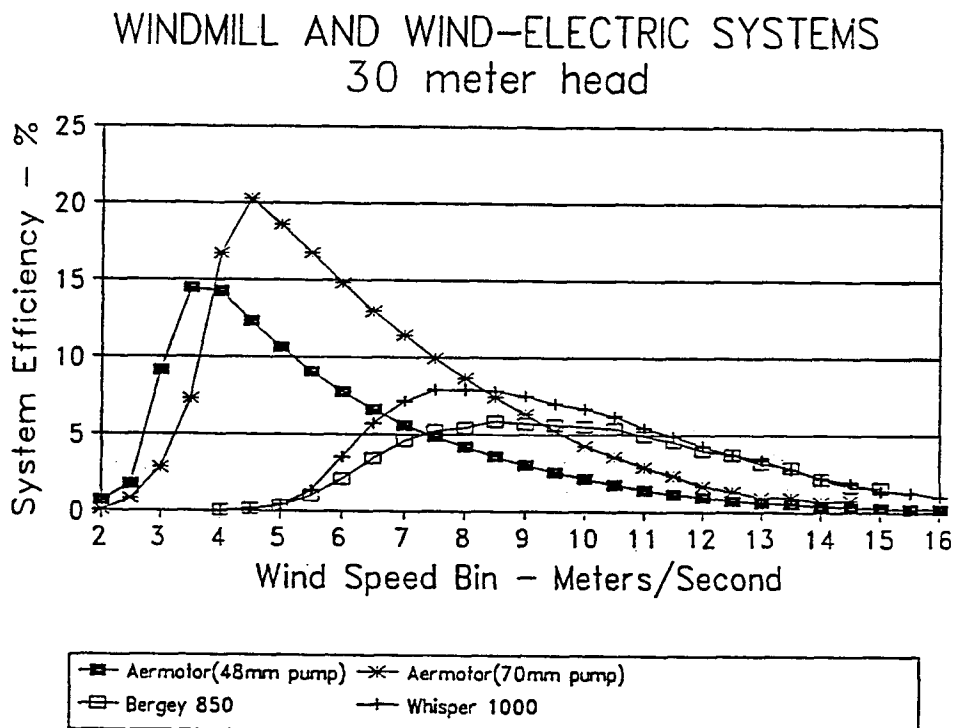


Figure 2. System efficiency at a 30 meter head for windmill and wind-electric systems.

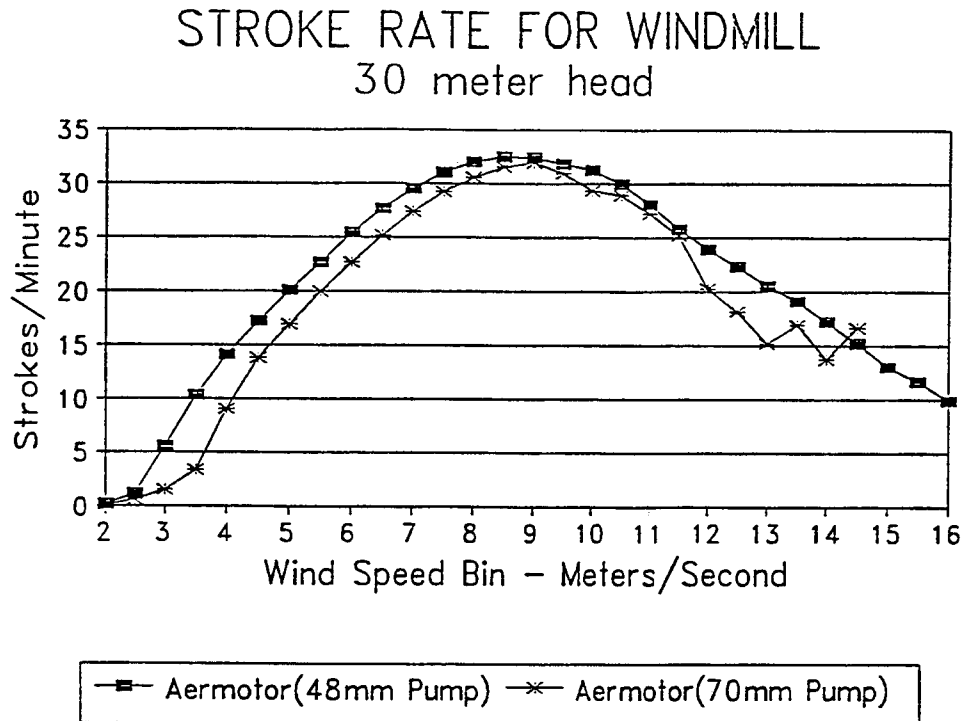


Figure 3. Stroke rate for two different size pumps on Aermotor 2.44m windmill.

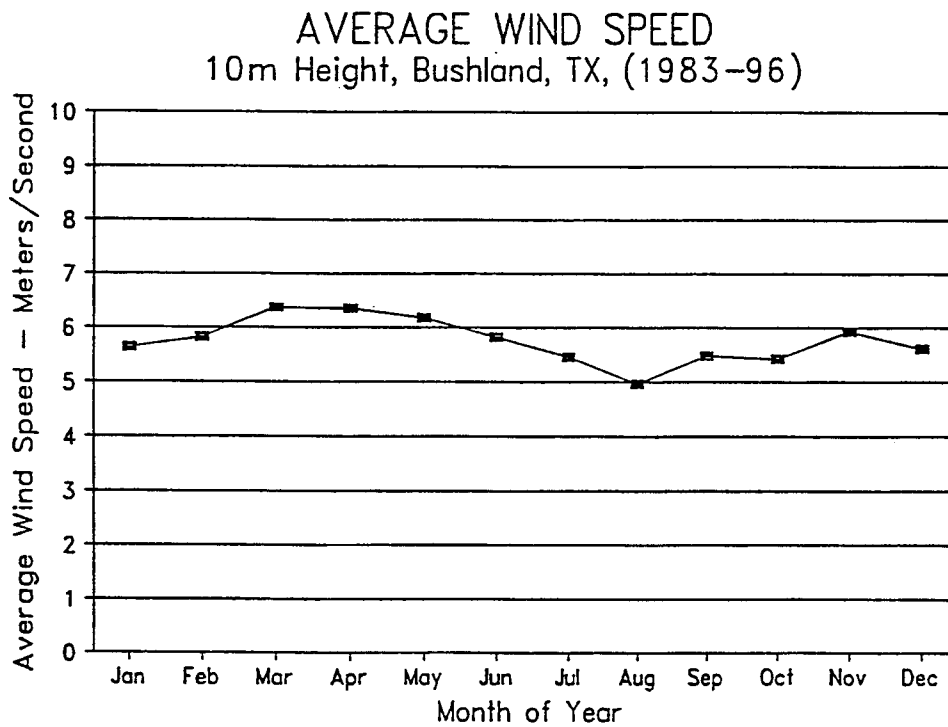


Figure 4. Average monthly wind speed at 10 meter height for Bushland, TX(1983-1996).

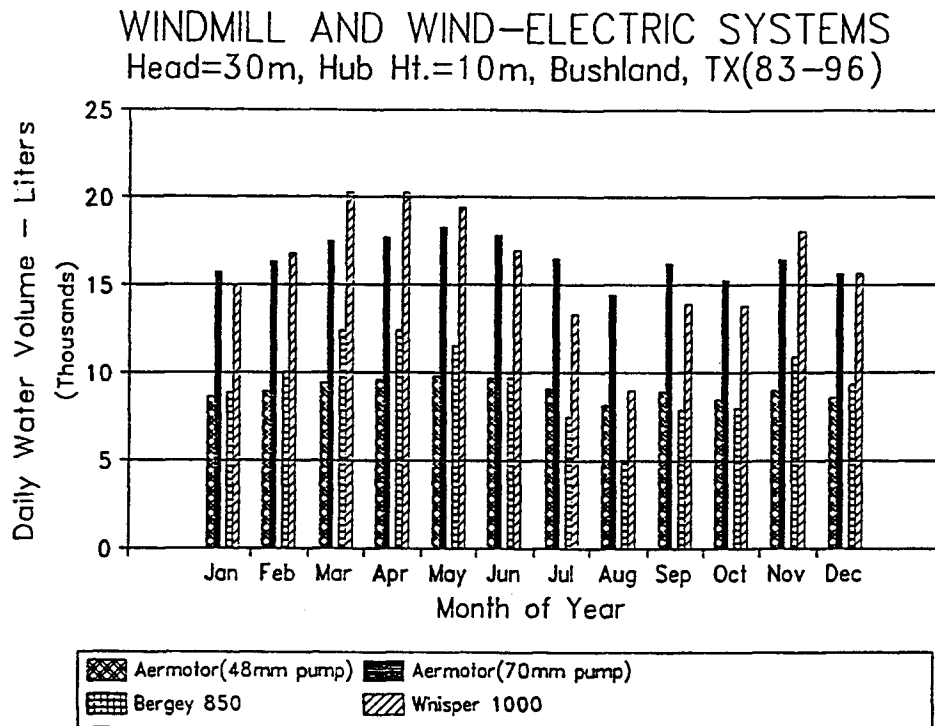


Figure 5. Monthly daily water volume at a 30 meter head and a hub height of 10 meters at Bushland, TX (1983-1996).

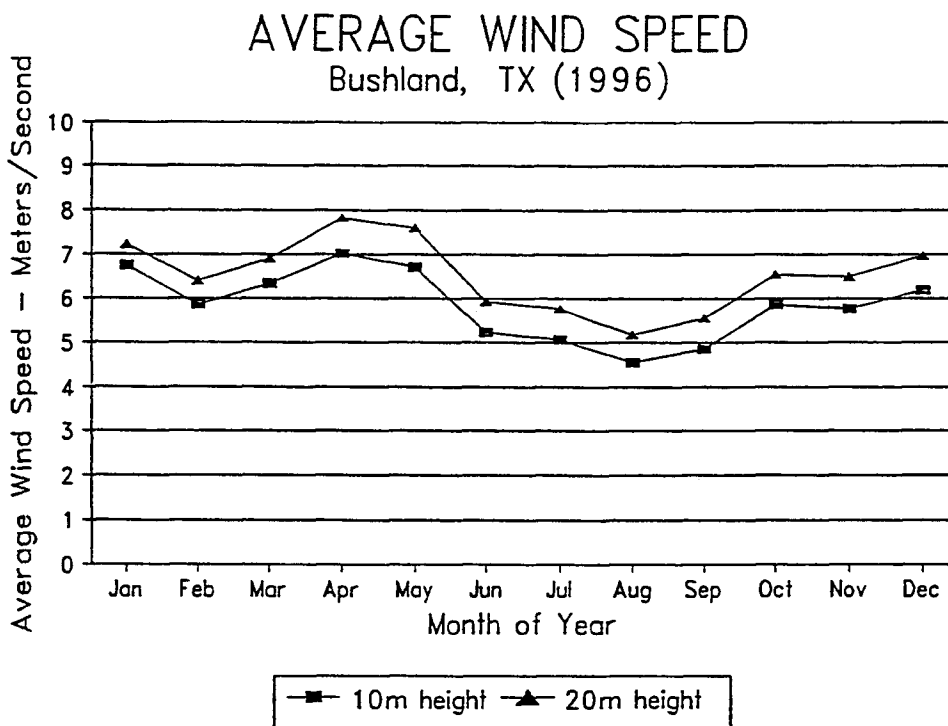


Figure 6. Average monthly wind speeds at 10 and 20 meter heights for Bushland, TX(1996).

AERMOTOR WITH 48mm PUMP AND BERGEY 850
30 Meter Head, Bushland, TX(1996)

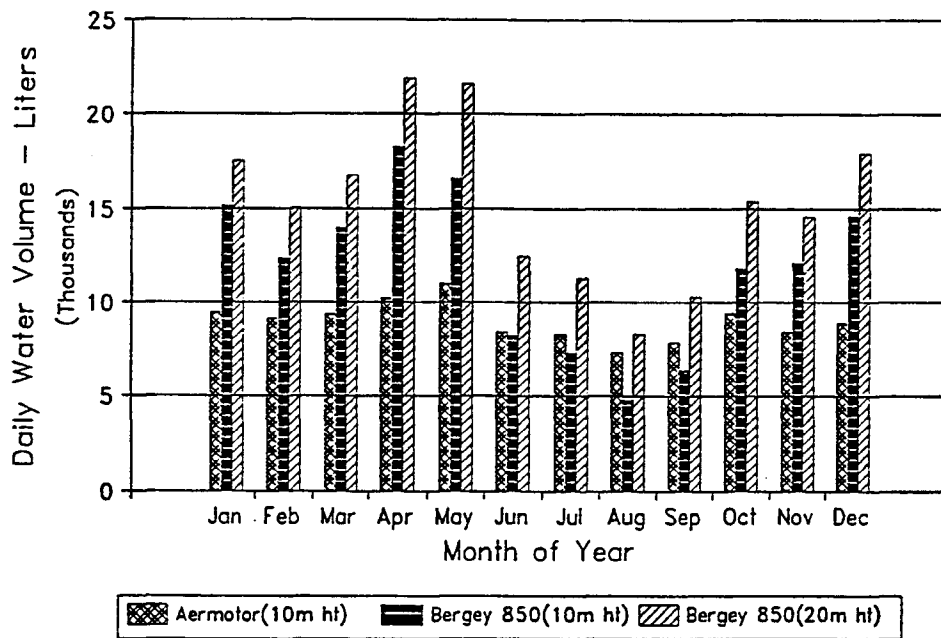


Figure 7. Average monthly daily water volume for Aermotor(48mm pump) at 10 meter height and Bergey 850 at 10 and 20 meter heights.

AERMOTOR WITH 7cm PUMP AND WHISPER 1000
30 Meter Head, Bushland, TX(1996)

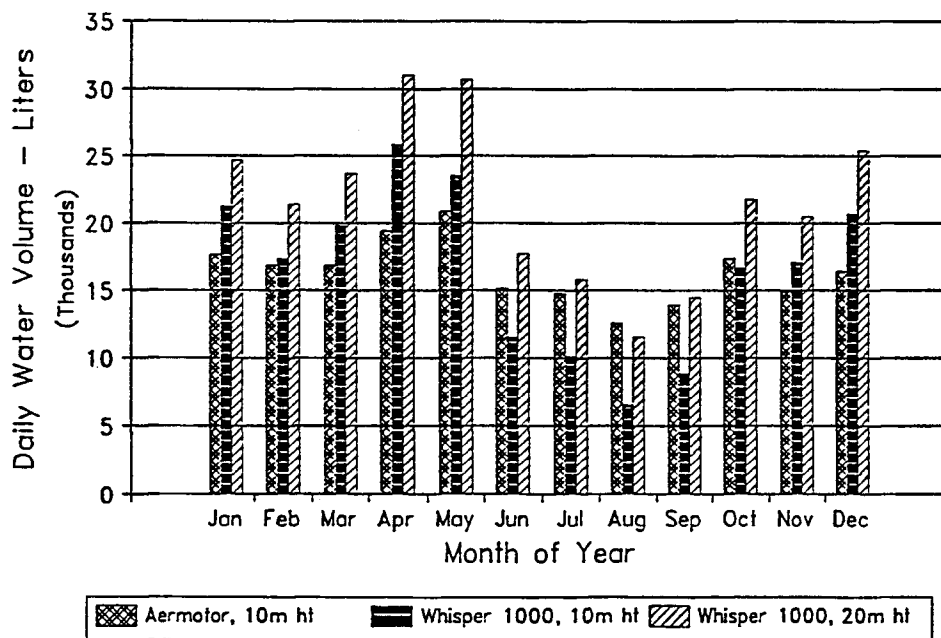


Figure 8. Average monthly daily water volume of Aermotor(7cm pump) at 10 meter height and Whisper 1000 at 10 and 20 meter heights.