TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE CASPER, WYOMING SOIL CONSERVATION SERVICE

Engineering No. 12 (Rev. 1) May 17, 1977

Pressure Relief Valves

Each Wyoming Engineering Standard for Irrigation Pipelines (430 series) require the installation of a surge chamber or pressure relief valve when operating under certain conditions. The standards further state that "Pressure relief valves shall be no smaller than $\frac{1}{2}$ inch nominal size for each diameter inch of the pipeline and shall be set at a maximum of 5 psi above the designed working pressure or static pressure of the pipeline.

A surge chamber, properly designed, is very effective in controlling surges within a pipeline. In most instances, surge chambers are more costly than pressure relief valves. They also have some installation problems due to their size and exposure to vandalism.

Pressure relief valves, properly sized, adjusted, and maintained, will provide adequate protection for irrigation pipelines at a relatively low cost.

Using the minimum criteria stated in the Engineering Standards for sizing and setting, a pressure relief valve may result in an inadequately protected system. This Technical Note will outline a method of determining the size and the pressure setting required to safeguard a pipeline and its appurtenances.

Basically, there are two types of pressure relief valves. The capabilities and installation requirements are different. The designer must specify the type of valve upon which his design was based. The following is a description of the two types of pressure relief valves along with some of their advantages and disadvantages:

1. HYDRAULICALLY OPERATED PRESSURE RELIEF VALVE.

   The main valve body and cover is cast iron. They are either globe or angle type. The valve operation is regulated by a hydraulically operated pilot control. The pilot control is a direct acting spring loaded diaphragm valve. Such valves are manufactured by the Ross Valve Company, Cla Val Company, Rainbird and others.

   The advantages of this type of valve are:

   a. The discharge can be confined in a pipeline and directed to a protected outlet location.

   b. It is fast acting and slow closing, thus reducing surge potential.

   c. It is capable of discharging at a high velocity for intermittent surge relief (up to 45 feet per second).

   d. They are available in a large variation of sizes, ie., 1", $1\frac{1}{4}$", $1\frac{1}{2}$", 2", $2\frac{1}{2}$", 3", 4", 6", 8", 10", 12", 14" and 16". Some manufacturers make larger valves.

The disadvantages of this type of valve are:

a. Depending on water quality and sediment quantity, frequent cleaning of the screens in the pilot control system may be required.

b. Installation requirements are more exacting and therefore more costly than for the spring operated pressure relief valve.

2. SPRING OPERATED PRESSURE RELIEF VALVE

The spring operated pressure relief valve operates, basically, on the same principal as the pilot control portion of the hydraulically operated valve. The pressure setting is controlled by adjusting the tension on a coil spring. The coil spring maintains pressure on a seal. This valve is usually installed on a riser. There are a number of manufacturers that market a spring operated pressure relief valve. Each manufacturer has a number of models of valves. In many instances, the designated diameter of the valve is not the port diameter.

Before approving a valve, the designer should request the test results on the valve in question. The valve must be capable of releasing the designed flow at a pressure differential of 10 psi greater than the valve setting. The Waterman AA-9 valve is capable of meeting this requirement.

The advantages of this type of valve are:

a. Installation is relatively simple at a low cost.

b. Maintenance is relatively trouble free if protected from livestock and machinery.

c. Valves are available in the following sizes: 2", 3", 4" and 6".

The disadvantages of this type of valve are:

a. The valves are not fast acting, therefore, the degree of protection is less.

b. Unless special provisions are provided, the erosion potential is great at the point of discharge, which is usually around or over the pipeline.

c. The velocity through the valve is limited. For Wyoming, the maximum permissible velocity shall be 10 feet per second.

d. There are a number of pressure relief valves on the market that will not provide the necessary protection.

The theory behind the use of a pressure relief valve is to provide a means of releasing a large volume of water at a high velocity which in turn will reduce the pressure within the pipeline.

DESIGN

The procedure for designing, sizing and determining the proper setting for a pressure relief valve can best be explained by the use of examples (attached). The following is a glossary of terms that will be used in the examples.

H.G.L. - Hydraulic Grade Line - A line drawn through a series of points to which water would rise in piezometer tubes attached to a pipe through which water is flowing.

Operating Head - Difference in elevation between the H.G.L. and the centerline of the pipe. May be expressed in feet or pounds per square inch. (1 foot of water = 0.4334 psi or 1 psi = 2.3071 feet of water.)

Head Loss - Reduction in elevation of the H.G.L. resulting from friction or obstructions during the passage of water.

Operating Pressure - Available pressure within the pipeline to discharge flows.

The design and size selection of hydraulically operated pressure relief valves shall be referred to the State Conservation Engineer.

STATE Wyoming		PROJECT Gravity Sprinkler Line		
BY You	DATE	CHECKED BY	DATE	JOB NO.
SUBJECT Sample Problem #1				SHEET 3 OF 4

The 8.01 psi can be offset by the release of water. To determine the volume required the following formula can be used.

$$Q = A\sqrt{\frac{2gH}{1+\Sigma K}}$$

Where: Q = Required flow in cfs
A = Area of pipe line
g = 32.2 (acceleration of gravity)
H = Head to be offset in feet
ΣK = Summation of head losses in the system, above the valve location.

Determine ΣK

Kp = Eng Tech Note #10

A = Eng Tech Note #10

ΣK is not a true head loss - It is a ratio of the smaller pipe to the larger

Item	Kp	Length	A sq ft	A^2	C	K
10" dia Pipe	0.0186	1500	0.5703	0.325	0.145	4.05
10"-8" Reducer	0.09 *	1	0.3672	0.135	0.348	.03
8" dia Pipe	0.0249	1200	0.3672	0.135	0.348	10.39
8"-6" Reducer	0.14 *	1	0.2165	0.047	1.0	.14
6" dia Pipe	0.0354	1300	0.2165	0.047	1.0	46.02
				ΣK		60.63

*Kp for reducers - Table 67 - Kings, Handbook of Hydraulics, 4th Edition (use V = 5'/sec)

C - Ratio $\frac{A^2 \text{(smallest Pipe)}}{A^2 \text{(pipe in question)}} = \frac{A_{6''}^2}{A_{10''}^2}$ & $\frac{A_{6''}^2}{A_{8''}^2}$

$$K = (K_p)(\text{Length})(C)$$

Change 8.01 psi to feet of water

$$\frac{8.01}{0.4334} = 18.48 \text{ ft}$$

STATE Wyoming		PROJECT Gravity Sprinkler System		
BY You	DATE	CHECKED BY	DATE	JOB NO.
SUBJECT Sample Problem 1				SHEET 4 OF 4

$$Q = 0.047\sqrt{\frac{(64.4)(18.48)}{(1 + 60.63)}} = 0.207 \text{ cfs.}$$

A pressure relief valve capable of releasing 0.207 cfs at a velocity of 10 f/sec or less will be required

Area 3" valve = 0.0491 sq ft.

Velocity Through 3" valve = $\frac{0.207}{0.0491} = 4.2$ f/s

A 2" valve would release the required volume at a velocity of 9.5 ft/sec but standards require a minimum of ½ in. dia for every dia. inch of pipeline.

The valve should be set to open at Max. static head + 5 psi =

79.31 + 5 = 84.31 psi use 85 psi

Place valve at or near sta 40+00

STATE	PROJECT			
Wyoming	Gravity Sprinkler Line			
BY	DATE	CHECKED BY	DATE	JOB NO
You				
SUBJECT	Profile of Line - Sample Problem #1			SHEET 1 OF 4

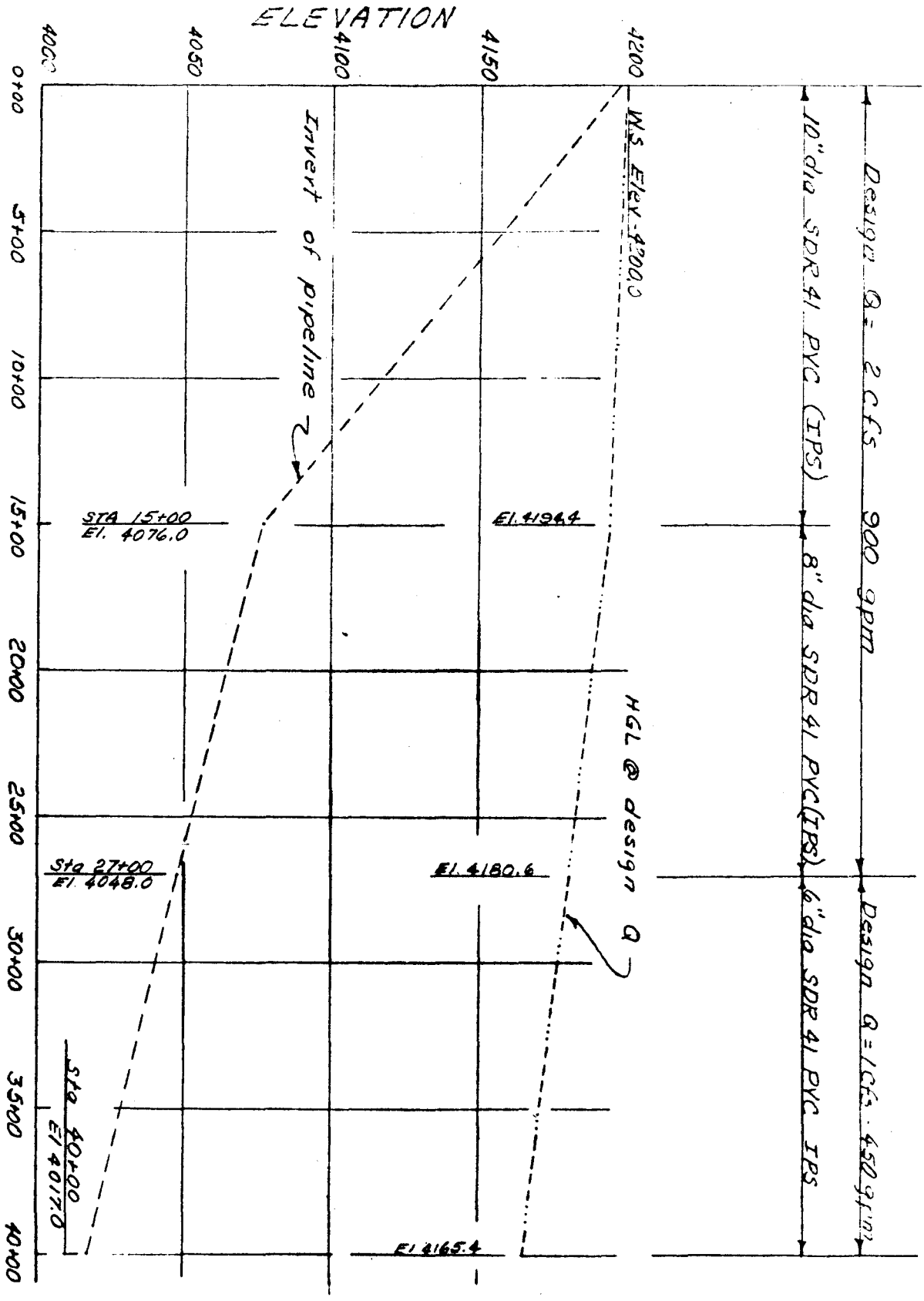

FIGURE 1

STATE W. Yoming		PROJECT Gravity Sprinkler Line		
BY You	DATE	CHECKED BY	DATE	JOB NO.
SUBJECT Sample Problem No 1				SHEET 2 OF 4

Given: Pipe line profile, and design information shown on Figure 1. Assume irrigation risers @ 50 ft interval sta 15+00 to 40+00.

Required: Determine need for pressure relief valve - if needed determine size.

Solution:

1' H_2O = 0.4334 Psi

Maximum static pressure in Line - (4200 - 4017)(0.4334) = 79.31 PSI

Page 3 Eng Tech Note No 10 Rev

Velocity in 6" dia SDR 41 IPS PVC pipe @ 1 cfs = $\frac{1}{0.2165}$ = 4.62 feet/sec

Two field laterals are operating off the 6 inch line, if one is instantly closed A surge pressure would be created. Determine the magnitude of the pressure increase.

Velocity in 6" dia. SDR 41 IPS PVC pipe @ 0.5 cfs = $\frac{0.5}{0.2165}$ = 2.31 feet/sec

Velocity Change = 4.62 - 2.31 = 2.31 ft/sec

Eng Tech Note No 16 Fig 1

Pressure Increase = 28.7 Psi.

Possible pressure = static pressure + surge Pressure

Possible Pressure = 79.31 + 28.7 = 108.01 P.S.I

SDR 41 pipe has a pressure rating of 100 psi, so a pressure Relief Valve will be required. This Valve must be sized to offset the additional 8.01 Psi

STATE Wyoming		PROJECT Pump Sprinkler System		
BY You	DATE	CHECKED BY	DATE	JOB NO.
SUBJECT Sample Problem #2				SHEET 1 OF 5

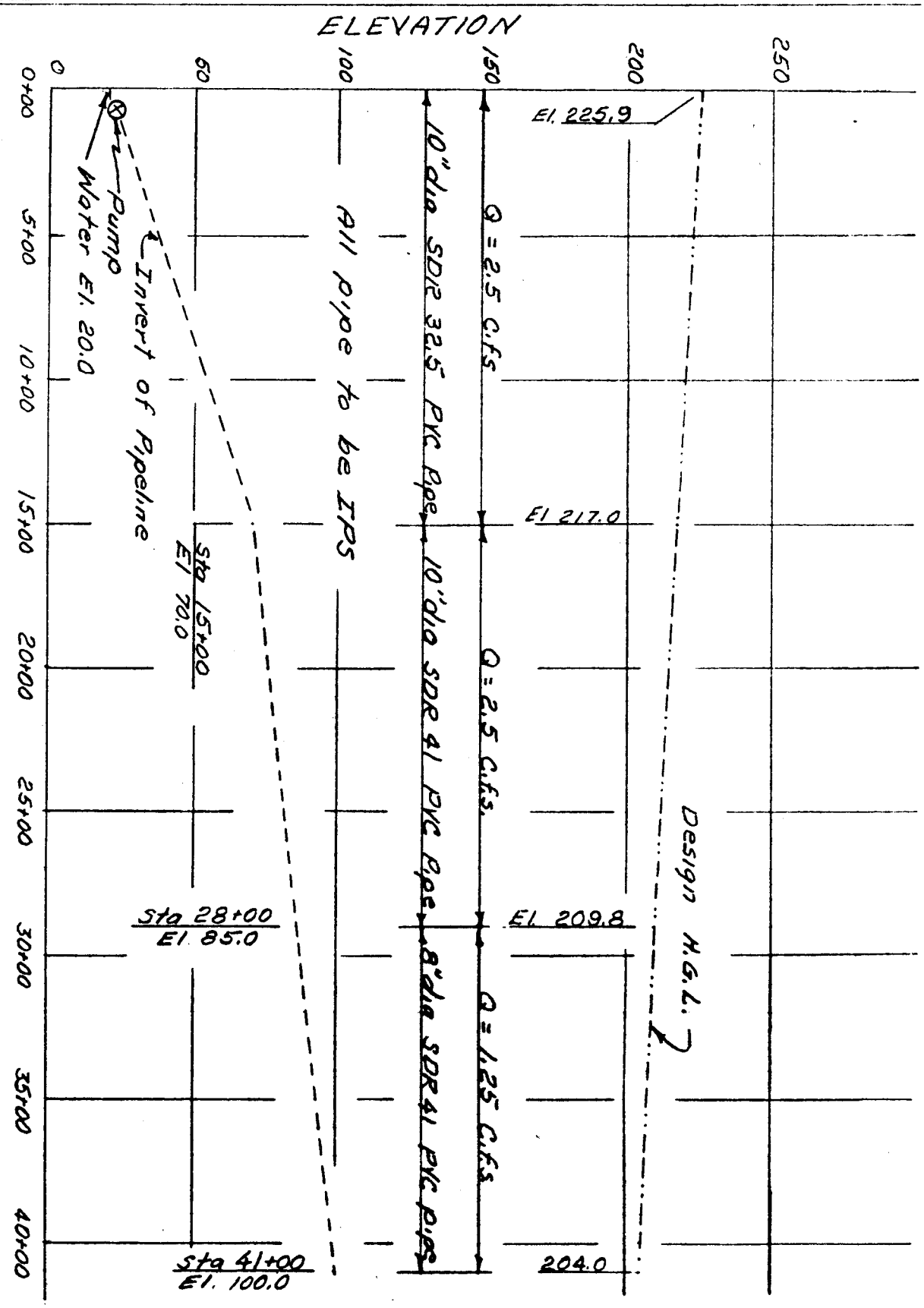

FIGURE 2

STATE Wyoming		PROJECT Pump Sprinkler System		
BY YOU	DATE	CHECKED BY	DATE	JOB NO.
SUBJECT SAMPLE PROBLEM #2				SHEET 2 OF 5

Given: Design information shown on Figure. 2. Irrigation risers will be spaced @ 50' OC from sta 15+00 to 41+00.

Required: Determine need for a pressure Relief Valve. If needed size and locate the Pressure Relief Valve

SOLUTION

Determine Velocities in Pipe line

Areas from Eng. Tech Note 10 Rev

10" SDR 32.5 $= \frac{2.5}{0.5551} = 4.503$ ft/sec

10" SDR 41 $= \frac{2.5}{0.5703} = 4.384$ ft/sec

8" SDR 41 $= \frac{1.25}{0.3672} = 3.404$ ft/sec.

As surge pressures are a result of a velocity change The greatest surge would occur when the pump was stopped. The Chart on page three (3) of Tech. Note Eng. 16 does not indicate the velocities involved. We can use the formula from which the Curves were developed.

$$\text{Pressure Increase} = \frac{(79.22)(\text{Velocity Change})}{\sqrt{SDR - 0.443}}$$

$$\Delta P \text{ - } 10'' \text{ SDR } 32.5 = \frac{(79.22)(4.503)}{\sqrt{32.5 - 0.443}} = 63.00 \text{ Psi}$$

$$\Delta P \text{ - } 10'' \text{ SDR } 41 = \frac{(79.22)(4.384)}{\sqrt{41.0 - 0.443}} = 54.53 \text{ Psi}$$

STATE Wyoming		PROJECT Pump Sprinkler System		
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SUBJECT Sample Problem #2				SHEET 3 OF 5

$$\Delta P - 8'' \text{ SDR } 41 = \frac{(79.22)(3.404)}{\sqrt{41-0.443}} = 42.34$$

From Figure 2. Determine Pressures at design Conditions.

1' H_2O = 0.4333 Psi

0+00 - (225.9 - 20.0)(0.4333) = 89.22 Psi

15+00 - (217.0 - 70.0)(0.4333) = 63.70 Psi

28+00 - (209.8 - 85.0)(0.4333) = 53.73 Psi

41+00 - (204.0 - 100.0)(0.4333) = 45.06 Psi

The Possible pressure at the pump Could be 89.22 + 63.00 = 152.22 Psi which exceeds the 125 psi rating of the pipe. So a pressure relief Valve will be required at the pump.

Determine release Quantity required by following formula.

$$Q = A\sqrt{\frac{2g\,H}{1+\Sigma K}}$$

A = Area Pipe where Valve will be placed

g = 32.2 (acceleration of gravity)

H = Head to be offset = $\frac{(152.22 - 125.00)}{0.4333} = 62.8$

(use 63.0)

ΣK = Summation of head losses in system above the Valve location

Kp & A from Eng. Tech Note #10

Item	Kp	Length	Area	A^2	C	K
10" SDR 32.5	0.018903	1500	0.5551	0.3081	1.0	28.35
10" SDR 41	0.018564	1300	0.5703	0.3252	0.947	22.85
8" SDR 41	0.024899	1300	0.3672	0.1348	2.285	73.96

ΣK = 125.16

STATE Wyoming		PROJECT Pump Sprinkler System		
BY You	DATE	CHECKED BY	DATE	JOB NO.
SUBJECT Sample Problem - #2				SHEET 4 OF 5

Note: In determining the ΣK Note a "C" value of 1.0 is always assigned to the pipe diameter at the location of the pressure relief valve. The other diameters are related to it.

Kp for reducers are not included in the example. They are so small that normally they could be omitted.

$$C = \text{Ratio} \quad \frac{A^2_{10''\,SDR\,32.5}}{A^2_{10''\,SDR\,41}} \quad \& \quad \frac{A^2_{10\,SDR\,32.5}}{A^2_8}$$

$$K = (K_p)(\text{Length})(C)$$

$$Q = A\sqrt{\frac{2g\,H}{1+\Sigma K}}$$

$$Q = 0.5551\sqrt{\frac{(64.4)(63.0)}{1+125.16}} = 3.15 \text{ c.f.s.}$$

The 3.15 cfs is greater than the pump discharge requirements so design on the basis of pump discharge requirement (2.5 c.f.s).

A 6" pressure relief valve will discharge $Q = AV$

$$A = .1963\,\square', \; V = 10 \text{ ft/sec (Max)}$$

$$Q = 1.963 \text{ c.f.s.}$$

A 4" Pressure relief valve will discharge:

$$A = 0.0873\,\square' \quad V = 10 \text{ ft/sec (max)}$$

$$Q = (0.0873)(10) = 0.873 \text{ cfs}$$

$$\text{Total } Q = 1.963 + 0.873 = 2.836 \text{ cfs}$$

STATE WYOMING		PROJECT Pump		
BY You	DATE	CHECKED BY	DATE	JOB NO.
SUBJECT Sample Problem #2				SHEET 5 OF 5

One six (6) inch and one four (4) inch Pressure Relief Valve would be required (Spring Operated Valves). One four (4) inch hydraulically Controlled Valve would be desirable.

Locate Valve ahead of Check Valve and set to operate at

89.22 (operating Pressure) + 5 = 95 P.S.I.

It would be desirable to specify a a Check Valve such as a Non Slam or Silent Check Valve. Avoid the use of Swing Check Valves.

STATE WYOMING		PROJECT XYZ Pump Project		
BY You	DATE	CHECKED BY	DATE	JOB NO.
SUBJECT Sample Problem 3				SHEET 1 OF 5

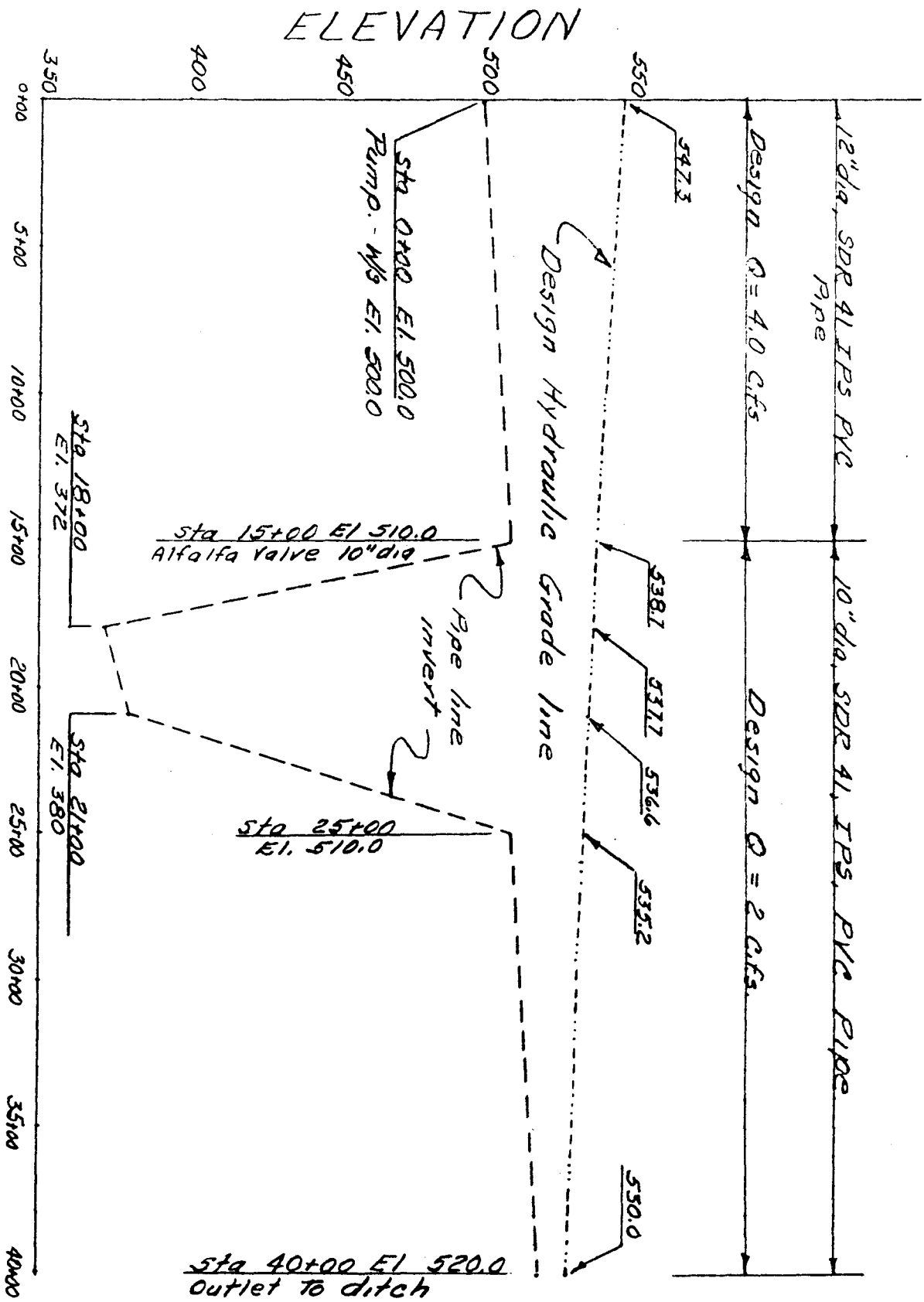

FIGURE 3

STATE Wyoming		PROJECT X Y Z PUMP PROJECT		
BY You	DATE	CHECKED BY	DATE	JOB NO.
SUBJECT Sample Problem 3				SHEET 2 OF 5

Given: Basic Hydraulic design as shown on Figure 3.

Required: Determine need for Pressure Relief Valve or Valves - locate and determine pressure Setting for Valves.

SOLUTION

Determine design operating pressure in Line:

Operating Pressure = (HGL. El. - Pipe El)(0.4333)

Sta 0+00 = (547.3 - 500.0)(0.4333) = 20.5 psi
Sta 15+00 = (538.7 - 510.0)(0.4333) = 12.4 Psi
Sta 18+00 = (537.7 - 372.0)(0.4333) = 71.8 Psi
Sta 21+00 = (536.6 - 380.0)(0.4333) = 67.9 Psi
Sta 25+00 = (535.2 - 510.0)(0.4333) = 10.9 Psi
Sta 40+00 = (530.0 - 520.0)(0.4333) = 4.3 Psi

Note. Operating pressures should be figure to ℄ of pipe. When working with small diameter pipe and rounding values - Compute pressures to invert.

$Q = AV$
$V = \frac{Q}{A}$
A from Eng Tech Note 10 (Rev.)

Design Velocity 12" pipe $= \frac{4}{0.8022} = 4.98$ ft/sec

10" pipe $= \frac{2}{0.5703} = 3.50$ ft/sec

There are two obvious Conditions That Could Cause damaging Surges:

1. Pump Could stop suddenly With power Outage.

2. Rapid Closure of Alfalfa Valve at Sta 15+00.

STATE Wyoming	PROJECT XYZ Pump Project		
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SUBJECT Sample Problem 3			SHEET 3 OF 5

If the system was operating at design capacity and power was turned off the change in velocity would be 4.98 ft/sec.

The chart in Eng. Tech. Note 16 does note cover this velocity change.

Use Formula $\Delta P = \frac{79.22(\text{Change } V)}{\sqrt{SDR - 0.443}}$

Surge Pressure $\Delta P = \frac{(79.22)(4.98)}{\sqrt{41 - 0.443}} = 61.95$ P.S.I.

This could result in a pressure at the pump of 20.5 + 61.95 = 82.45 p.s.i.

The pressure would be less than the pressure rating of the pipe. The 10" Alfalfa valve should be open which would relieve the surge prior to it entering the 10" dia pipe. No special precautions would be required for a power outage.

In the event the valve at station 15+00 was rapidly opened or closed with the pump operating at design capacity, the pump efficiency would be greatly affected. In all probability it would not be capable of delivering the full 4 c.f.s.

In order for the 10" dia. pipe to transport 4 cfs the velocity must be:

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

$$V = \frac{4}{.5703} = 7.01 \text{ f.s.}$$

This would result in a velocity change of 7.01 − 3.50 = 3.51 ft/sec.

STATE Wyoming	PROJECT XYZ PUMP PROJECT		
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SUBJECT SAMPLE PROBLEM 3			SHEET 4 OF 5

The change of velocity could result in a surge pressure 43.2 Psi (Figure 1 Eng. Tech Note 16).

Surges, when created, travel at sonic velocities and develop upstream from the source. In this instance the shock wave would travel to the pump reverse and proceed to the outlet.

Without the pump capability curves it is impossible to determine the actual conditions that might develope as a result of the rapid valve closure. Design on basis of a pressure rise of 43.2 p.s.i.

Possible pressures in the line:

Sta 0+00	20.5 + 43.2	= 63.2	Psi
Sta 15+00	12.4 + 43.2	= 55.6	Psi
Sta 18+00	71.8 + 43.2	= 115.0	Psi
Sta 21+00	67.9 + 43.2	= 111.1	Psi
Sta 25+00	10.9 + 43.2	= 54.1	Psi
Sta 40+00	4.33 + 43.2	= 47.5	Psi

The possible pressures across the low portion of the profile will exceed the pressure rating of the pipe.

There are two possible corrective measures that could be taken:

1. Specify SDR 32.5 (125 psi pipe) for installation across the low portion in the profile

2. Install a pressure relief valve above the Alfalfa Valve

utilizing the stronger pipe would be more economical.

STATE Wyoming	PROJECT XYZ Pump Project		
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SUBJECT Sample Problem 3			SHEET 5 OF 5

It would be advisable to install a 2 or 3 inch diameter pressure relief valve upstream (2-3 feet) from the alfalfa valve. Set the Pressure Relief Valve to open at 12.4 + 5 = 17.4 use 18 p.s.i.

Its operation would serve as a reminder to open or close the Alfalfa Valve slowly. It wouldn't provide much protection to the line.