TECHNICAL NOTES

USDA-Natural Resources Conservation Service
Boise, Idaho

ENGINEERING TECHNICAL NOTE NO. 08 July 30, 1993

DETERMINING THE SIZE OF THE MOST COST-EFFECTIVE IN-LINE VALVE FOR PIPELINES PRESSURIZED BY ELECTRIC POWER

The question is often asked as to what size of in-line valves SCS recommends for any given pipe size in a pressurized irrigation system receiving water from a pump. While most valve manufacturers say that their valves will operate satisfactorily with velocities up to 15 feet per second or more, this does not justify sizing the valve to accommodate those velocities. To determine the most practical size valve to install, one must consider the costs of ownership and operation that the valve adds to the system.

We generally recommend that the valve diameter should be the same as the pipe diameter for valves under about 12 inches in diameter. However, there may be cases where a cost savings can be obtained by using a valve that is smaller than the pipe diameter for these sizes. Conversely, there may be larger sizes where it is more economical to use the same size valve. Before approving a smaller valve than the main pipe diameter, the designer should consider the effect on the rest of the system. To accurately determine whether a cost saving can be obtained requires an analysis of all annual costs associated with each valve size under consideration. This usually amounts to a simple amortization of the initial costs of the valve and appurtenances plus the increase in annual power costs caused by the valve and appurtenances.

The annual cost of the valve and appurtenances is a matter of determining the installed cost of the valve and cones, estimating a life span and a typical interest rate, and multiplying the costs by an appropriate amortization factor. A typical amortization table for a 20-year life is shown below.

Interest Rate (%)	8	10	12	14	16
Factor	.1019	.1175	.1339	.1510	.1687

A significant increase in power costs may occur as a result of the increase in friction losses through the valves and reducing and expanding cones. Compensation for these losses must be made by increasing horsepower in the pump.

Using the head loss coefficient, K_n, to modify the velocity head, $V^2/2g$, for both the cones and the valve gives a procedure for finding the head loss caused by the valve assembly that is consistent with that used on ID-2l0—l57A and B, “Irrigation Pipeline Design Sheet”. Unless specific information is available, the following values for K_n are recommended.

TYPE OF APPURTENANCE	K_n
Gate Valve, Wide Open	0.2
Butterfly Valve, Wide Open	0.45
Contracting Cone, Steel	0.15
Expanding Cone, Steel	0.25

The velocity to be used in computing friction losses for each of these appurtenances is the velocity through the valve; not the velocity in the pipeline.

There is one aspect of power costs that is often overlooked when calculating the cost of a valve. When a valve is in a lateral or a sub-main that carries only a portion of the total flow being pumped, the increase in head may need to be added to the cost of pumping the total flow. For example, if a pump outflow is 1,000 gpm and the valve being considered is in a sub-main carrying 500 gpm, then the increase in annual power cost would be double (1,000/500) what it would be for the flow in the sub-main only, if the required increase in head for the valve will add directly to the head on the pump.

On the other hand, if the sub-main is not the critical line dictating the horsepower for the pump, then the head loss through the valve may not affect the operation of the system. In this case, the main consideration is the cost of the valve and the limiting velocities to prevent damage to the valve and other appurtenances. One must be careful not to reduce the valve size too much so that the extra available head is exceeded. As a rule of good practice, it is not recommended that the valve be more than two sizes smaller than the pipe under any circumstances.

The attached tables are included to show the average cost relationship for the typical valve sizes used in SCS work. They illustrate the procedures to be used in determining the most cost-effective valve sizes to be used in typical irrigation pipelines. The flow rates, Q, shown in column 3, are the flows with a velocity of 5 feet per second in PVC pipe rated at 100 psi. Valve prices are based on prices found for geared butterfly and gate valves shown in the 1993 Waterman Catalog. Amortization factor for valve and cone prices is 0.1339 based on a 20-year life and 12% interest rates.

The annual power costs are based on an operating time, T, of 2,000 hours, a pump efficiency of 75% and a power rate, R, of $0.04/KWH applied to the following equation:

$$\text{Annual Power Cost} = \frac{(Q,\text{gpm})\,(T)\,(R)\,(\text{Head Loss})}{(\text{Efficiency})\,(5300)}$$

The tables show that, for the conditions described, a full size valve is the most cost-effective from 6 inches through 12 inches for butterfly valves and through 14 inches for gate valves. For larger pipe sizes, a reduction of one size or more can be considered.

If valves cost substantially more or less than shown on the tables, and/or power costs vary greatly from that shown, some changes may be found in the general recommendations. However, the evidence shows that we should continue to recommend full size valves for most of the work done in SCS. A cost analysis similar to that shown should be done to justify valve sizes other than recommended.

ECONOMICS OF VALVE SIZE SELECTION IN PIPELINES PRESURIZED BY ELECTRIC POWER

BUTTERFLY VALVES

Pipe Size (In)	Valve Size (In)	Pipe Q @ 5 fps (gpm)	Valve Initial Cost ($)	Cones Initial Cost ($)	Total Initial Cost ($)	Annual Fixed Cost ($/Yr)	Velocity in Valve (Fps)	Velocity Head in Valve (Ft)	Valve "K"	Cone 1 "K"	Cone 2 "K"	Total "K"	Total Head Loss (Ft)	Annual Power Cost ($/Yr)	Total Annual Cost ($/Yr)
6.00	6.00	418.00	303.00	0.00	303.00	40.57	4.73	0.35	0.45	0.00	0.00	0.45	0.16	1.32	41.89
	4.00	418.00	278.00	50.00	328.00	43.92	10.65	1.76	0.45	0.15	0.25	0.85	1.50	12.58	56.50
8.00	8.00	740.00	368.00	0.00	368.00	49.28	4.71	0.34	0.45	0.00	0.00	0.45	0.16	2.31	51.58
	6.00	740.00	303.00	50.00	353.00	47.27	8.38	1.09	0.45	0.15	0.25	0.85	0.93	13.78	61.05
	4.00	740.00	278.00	50.00	328.00	43.92	18.85	5.52	0.45	0.15	0.25	0.85	4.69	69.78	113.70
10.00	10.00	1154.00	439.00	0.00	439.00	58.78	4.70	0.34	0.45	0.00	0.00	0.45	0.15	3.59	62.37
	8.00	1154.00	368.00	50.00	418.00	55.97	7.35	0.84	0.45	0.15	0.25	0.85	0.71	16.54	72.51
	6.00	1154.00	303.00	50.00	353.00	47.27	13.07	2.65	0.45	0.15	0.25	0.85	2.25	52.28	99.54
12.00	12.00	1663.00	574.00	0.00	574.00	76.86	4.71	0.34	0.45	0.00	0.00	0.45	0.15	5.18	82.04
	10.00	1663.00	439.00	70.00	509.00	68.16	6.78	0.71	0.45	0.15	0.25	0.85	0.61	20.28	88.43
	8.00	1663.00	368.00	70.00	438.00	58.65	10.59	1.74	0.45	0.15	0.25	0.85	1.48	49.50	108.15
	6.00	1663.00	303.00	70.00	373.00	49.94	18.83	5.51	0.45	0.15	0.25	0.85	4.68	156.44	206.39
14.00	14.00	2264.00	1270.00	0.00	1270.00	170.05	4.71	0.34	0.45	0.00	0.00	0.45	0.15	7.05	177.10
	12.00	2264.00	574.00	80.00	654.00	87.57	6.41	0.64	0.45	0.15	0.25	0.85	0.54	24.67	112.24
	10.00	2264.00	439.00	80.00	519.00	69.49	9.23	1.32	0.45	0.15	0.25	0.85	1.12	51.16	120.65
	8.00	2264.00	368.00	80.00	448.00	59.99	14.42	3.23	0.45	0.15	0.25	0.85	2.74	124.90	184.89
16.00	16.00	2961.00	1759.00	0.00	1759.00	235.53	4.71	0.35	0.45	0.00	0.00	0.45	0.16	9.25	244.78
	14.00	2961.00	1270.00	90.00	1360.00	182.10	6.16	0.59	0.45	0.15	0.25	0.85	0.50	29.79	211.90
	12.00	2961.00	574.00	90.00	664.00	88.91	8.38	1.09	0.45	0.15	0.25	0.85	0.93	55.19	144.10
	10.00	2961.00	439.00	90.00	529.00	70.83	12.07	2.26	0.45	0.15	0.25	0.85	1.92	114.45	185.28

KDL 7/93

ECONOMICS OF VALVE SIZE SELECTION IN PIPELINES PRESURIZED BY ELECTRIC POWER

GATE VALVES

Pipe Size (In)	Valve Size (In)	Pipe Q @ 5 fps (gpm)	Valve Initial Cost ($)	Cones Initial Cost ($)	Total Initial Cost ($)	Annual Fixed Cost ($/Yr)	Velocity in Valve (Fps)	Velocity Head in Valve (Ft)	Valve "K"	Cone 1 "K"	Cone 2 "K"	Total "K"	Total Head Loss (Ft)	Annual Power Cost ($/Yr)	Total Annual Cost ($/Yr)
6.00	6.00	418.00	547.00	0.00	547.00	73.24	4.73	0.35	0.20	0.00	0.00	0.20	0.07	0.58	73.82
	4.00	418.00	522.00	50.00	572.00	76.59	10.65	1.76	0.20	0.15	0.25	0.60	1.06	8.88	85.47
8.00	8.00	740.00	562.00	0.00	562.00	75.25	4.71	0.34	0.20	0.00	0.00	0.20	0.07	1.03	76.28
	6.00	740.00	547.00	50.00	597.00	79.94	8.38	1.09	0.20	0.15	0.25	0.60	0.65	9.73	89.67
	4.00	740.00	522.00	50.00	572.00	76.59	18.85	5.52	0.20	0.15	0.25	0.60	3.31	49.26	125.85
10.00	10.00	1154.00	688.00	0.00	688.00	92.12	4.70	0.34	0.20	0.00	0.00	0.20	0.07	1.59	93.72
	8.00	1154.00	562.00	50.00	612.00	81.95	7.35	0.84	0.20	0.15	0.25	0.60	0.50	11.68	93.62
	6.00	1154.00	547.00	50.00	597.00	79.94	13.07	2.65	0.20	0.15	0.25	0.60	1.59	36.90	116.84
12.00	12.00	1663.00	815.00	0.00	815.00	109.13	4.71	0.34	0.20	0.00	0.00	0.20	0.07	2.30	111.43
	10.00	1663.00	688.00	70.00	758.00	101.50	6.78	0.71	0.20	0.15	0.25	0.60	0.43	14.31	115.81
	8.00	1663.00	562.00	70.00	632.00	84.62	10.59	1.74	0.20	0.15	0.25	0.60	1.05	34.94	119.57
	6.00	1663.00	547.00	70.00	617.00	82.62	18.83	5.51	0.20	0.15	0.25	0.60	3.30	110.43	193.05
14.00	14.00	2264.00	919.00	0.00	919.00	123.05	4.71	0.34	0.20	0.00	0.00	0.20	0.07	3.13	126.19
	12.00	2264.00	815.00	80.00	895.00	119.84	6.41	0.64	0.20	0.15	0.25	0.60	0.38	17.42	137.26
	10.00	2264.00	688.00	80.00	768.00	102.84	9.23	1.32	0.20	0.15	0.25	0.60	0.79	36.11	138.95
	8.00	2264.00	562.00	80.00	642.00	85.96	14.42	3.23	0.20	0.15	0.25	0.60	1.94	88.16	174.13
16.00	16.00	2961.00	1230.00	0.00	1230.00	164.70	4.71	0.35	0.20	0.00	0.00	0.20	0.07	4.11	168.81
	14.00	2961.00	919.00	90.00	1009.00	135.11	6.16	0.59	0.20	0.15	0.25	0.60	0.35	21.03	156.13
	12.00	2961.00	815.00	90.00	905.00	121.18	8.38	1.09	0.20	0.15	0.25	0.60	0.65	38.96	160.14
	10.00	2961.00	688.00	90.00	778.00	104.17	12.07	2.26	0.20	0.15	0.25	0.60	1.36	80.79	184.96

KDL 7/93