A Study of Operating Efficiencies Comparing Aluminum Pipe Systems to Certa-Set PVC Irrigation Piping

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INTRODUCTION

In the design of all irrigation systems, consideration must be given to the system efficiency. The efficiency is defined as the ratio of water pumped to the water effectively applied to the crop. In determining a best estimate of efficiency, consideration must be given to the following losses:

1. Field runoff.
2. Aerial evaporation and drift.
3. Application pattern losses to seepage below the root zone.
4. Leakage from system components while in operation.
   - Sprinkler bearings
   - Pipe couplers
   - Air vents and valves
   - Pipeline imperfections
5. Drainage from system components when not operating thus requiring a refilling of the system on each start up.
6. Differential application from sprinklers caused by variation in operating pressure along the mainline and laterals.

For convenience, this paper will group items 1, 2, and 3 and term them as “application losses.” Items 4, 5, and 6 will be grouped and termed “operational losses.”

Over the years, application losses, in particular pattern losses, have been the subject of a major amount of study with special coefficients proposed and worked into design calculations. By contrast, there is very little data in the literature on studies of operational losses. This is partly accounted for by the fact that the dominant system utilized portable aluminum pipe with no alternatives that might give improved performance. In addition, the effect of varying system operating pressure has also been largely ignored and accepted as a consequence of limited system component options. The availability of pressure-compensated sprinkler components are an exception. This pressure variation is manifested as lower pressures at the distal end of the

laterals as a result of frictional headloss. Recognition of this pressure variation has been enshrined in the following rule that presumably represents good design practice.

- Limiting frictional headloss to not over 20% will limit application rate variation to not over 10%.

If the system operation focuses on the health of the "driest plant," then excess water is being applied to all sprinklers operating at higher pressures. In addition to wasting water, the surplus applied can have a negative impact on the crop. As we develop ever more refined designs, in an attempt to save water and energy, the impact of these accepted "rules of thumb" should be investigated. The availability of the "Certa-Set PVC Irrigation Pipe" by Certainteed Corp. when compared to standard portable aluminum pipe provides one such opportunity. This study then determines the operational losses for a commonly used configuration of portable solid set system using both aluminum and PVC piping components. The study addresses only the determination of operational losses and does not address any other factors involved in a system selection decision such as first cost, probability, application losses, system maintenance, corrosion, etc.

The study was funded by the Certainteed Corp. The work was conducted during the period from January through March, 2003.

RESULTS: PORTABLE ALUMINUM PIPE SYSTEM

Shown in Table #1 are the results from six test runs with an aluminum pipe system. The system consisted of 1200 ft. of 8 in. mainline with five 3 in. by 1140 ft. laterals attached at the distal end. The sprinklers were spaced 30 ft. X 50 ft. The runs simulate irrigation events with gross applications ranging from 1.2 to 1.7 inches. The net volume shown in Table #1is calculated knowing the pressure at the end of the laterals, the number of sprinklers operating, and the net runtime when the sprinklers have reached the correct operating pressure. The gross volume is determined from the 8-in. mainline flow meter and the net runtime. The operating efficiency is the ratio of net to gross volume. The resulting average operating efficiency is 86.3%. These results show the losses to be 13.7% from the combined effects of leakage when the system is operating, drainage when it is shut down and variations in sprinkler operating pressure.

RESULTS: CERTA-SET PVC IRRIGATION PIPING

Shown in Table #2 are the results from six test runs with the Certa-Set irrigation pipe system. In this case the runs simulate irrigation events with gross applications ranging from 0.4 to 1.7 inches. The PVC pipe system was laid out in a manner identical to the aluminum pipe system except the sprinkler pipe spacing was 40 ft. X 40 ft. In this case, the average operating efficiency was 94.8% which shows the losses to be 5.2%. After the initial filling of the system, it stayed full between runs even during a weekend shut down. This suggests that the water loss is limited to the variations in sprinkler operating pressure. It follows then that this value could be minimized by reducing the headloss in the laterals or the use of pressure-compensated sprinkler components.

For the conditions as defined by this study, direct comparison of an aluminum pipe system versus the Certa-Set PVC irrigation piping system, operational losses have been reduced on average from 13.7% to 5.2% or by 62 %.

Table #1 – Portable Aluminum Pipe System

Test (#)	Average Pressure (psi)	Average Sprinkler Flow Rate (gpm)	Run Time (min)	Net Volume (gallons)	Gross Volume (gallons)	Op. Efficiency (%)	Gross App. (in.)
1 (1)	53.6	2.44	450	208,449	244,078	85.4	1.47
2 (2)	53.9	2.45	534	246,865	283,764	87.0	1.74
3 (3)	55.0	2.47	514	233,659	271,187	86.2	1.70
4 (4)	54.1	2.45	500	231,620	264,345	87.6	1.64
5 (5)	54.0	2.45	360	167,512	195,660	85.6	1.18
6 (6)	53.2	2.43	397	179,872	209,541	85.8	1.29
Total			**45.9 hrs.**	**1,267,977**	**1,468,575**		**9.02 in.**
Average	**54.0**	**2.45**				**86.3**	**1.503 in.**

(1) system drained overnight
(2) system flooded at start of test
(3) system drained overnight (mainline end plug removed)
(4) system drained overnight
(5) system drained overnight
(6) system drained overnight

Table #2 – Certa-Set PVC Irrigation Piping

Test (#)	Average Pressure (psi)	Average Sprinkler Flow Rate (gpm)	Run Time (min)	Net Volume (gallons)	Gross Volume (gallons)	Op. Efficiency (%)	Gross App. (in.)
1	52.0	3.19	125	55,045	58,323	94.4	0.39
2	56.0	3.31	189	90,112	97,032	92.9	0.63
3	54.5	3.27	369	162,696	171,712	94.7	1.21
4	53.5	3.23	469	212,082	219,478	96.6	1.52
5	53.7	3.24	500	233,428	248,282	94.0	1.63
6	55.3	3.29	500	236,880	249,520	94.9	1.65
Total			**35.9 hrs.**	**990,243**	**1,044,247**		**7.03 in.**
Average	**54.2**	**3.26**				**94.8**	**1.17 in.**

(1) system observed to be flooded at the beginning of each test.

SITE INSTRUMENTATION PROCEDURE

The site was on the California State University, Fresno Farm Laboratory, field 13 with a gross area of approximately 25 acres. The mainline and lateral layout was meant to be typical of commercial systems. The area was not cropped. Observations on the flooded condition of the PVC plastic pipe system suggested that the field topography was generally flat. Figure #1 and Figure #2 show the aluminum pipe and the PVC piping systems in operation, respectively. Water was supplied to the system using a portable diesel-powered pump as shown in Figure #3. The pump drew water from a standpipe on the edge of a large reservoir. The flow meter is a McCrometer 8 in. saddle meter model M0300. The flow meter calibration was checked against the master meter in the CIT laboratory.

Table #3 - 8 in. Portable Flow Meter Accuracy Test

Run No.	Flow Rate Read (1)	Test Run Time	Laboratory Flow Meter		8-in. Portable Meter		Error (2)
			Volume	Flow Rate	Volume	Flow Rate	
	(gpm)	(min)	(gallons)	(gpm)	(gallons)	(gpm)	%
1	400	5	2025	405	1955	391	-3.5
2	485	5	2385	477	2444	489	+2.5
3	690	5	3410	682	3585	717	+5.1
4	970	5	4870	974	4887	977	+0.35

(1) Instantaneous Reading

(2) All tests run between 460 and 545 gpm suggesting that the 8 in. portable meter was over-stating the flow rate by 2 to 3%. The 8-in. portable meter installation was the same for both the aluminum and plastic pipe systems.

The portable aluminum pipe system was rented from a local vendor and thought to be representative of commercial offerings. The Certa-set PVC irrigation pipe system was supplied by Golden State Irrigation Services. All components in both systems were taken from existing supplies of used equipment except for the Certa-Set sled coupling which was new.

The system operating pressure was measured on a riser at the high end of the lateral as shown in Figure #4. The pressure tap was designed to recommend good practice standards. The same tap was used for the sprinkler calibration tests. The gauge is an Ascroft test gauge with a 4½" face and a Grade 3A with an accuracy of ¼" of full scale. It was checked before and after test sequences and found to agree with a dead weight tester to within ¼ psi. During the test run the pressure was recorded and a Dickson Model PW4 Recorder. These chart records were confirmed by periodic reading of the pressure gauge and stop watch manual records of run times.

The sprinkler flow rates shown in Tables #1 and #2 are the results of laboratory calibrations using representative sprinklers. The sprinkler flow rate versus pressure calibrations of four sprinklers were analyzed by a curve fit routine and gave the following results.

- Aluminum Pipe System (½-inch impact sprinklers – full circle, 7/64-in. nozzle)
  $q = 0.286 (P)^{0.538}$, gpm P, pressure, psi
  $R^2 = 0.973$

- Certa-Set PVC Irrigation Pipe System Sprinkler (Nelson model Red WR15, Wind Fighter)
  $q = 0.446 (P)^{0.498}$, gpm P, pressure, psi
  $R^2 = 0.998$

The net volume shown in Tables #1 and #2 are calculated by the following expression:

Net volume = (average sprinkler flow rate) (run time) (no. of operating sprinklers)

Note: The number of operating sprinklers was 190 and 145 for the aluminum pipe system and the PVC pipe system respectively corrected for plugged sprinklers.

The gross volume shown in Tables #1 and #2 were taken directly from the flow meter readings. The operating efficiency is calculated by dividing the net by the gross volume. The gross application is calculated using the following formula:

$$i \text{ (gross application)} = \left[\frac{q\ (96.3)}{S_1 \times S_2}\right] \text{ (run time, hrs.), in.}$$

S_1 and S_2 are the sprinkler spacings. They were 30 ft. by 50 ft. for the aluminum pipe system and 40 ft. by 40 ft. for the PVC irrigation piping system.

Figure 1 Portable aluminum pipe solid set system in operation.

Figure 2 Certa-Set PVC irrigation piping portable solid set system in operation.

Figure 3 Portable pumping plant. Note the water meter is visible in the 8 inch mainline just outside of the security fence.

Figure 4 Pressure gauge mounted on a riser at the end of the lateral.

Figure 5 Recording pressure gauge located on the second from the end sprinkler.