PVC Pressure Pipe Endures Over Ten Million Cycles

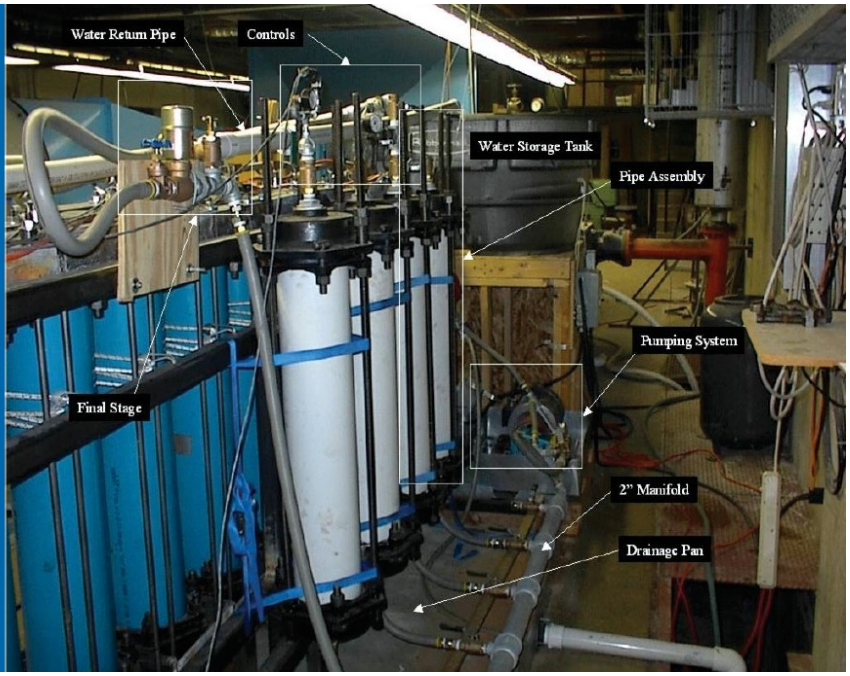

Figure 1:
Test Apparatus for cyclic testing. The blue pipe is AWWA C900, DR18, from Phase I. The white pipe is ASTM D2241, SDR41, introduced in Phase II

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No, it is not a typographical error. Ten specimens of six-inch, DR 18, AWWA C900 pipe endured over 10 million cycles without any failures. Ten Million! That is a one with seven zeros after it: 10,000,000!

The researchers at Utah State University (USU) cycled the DR 18, which has a Pressure Class of 150 psi, between 185 psi and 235 psi for exactly 10,209,535 cycles. At 18 cycles per minute, it took a total of 394 days and two research phases to finish the testing. The test was stopped without any of the AWWA C900 specimens failing. The pump and the pressure relief valve did not fare as well. During the testing, USU failed six pumps and five relief valves in order to log ten million cycles on

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Table 1. Test Pressures and Stresses

Test	Specimen Description	Minimum Pressure (psi)	Maximum Pressure (psi)	Mean Stress (psi)	Stress Amplitude (psi)
One	DR 18, AWWA C900, PC 150 psi	185	235	1787	213
Two	SDR 41, ASTM D2241, PR 100 psi	82	123	2000	400
Three	SDR 41, ASTM D2241, PR 100 psi	0	154	1500	1500
Four	SDR 41, ASTM D2241, PR 100 psi	56.5	149	2000	900

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the PVC pipe. The test set-up is shown in Figure 1 on page 9. The blue pipe is the AWWA C900 pipe, and the white pipe is six-inch, SDR 41, ASTM D2241 pipe.

This testing was a part of Phase II of USU's research project on the cyclic capabilities of PVC pressure pipe. In the Spring 2001 edition of the PVC News, we reported on the research results from Phase I and said that more data points would be collected. Well the data is in, and the results are impressive.

Background

Uni-Bell first contracted with USU in 1999 to re-evaluate the cyclic capabilities of PVC pressure pipe. At the time, there were two competing theories. The first theory was developed by Vinson and stated that the cyclic life of PVC was a function of peak stress only. (The third edition of The Handbook of PVC Pipe: Design and Construction shows Vinson's theory.) The Europeans had a competing theory that stated the cyclic life was a function of only the stress amplitude. Dr. Moser completed the first phase of the testing in the summer of 2000 and published his finding in February of 2001. That testing showed that the cyclic life of PVC was a function of two variables - not one. PVC pipe fatigue is a function of both the mean stress and the stress amplitude. (The fourth edition of the Handbook, published in August of 2001, shows Moser's 2001 theory.)

During the testing, Utah State University failed six pumps and five relief valves in order to log ten million cycles on the PVC pipe.

Phase I

The first phase involved only AWWA C900 pipe. As mentioned earlier, this pipe was cycled from 185 psi to 235 psi, which resulted in an average stress of 1,787 psi and a stress amplitude of 213 psi. Vinson's formula predicted failure at 322,000 cycles. After successfully logging 3.5 million cycles, the first phase of testing was concluded and a new cyclic theory for PVC was published. However, Dr. Moser stated that more data points were needed in order to fine-tune the design chart that he developed.

Phase II

So in April of 2001, Uni-Bell entered its second contract on this project with USU in order to continue the work begun in Phase I. This time, ASTM D2241 PVC pipe would be subjected to pressures and amplitudes well beyond that recommended in the design standards. Also, the testing on the AWWA C900 pipe would be re-started.

SDR 41, ASTM D2241 pipe, with a Pressure Rating of 100 psi, was selected for the abusive cyclic pressure combinations. Using pipe with a higher dimension ratio allowed higher stresses to be generated in the pipe wall at lower pressures. Generating the same stresses in DR 18 would require a prohibitively expensive pumping system. Also, the researchers learned in Phase I to expect equipment failures. The extreme pressures take their toll on the equipment, and so, replacement pumps were a large part of the equipment cost in the research budget.

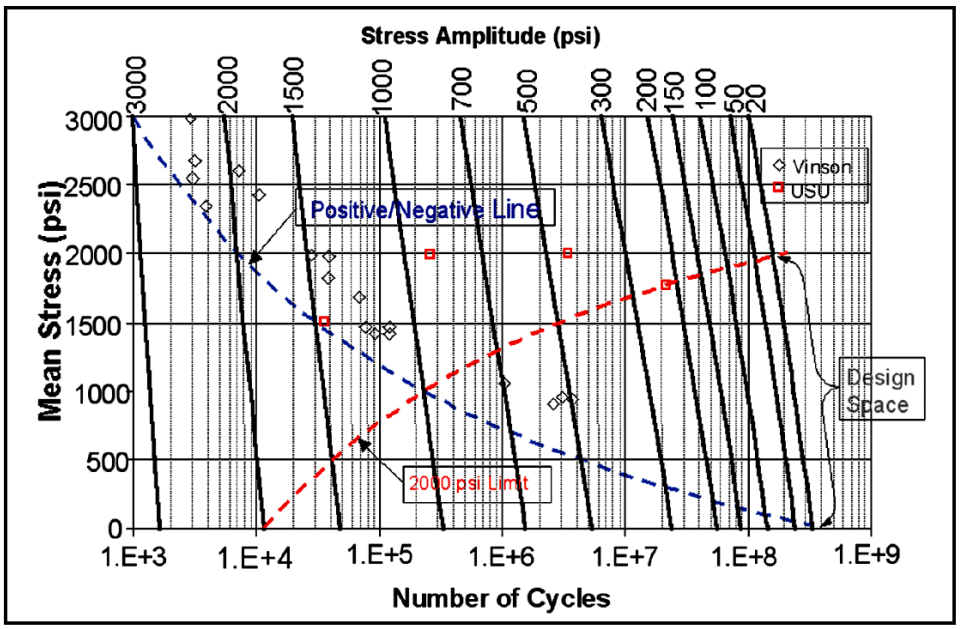

Figure 3: New cyclic design chart updated after collecting extra data points from the second phase of testing.

Table 1 on page 10 shows the average pressure and amplitude for the four pressure combinations. The corresponding wall stresses are also listed. The pattern of cyclic pressure applied was a sawtooth. The computer screen in Figure 2 (above) displays the pressure wave applied.

Figure 2: The cyclic pressures applied during testing followed a sawtooth pattern.

The minimum and maximum pressures on Test One were regulated to within +/- 5 psi. A more accurate control system was used on Test Two, Three, and Four. Pressures were regulated to within +/- 3 psi. Temperature was 22°C +/- 2 (71.6°F +/- 3.6).

Cyclic Design Graph

With the help of the new data points, a fine-tuned design graph is now available. It appears in Figure 3 on page 10.

The chart is a wonderful design tool for engineers involved in turf irrigation or sewer force main design. Those types of systems sometimes see surges of greater magnitude with greater frequency. We plan a follow-up article that provides a cyclic design example for a force main system.