detection programs are not necessary in the sectors where the water distribution lines are constructed with PVC pipes. “This fact allows us to concentrate our limited resources where they are most needed, in the sectors built with iron pipe,” states Mr. Perreault, who points out that flushing is also a thing of the past for the PVC sectors.

To this day, the Technical Services officials for the West Infrastructures Division of Quebec City, which includes the Burroughs of Sainte-Foy-Sillery and Laurentien, are specifying PVC pipes for constructing and rehabilitating its water distribution system. While Mr. Proulx is now enjoying a well-deserved retirement, Mr. Perreault is supported by a new technical team, which includes Mr. Donald Desrosiers, P.Eng. Mr. Desrosiers also recognizes the several qualities of PVC pipes that make it a reliable investment for underground infrastructure for the water distribution system as well as the sanitary and storm sewer systems.

A majority of North American cities are recognizing the efficiency and high reliability of PVC pipes by authorizing their use for infrastructure construction. The Burroughs of Sainte-Foy Sillery decision makers have gone one step further in recognizing the superior performance of the PVC material by specifying its sole use in order to promote sustainable development.

In addition to the citizens living in the burroughs, all Quebec City citizens are benefitting from the superior performance of PVC water pipes; their use allows the city engineers to devote their efforts to the sectors where conventional materials are currently failing due to corrosion, knowing that the PVC sectors will continue to offer their superior level of performance.

At this juncture where all North American cities are struggling to breach the infrastructure gap, which is caused mainly by corrosion, there are solutions available that will allow the building of reliable infrastructure within a sustainable development concept. The professionals of the Sainte-Foy-Sillery Laurentien Burroughs of Quebec City have shown it is possible. Follow their lead and you will soon be writing one of the most durable chapters of your own city’s history.

CONTINUED FROM PAGE 7

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 PVC Pressure Pipe Endures Over Ten Million Cycles

By Craig Fisher, P.E.
Technical Director

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

CONTINUED ON PAGE 10
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.)

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

### Table 1. Test Pressures and Stresses

<table>
<thead>
<tr>
<th>Test</th>
<th>Specimen Description</th>
<th>Minimum Pressure (psi)</th>
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<tbody>
<tr>
<td>One</td>
<td>DR 18, AWWA C900, PC</td>
<td>185</td>
<td>235</td>
<td>1787</td>
<td>213</td>
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<td>Two</td>
<td>SDR 41, ASTM D2241,</td>
<td>82</td>
<td>123</td>
<td>2000</td>
<td>400</td>
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<tr>
<td>Three</td>
<td>SDR 41, ASTM D2241,</td>
<td>0</td>
<td>154</td>
<td>1500</td>
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**Background**

Uni-Bell first contracted with USU in 1999 to re-evaluate 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 in, and the results are impressive.

**DURING THE TESTING,**

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

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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.

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. 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.

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