Because friction or head losses increase exponentially (to the power of 2 with the Darcy-Weisbach friction equation and to the power of 1.85 in the Hazen-Williams equation), higher flows intensify such losses, resulting in a pronounced lowering of the hydraulic grade line (HGL). With the HGL lowered, modeling results are more sensitive to roughness coefficients, which, in turn, allows for ease and accuracy in determining roughness coefficients. The model is applied to flow and operational conditions experienced during a fire-flow test; the pressures or HGL observed in the field are compared to the model results. If significant differences are found between the model and field results, adjustments are made in model parameters to reduce the differences or “calibrate” the model. Adjustments are typically made in the roughness coefficient (e.g., Hazen-Williams C factor), demands, or shutoff valve positions. They can be made manually through trial and error or through automated optimization programs that systematically examine a wide range of coefficients and choose the combination that best fits the observed field data.

In most traditional fire-flow tests, water is released from a single hydrant and pressure is measured at another hydrant. If the single hydrant does not sufficiently stress the system (i.e., produce enough head loss) additional hydrants can be opened simultaneously to further lower the HGL. Also, pressure and HGL measurements can be made at additional hydrants to provide more data for use in the calibration process. However, opening more hydrants and making more measurements usually require more personnel or a longer time between tests so crews can travel to the next hydrant.

Alternative Approach to Flow Testing

An alternative approach for conducting a fire-flow test was developed as part of an ongoing study at the US Marine Corps Base Camp Lejeune, N.C. The enhanced test procedure was developed to improve labor efficiency associated with conducting fire-flow tests and to collect additional data for calibration purposes.

Continuously recording pressure gauges (Figure 1) were installed at up to six hydrants in the test area. These gauges were set to record a pressure measurement at 1-min intervals. Pitot gauges were also installed on two hydrants designated as flow hydrants. An integrated Pitot tube and wire-cage diffuser was used to measure and control the discharge from the hydrant.

Table 1. Sample results from fire-flow test. $Q_1$ and $Q_2$ refer to the discharge from the two hydrants that are being flowed. $P_{00}$, $P_{01}$, $P_{02}$, and $P_{03}$ refer to the pressure measurements at the four hydrants.
(Figure 2). At the hydrant nearest to the flowing hydrants, an analog pressure gauge was installed in addition to the continuous-recording pressure logger so that the pressure drop could be visually monitored to be sure it dropped sufficiently, but not below 20 psi.

During the test, five different flow conditions were studied, each for a period of 3 to 4 min:

- Static conditions (no water flowed from hydrants)
- Water flowed from hydrant number 1 ($Q_1$)
- Water flowed from hydrant numbers 1 and 2 ($Q_1$ and $Q_2$) simultaneously
- Water flowed from hydrant number 2 ($Q_2$)
- Static conditions (no water flowed)

The last condition is a repeat of the first condition and is used to ensure the system returns to the conditions obtained before the test was started. $Q_1$ and $Q_2$ refer to the discharge from the two hydrants that are being flowed.

**Test Results**

Fire-flow tests were performed at eight sites. Figure 3 (on page 12) shows the location of the four pressure gauges and two tested hydrants for the simultaneous test at one of the sites. The pressure gauges were placed on four hydrants upstream of the two hydrants being flowed. Based on the 1-min pressure data readings (Figure 4), an

*continued on page 12*
average pressure during each of the five stages of the test was computed; starting and ending static conditions for all pressure recording hydrants were within ± 0.5 psi (Table 1 on page 10). Slight variations were made at some of the test locations in terms of the number of pressure gauges that were installed or other minor variations in the protocol.

The total time to conduct this compound fire-flow test was generally less than one hour, including installation of equipment (Pitot and pressure gauges), running the test under the five conditions, and disassembling the equipment. A crew of three people can safely and quickly perform this procedure. Typically, one person is stationed at each of the flowing hydrants, and the third person reads the analog pressure gauge at a nearby hydrant. The method can be expanded if additional Pitot gauges and pressure loggers are available.

Summary

The use of continuous-recording pressure loggers and simultaneously releasing water from multiple hydrants proved to be an effective and efficient method for conducting flow tests. When compared to normal protocols for conducting flow tests, this procedure can be accomplished by smaller crews and performed faster, and can result in more data that could be used for model calibration. The cost of the equipment is relatively inexpensive, rendering this methodology quite feasible with even a limited budget.

Disclaimer: The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the Agency for Toxic Substances and Disease Registry.