

Calibrating Distribution System Models with Fire-Flow Tests

by Walter M. Grayman, Morris L. Maslia, and Jason B. Sautner

Fire-flow tests, a widely used method for estimating the available fire flow from hydrants, are also frequently used in the calibration process for a hydraulic water-distribution system model to determine roughness coefficients and to find closed valves. The process is straightforward: A hydrant is opened and water is released to increase flows in the distribution system in the vicinity of the hydrant.



Figure 1. Hydrants were equipped with an analog pressure gauge (left) and a continuous recording pressure (digital) logger (right).

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

Test Condition	Flow, gpm		Pressure, psi			
	Q ₁	Q ₂	P ₀₀	P ₀₁	P ₀₂	P ₀₃
Starting static case	0	0	53.1	50.7	56.2	52.6
Hydrant 1 flowed	773	0	41.4	37.3	46.8	42.9
Hydrant 1 and 2 flowed	631	579	29.7	24.5	36.5	32.7
Hydrant 2 flowed	0	747	43.9	40.7	48.1	44.1
Ending static case	0	0	53.5	51.2	56.5	52.9

Table 1. Sample results from fire-flow test. Q₁ and Q₂ refer to the discharge from the two hydrants that are being flowed. P₀₀, P₀₁, P₀₂, and P₀₃ refer to the pressure measurements at the four hydrants.

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

Walter M. Grayman is a consulting engineer in Cincinnati. Morris L. Maslia is a research environmental engineer for the Agency for Toxic Substances and Disease Registry in Atlanta. Jason B. Sautner is an environmental health scientist with the same agency.

(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



Figure 2. An integrated Pitot gauge and a wire-cage diffuser were installed on two flow hydrants.

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

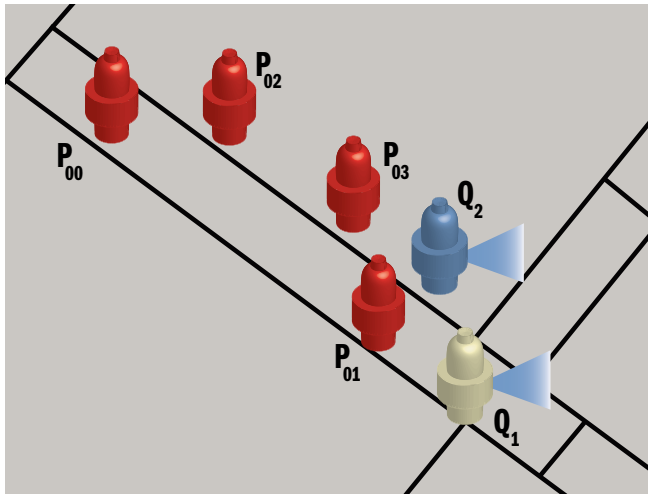


Figure 3. A schematic diagram shows the location of pressure gauges (P_{00} , P_{01} , P_{02} , and P_{03}) and flow hydrants (Q_1 and Q_2).

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 (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

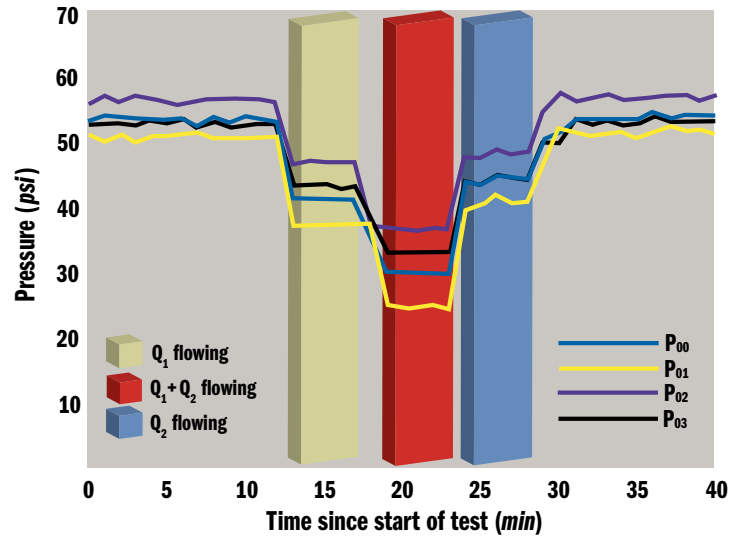


Figure 4. Hydrant pressure data and flow conditions were recorded during the fire-flow tests.

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.*

