A Case Study In Model Calibration

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Introduction & Background

A system model is often created to answer questions about proposed changes to the system's configuration, or demands. A well calibrated model allows these questions to be confidently answered.

The process of calibrating a model involves tuning or adjusting a model so that the model results closely match observed field values. This process starts by recording and collecting pressure, demand, and flow data for a specific period of time and set of operational conditions. Once collected, certain model parameters are set to reflect the operational conditions, and the calculated results are compared to the field recorded values. Depending on the quality of the model, the comparisons may be very close and require no further action, or the comparisons may be sufficiently different as to require further study and model adjustments.

The ultimate goal of the calibration process is to ensure that the model accurately reflects the actual performance of the system being modeled. The idea being that if the model accurately simulates the system's performance under one set of conditions, it will similarly reflect the system's performance under another set of conditions.

In this case study, we will see how the GASWorkS software was used to perform a calibration of a distribution system model and how the calibration process helped to identify a number of issues with the system being modeled. The steps associated with the calibration process and the resulting findings are described in the following sections.

Building the Base Model

The system was supplied by 4 gate stations (town border stations) and mainly served residential and small commercial type customers.

A base model of the client's gas distribution system was created from Geographic Information System (GIS) data provided by the client. The piping portion of the system was created by importing the pipe size, material, and configuration data from the GIS data. Some cleanup of the resulting model data was required. Primarily this involved reconciling connectivity issues.

The customer (meter) locations were then added to the piping portion of the model and assigned to the supplying pipe (main) segment. Customer demands were assigned by attaching a copy of the billing file to the model and matching the records in the billing file to the appropriate meter location in the model. Usage values were then shared with the model through this connection.

The resulting model consisted of about 7100 nodes, 7700 pipes, and 24,000 customer/meter locations. The general system configuration is depicted in Figure 1.

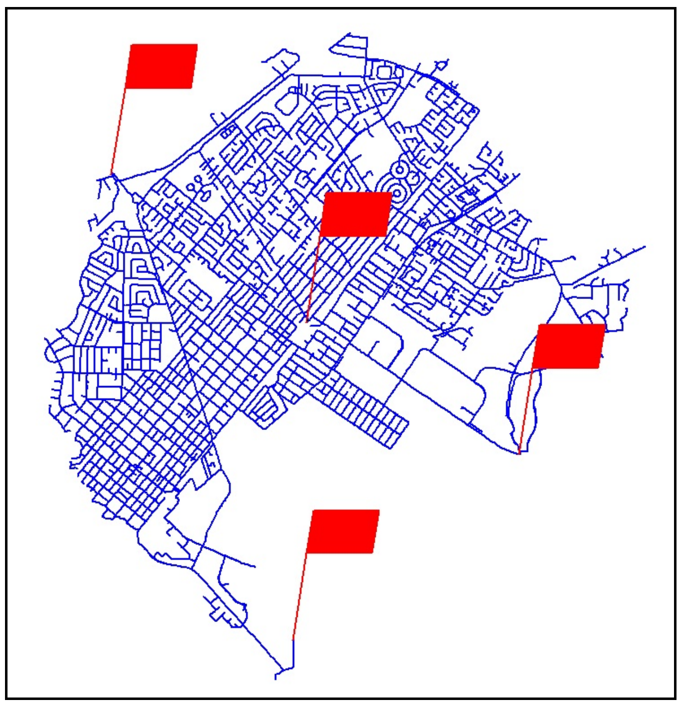

Figure 1: System Configuration.
Flagged locations represent supply points (Gate Stations).

Data Collection

Demands, flows, and pressures are constantly changing in a distribution system. Because of this, it is important that the operating data used for calibration be from the same operational period (time and date). Generally it is best to try to use data from high demand, high system pressure drop conditions, such as the peak flow hour of the peak day. The more "stressed" the system, the more likely that differences between the model and the physical system configuration will be revealed.

For this model, operating data for a peak hourly flow during the height of the heating season was collected. This data included gate station supply pressures, gate station flow rates, operating pressures from various locations in the system, and customer usage information for the billing period that overlapped the peak flow period.

Model Preparation

A model is "tuned" to match certain field results by adjusting the system configuration. In practice this means setting the GASWorkS "status" parameter of certain pipe segments to "off" to simulate valve closures, adjusting regulator set pressures to reflect regulator droop, adjusting customer demand to reflect demand coincidence, and adjusting the pipe hydraulic efficiencies to reflect restrictions, liquid build-up, or inaccuracies of the pipe flow equation.

To prepare for the calibration, the base model was copied and revised to reflect the conditions present during the calibration period. A copy of the billing file for the calibration period was attached to the model and usage values from this period were assigned to the customers in the model. The delivery pressures at the gate stations were set to the recorded values. The GASWorkS "total system flow" parameter was set to the summation of the gate station flow rates during the peak hour and a corresponding GASWorkS "design factor" value was calculated. The customer demand values were adjusted using the computed design factor, forcing the total demand on the system to match the total of the gate station flows.

Recorded flows and pressures were entered for the "calibration values" at the corresponding nodes in the model.

The hydraulic efficiency was set to 1.00 for all of the pipes in the model.

Model Comparison And Adjustment

Generally the model comparison part of the calibration process reviews two types of values: the flow distribution between the gate stations when multiple stations are present, and the system pressures at coincident node and recorder locations.

In this case, the initial predicted flow distribution between the gate stations did not compare well with the field data. The model predicted a value for one of the stations that was much higher than the recorded field value. A difference in values can be caused by a variety of issues including incorrect model data, issues with the data measurement and collection, or issues in the physical system configuration.

Based on the model results, the mismatch in this situation indicated that flow from the station was likely being restricted in some fashion. A study of the model results suggested that the field configuration of the system may not have been accurately reflected in the model. Specifically it appeared that there could be a valve closed or a "bad connection" near the station. After reviewing the potential issues with the client, they did some field checking and located two valves in the "off" position near the station outlet. Closure of the valves in the model satisfied the flow distribution comparison.

The next step was a review of the pressure comparisons at the various recording locations in the system. Some locations compared well to the field recorded values without adjustment. However, locations in a large central portion of the system did not compare well. In this area the model suggested that a newly installed large main was not supplying as much of the system as expected. The findings were reviewed with the client. They found as-built documents indicating that many of the laterals that the GIS and model data showed as connected to the new main were, in fact, connected but never tapped. When these laterals were disconnected in the model, the predicted pressure values compared well with the field recorded values.

Ultimately, the calibrated model was compared to field results from another set of operating conditions. When compared to data for these conditions, the average difference between the predicted and field values for the flow distribution at the gate stations was 0.6%. The average difference between the predicted and field values for the system pressures was 1.6% of the absolute pressure values.

Field To Model Comparison Values...

Location	Actual Value	Calculated Value	Difference, % ③
Total System Flow	582 Mcfh	581 Mcfh	-0.2
Gate Station 1	201 Mcfh	198 Mcfh	-1.6
Gate Station 2	205 Mcfh	206 Mcfh	0.6
Gate Station 3	139 Mcfh ①	N/A	
Gate Station 3	22 to 24 Psig ②	22.3 Psig	
Gate Station 4	37 Mcfh	38 Mcfh	2.6
Pressure Point 1	21.1 Psig	21.6 Psig	1.4
Pressure Point 2	21.7 Psig	21.9 Psig	0.2
Pressure Point 3	21.1 Psig	21.7 Psig	1.6
Pressure Point 4	21.9 Psig	21.9 Psig	0.0
Transport Pressure Point	21.7 Psig	22.0 Psig	0.8

① Estimated value based on proportion of total daily system volume.
② Anticipated value range.
③ Pressure comparison was done using absolute pressure values, Patm = 14.72 psia.

Summary

Sometimes the calibration process reveals discrepancies (or surprises) between the “data” depicting the system and the physical system itself. In this case the calibration process revealed various system configuration issues that were not reflected in the client’s GIS data, and consequently not reflected in the resulting model. Once the model was configured to match the field conditions, the model results closely matched the system’s actual performance. Because of the findings revealed during the process, the client was able to correct these configuration issues, allowing the system to operate more efficiently.

In this case, sufficient operating data was available to allow the model to be calibrated. Sometimes however, calibration cannot be performed because the appropriate or sufficient data does not exist. Where the appropriate data does exist, calibration is an important step which should not be overlooked in the modeling process.