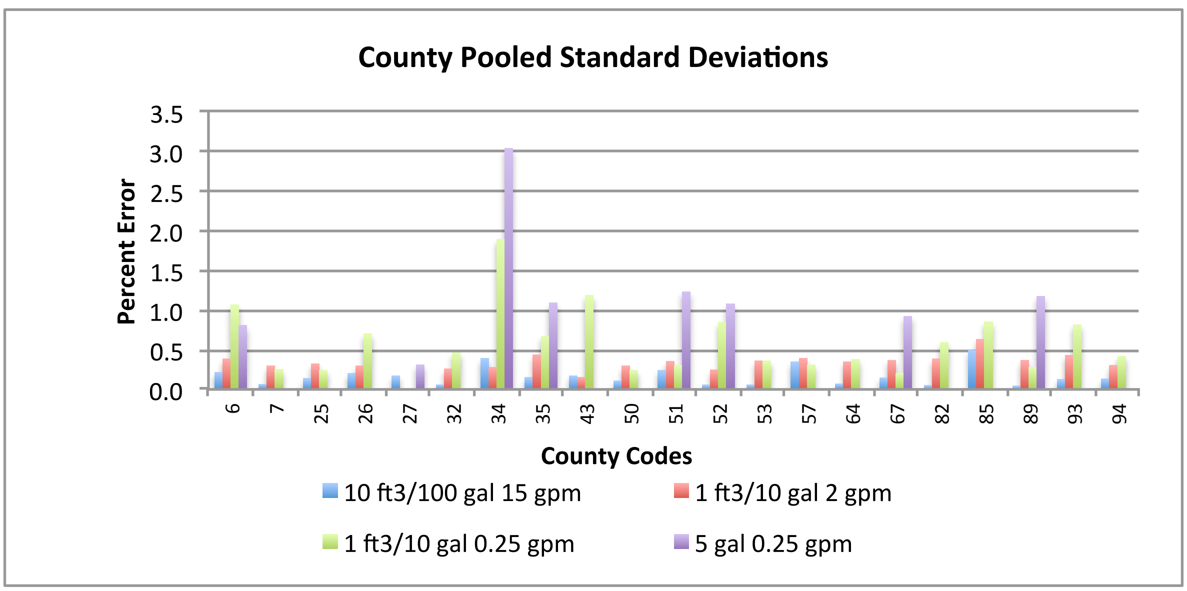
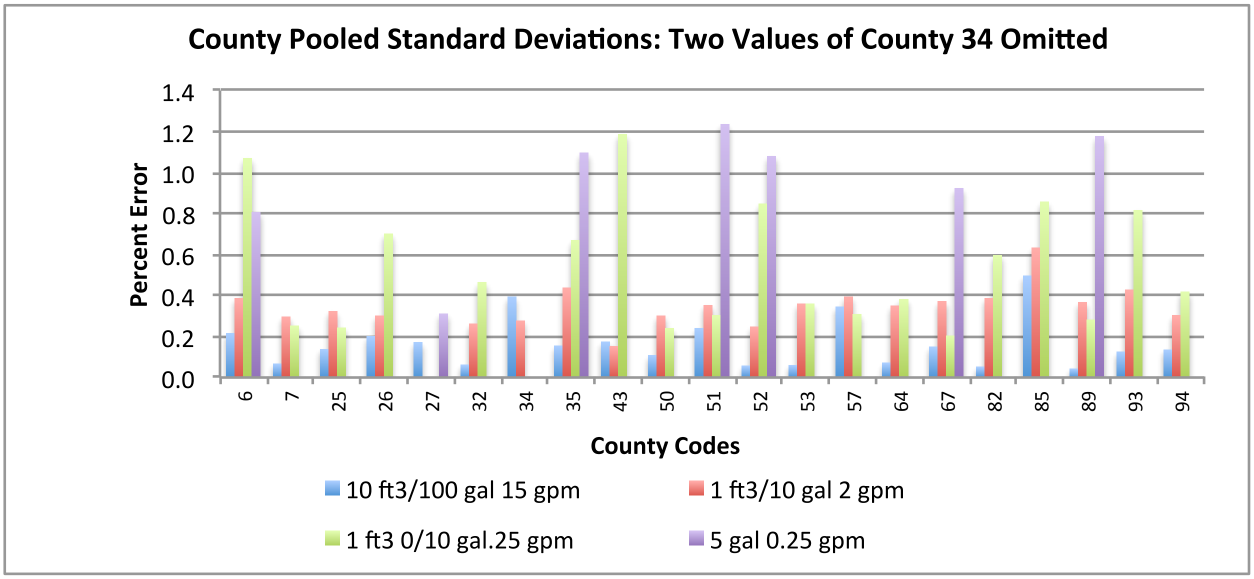
Repeatability of Test Results in County Laboratories

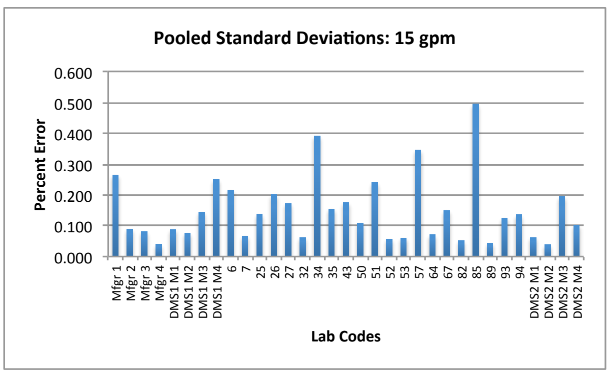
The standard deviations were computed for the three repeat tests for each laboratory at each flow rate. The standard deviations for each meter in a group tested by each laboratory were combined to obtain the pooled standard deviation for each flow rate. When a laboratory participated in the round robin exercise and tested two groups of meters, the standard deviations for each flow rate for the two groups of meters were combined (pooled). The standard deviations are based upon a limited amount of test data, so the standard deviations may not reflect the variations that may exist over time for a large number of meters.

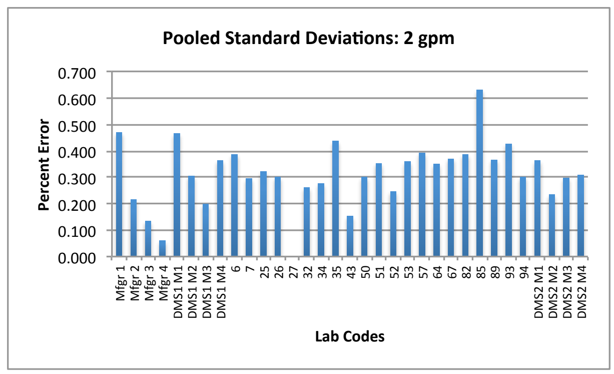
The repeatability of individual test results varied significantly from county to county, especially for tests conducted at the minimum flow rate of 0.25 gpm. The actual flow rates for the counties when testing at the minimum flow rate ranged from 0.25 to 0.32 gpm. The chart below shows the pooled standard deviations of the individual test results by county. The standard deviations for the 10-gal test drafts can be identified, since a column follows the column for the lab for "5 gal 0.25 gpm." The results for county 34 included several tests for which the actual flow rates for several of the tests were below 0.25 gpm. The standard deviations for this laboratory were much larger than for the other labs (1.9% and 3.0% for the 10-gal and 5-gal test drafts, respectively). If the actual flow rates for these tests had been at or slightly above 0.25 gpm, one would expect that the standard deviations would have been significantly smaller for this lab and for this flow rate at these test drafts.

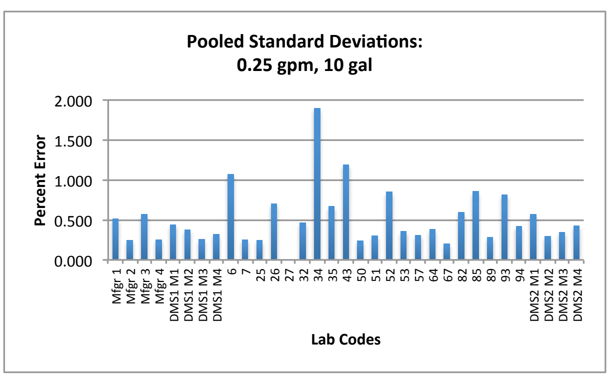


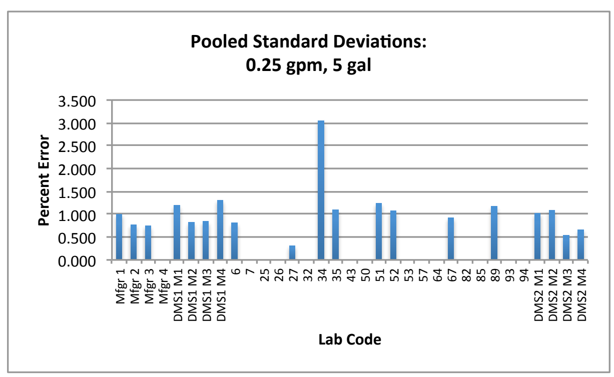
In the chart below, the pooled standard deviations for lab 34 for the flow rate of 0.25 gpm were omitted from the chart to provide a better visual comparison of test results for the other flow rates.


County Pooled Standard Deviations: Two Values of County 34 Omitted
Percent Error
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
6 7 25 26 27 32 34 35 43 50 51 52 53 57 64 67 82 85 89 93 94
County Codes
10 ft3/100 gal 15 gpm
1 ft3/10 gal 2 gpm
1 ft3 0/10 gal.25 gpm
5 gal 0.25 gpm


Pooled Standard Deviations: 15 gpm
Percent Error
0.600
0.500
0.400
0.300
0.200
0.100
0.000
Mfgr 1 Mfgr 2 Mfgr 3 Mfgr 4 DMS1 M1 DMS1 M2 DMS1 M3 DMS1 M4 6 7 25 26 27 32 34 35 43 50 51 52 53 57 64 67 82 85 89 93 94 DMS2 M1 DMS2 M2 DMS2 M3 DMS2 M4
Lab Codes


Pooled Standard Deviations: 2 gpm
Percent Error
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
Mfgr 1 Mfgr 2 Mfgr 3 Mfgr 4 DMS1 M1 DMS1 M2 DMS1 M3 DMS1 M4 6 7 25 26 27 32 34 35 43 50 51 52 53 57 64 67 82 85 89 93 94 DMS2 M1 DMS2 M2 DMS2 M3 DMS2 M4
Lab Codes


Pooled Standard Deviations:
0.25 gpm, 10 gal
Percent Error
2.000
1.500
1.000
0.500
0.000
Mfgr 1 Mfgr 2 Mfgr 3 Mfgr 4 DMS1 M1 DMS1 M2 DMS1 M3 DMS1 M4 6 7 25 26 27 32 34 35 43 50 51 52 53 57 64 67 82 85 89 93 94 DMS2 M1 DMS2 M2 DMS2 M3 DMS2 M4
Lab Codes


Pooled Standard Deviations:
0.25 gpm, 5 gal
Percent Error
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
Mfgr 1 Mfgr 2 Mfgr 3 Mfgr 4 DMS1 M1 DMS1 M2 DMS1 M3 DMS1 M4 6 7 25 26 27 32 34 35 43 50 51 52 53 57 64 67 82 85 89 93 94 DMS2 M1 DMS2 M2 DMS2 M3 DMS2 M4
Lab Code

It was expected that the variations in test results as percent meter error (i.e., the standard deviations) would be greater at the slower flow rates and smaller volumes of test drafts than for the higher flow rates and larger test drafts. The key question is, "What are the causes of these larger variations?"

Repeat Tests on Meters

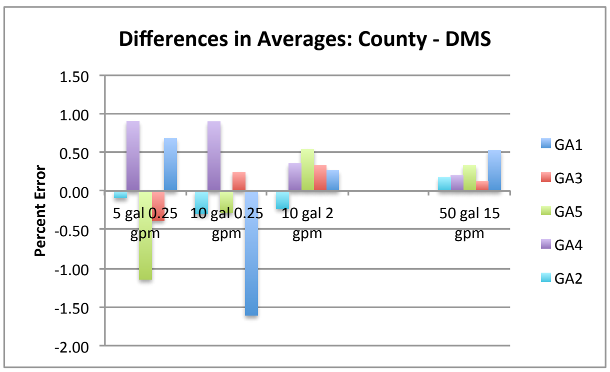
Five laboratories ran repeat sets of tests on a total of 10 meters. The laboratories did not have the capacity to test all five meters in a group in series, so repeat tests were run on some of the meters that were tested as part of the first subgroup. The purpose of the tests was to determine if there would be any unusually offsets of changes in repeatability in the results of the meters.

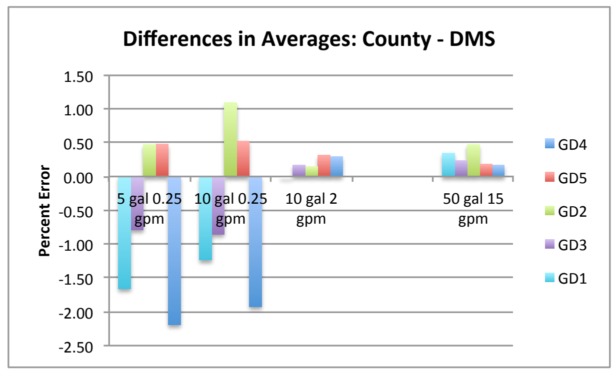
The results of the repeat tests agreed with the results of the initial tests within the uncertainties associated with each laboratory for each flow rate. The standard deviations for the meters in the repeat tests agreed with the standard deviations obtained in the first set of tests. Based upon these test results, one can conclude that the performance characteristics for the laboratories and the meters are repeatable under the same test conditions. Any other results would have indicated that significant problems or issues might exist.

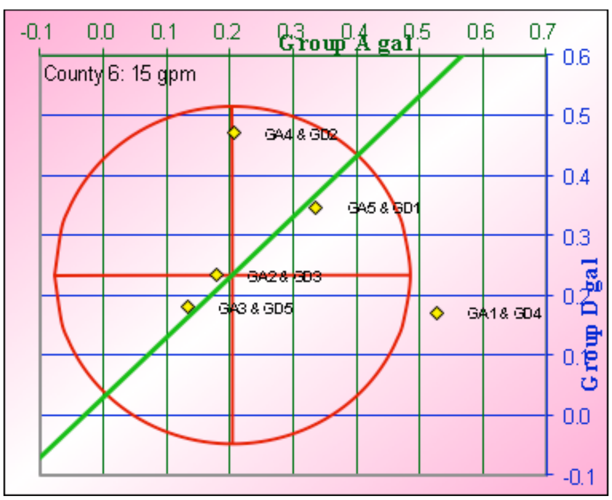
County 6

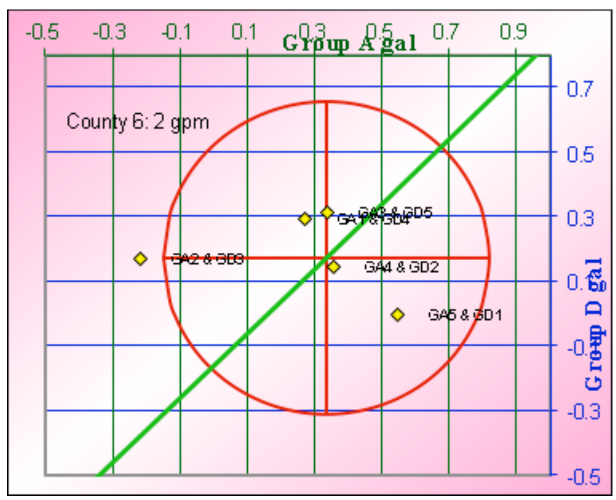
County 6 has a Ford test bench and uses supply tanks and a pumping system to recirculate water for the tests. The median offsets from DMS results for the flow rates of 15 and 2 gpm were reasonably small. At the flow rate of 0.25 gpm for the 10- and 5-gal test drafts, one group of meters (the GD group) had larger underregistration values compared to the DMS results, as evidenced by one of each of the median coordinates [(-0.28, -0.85) and (-0.09, -0.79)] being a relatively large negative value. The accuracy of meter, GD4, appears to be trending toward greater underregistration at the flow rate of 0.25 gpm.

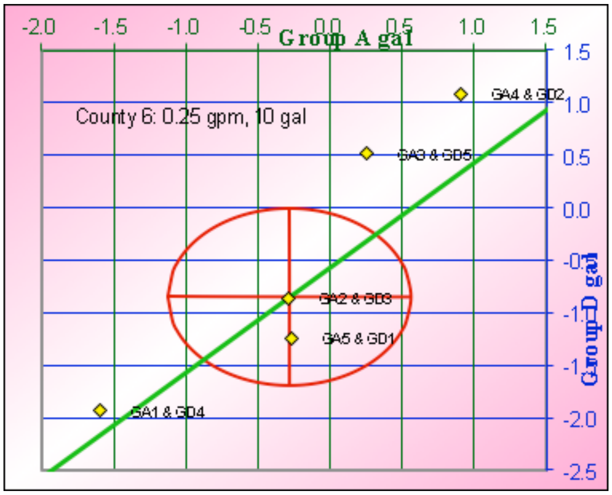
County 6 has one of the larger standard deviations for the 10-gal test draft at 0.25 gpm, but the standard deviation for the 5-gal test draft is smaller than for the 10-gal test draft and consistent with the results for the other labs.

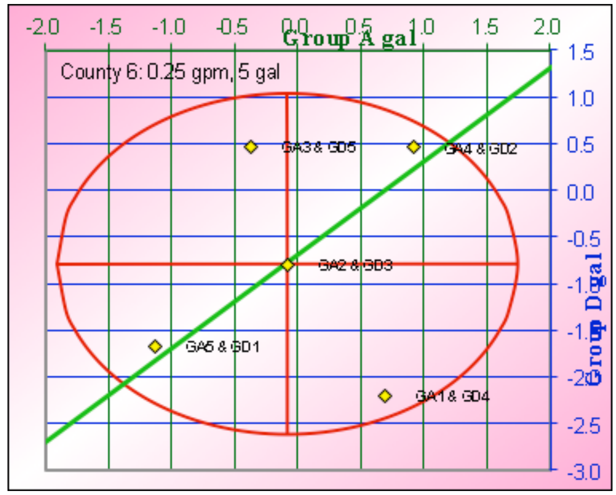









Group A gal
Group D gal
County 6: 0.25 gpm, 10 gal
GA4 & GD2
GA3 & GD5
GA2 & GD3
GA5 & GD1
GA1 & GD4


Group A gal
Group D gal
County 6: 0.25 gpm, 5 gal
GA3 & GD5
GA4 & GD2
GA2 & GD3
GA5 & GD1
GA1 & GD4

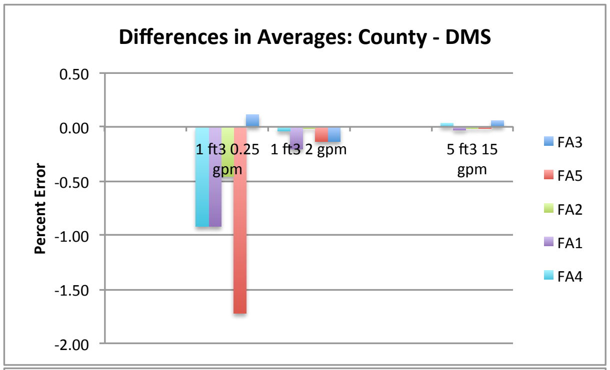
County 7

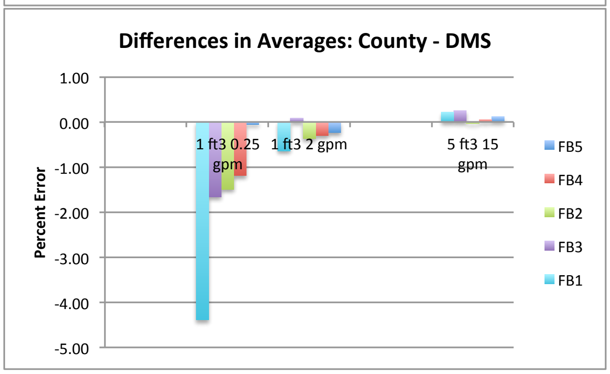
County 7 has a Ford test bench and uses city water to test water meters. The median offsets from DMS were relatively small for the flow rates of 15 and 2 gpm [(0.00, 0.11) and (-0.14, -0.31), respectively]. The median offset at 0.25 gpm was quite large (-0.92, -1.49). The three test results for one meter, FB1, at 0.25 gpm were all outside the tolerance limit for underregistration. The county lab (County 94) that tested meter FB1 prior to County 7 had test results with even greater underregistration. However, when DMS tested the meter at the conclusion of the survey, the test results for the meter at the flow rate of 0.25 gpm were well within tolerance. It isn't clear if the rather large underregistration errors are due to the laboratory facility or due to the performance of the meter.

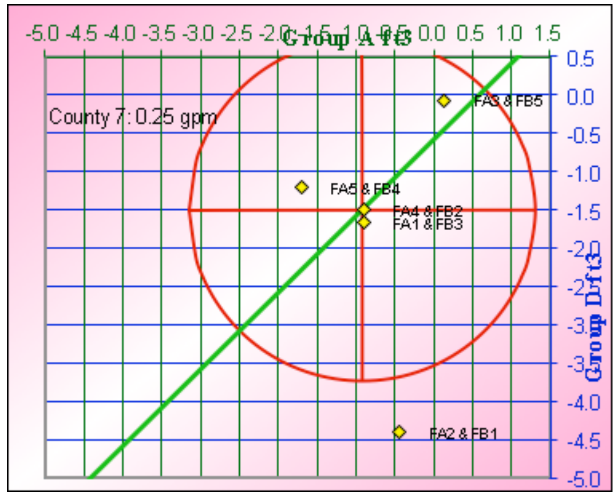
County 7 also had significantly larger underregistration errors at 0.25 gpm for meter FB2. Like meter FB1, when DMS tested the meter at the end of the survey, the test results were well within tolerance and the results were consistent with what DMS had at the beginning of the survey. The accuracy of meter FB3 may have changed at the flow rate of 0.25 gpm during the survey, because the last four labs to test the meter had significant underregistration errors compared to the labs that tested this meter earlier in the survey. The results for meter FB4 at 0.25 gpm were also lower (more underregistration) for the last four labs that tested the meter compared to the results from the manufacturer and the initial tests by DMS. For meter FB5, the test results for County 7 were typical for most of the other labs that tested this meter at 0.25 gpm.

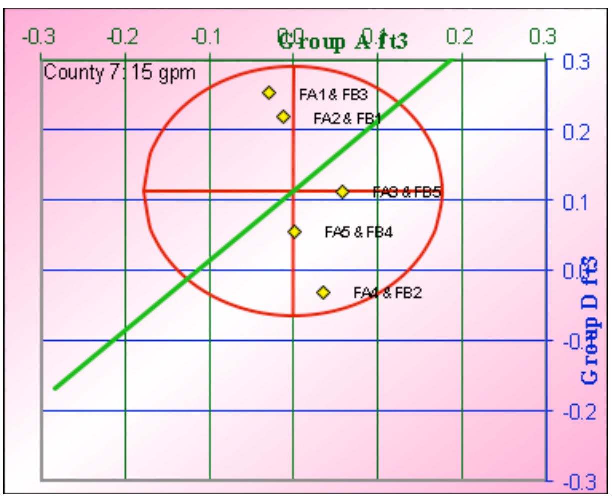
While the test results for the FA group of meters at 0.25 gpm for County 7 also appear to be significantly more negative than DMS, a review of the individual test results do not indicate as drastic a difference as it would first appear. The County 7 test results for meters FA2 and FA3 appear to be reasonably consistent with the DMS results. The initial DMS test results for meter FA5 at 0.25 gpm appear to be unusually high compared to the results of the other labs and to the end test results for DMS. This causes the results for County 7 to appear to be unusually low. However, the test results for County 7 for meter FA5 are consistent with the results from other labs.

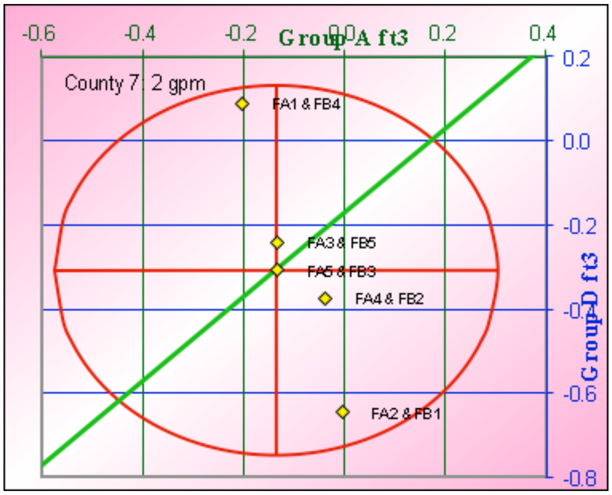
The repeatability (standard deviations) of the test results for County 7 at all flow rates is comparable or smaller than the results for the other labs.


Differences in Averages: County - DMS
Percent Error
0.50
0.00
-0.50
-1.00
-1.50
-2.00
1 ft3 0.25 gpm
1 ft3 2 gpm
5 ft3 15 gpm
FA3
FA5
FA2
FA1
FA4


Differences in Averages: County - DMS
Percent Error
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
1 ft3 0.25 gpm
1 ft3 2 gpm
5 ft3 15 gpm
FB5
FB4
FB2
FB3
FB1


Group A ft3
Group D ft3
County 7: 0.25 gpm
FA3 & FB5
FA5 & FB4
FA4 & FB2
FA1 & FB3
FA2 & FB1

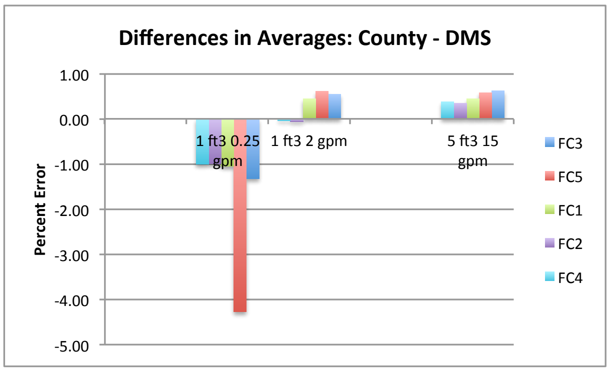

Group A ft3
Group D ft3
County 7: 15 gpm
FA1 & FB3
FA2 & FB1
FA3 & FB5
FA5 & FB4
FA4 & FB2



Group A ft3
Group D ft3
County 7: 2 gpm
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.2
0.0
-0.2
-0.6
-0.8
FA1 & FB4
FA3 & FB5
FA5 & FB3
FA4 & FB2
FA2 & FB1

County 25

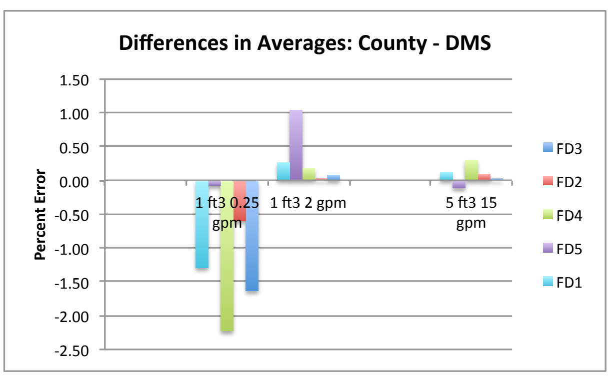
County 25 has a Ford test bench with a capacity to test two meters at a time. The test results at 15 and 2 gpm tended to be consistent with those of the other county labs. However, the results at 0.25 gpm tended to be lower than other county labs. One meter failed all three tests at the minimum flow rate, but the meter results for several labs were outside the tolerance on the negative (underregistration). The repeatability of the lab is consistent with other county labs.



County 26

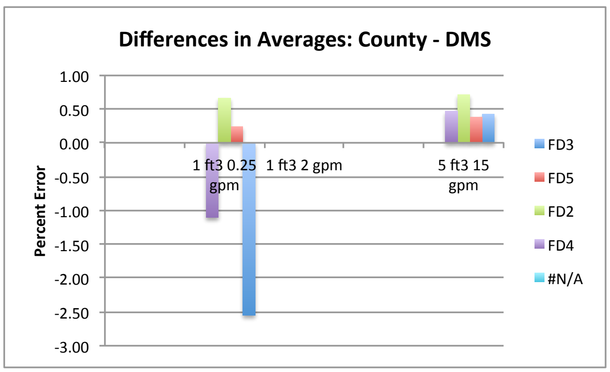
County 26 has a Ford test bench and uses supply tanks and a pumping system to recirculate water for the tests. There are several plumbing and procedural issues that should be addressed. The average results don't appear to be unusual, but there are some variations in test results for some individual meters that seem a little different for some meters compared to the results of the other labs that tested these same meters. To avoid pumping air entrained in the water, the reference tanks were not emptied completely, that is, a reference water level was established in the tank and then the test draft was run from the reference point. This is similar to using a "wet-bottom" prover. Procedurally, the tanks were not wet-down before the first test. Actually, the air was not purged from the meters before the first test. Surprisingly, except for one meter, the test results for the first test at 15 gpm were not significantly different from the subsequent tests. However, one meter failed the repeatability tolerance at 15 gpm, primarily because of an atypical error associated with the first test run. The failed repeatability tests are probably due to the failure to purge the air from the meters and test bench before the first test was conducted. Although the failure to purge air from the meters and the lack of a proper wet down of the reference tanks appeared to have limited impact on these particular results, the plumbing and procedural issues should be corrected.

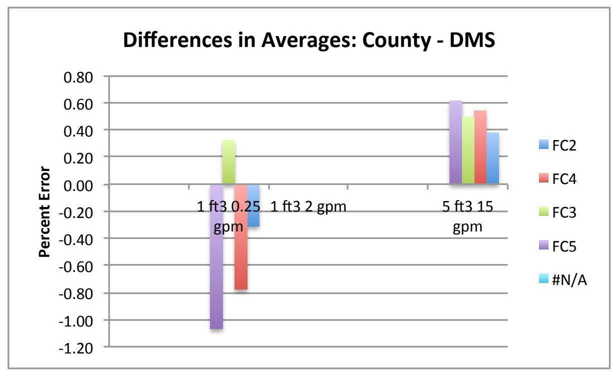
The test results at 15 and 2 gpm agreed well with the DMS results. The results at 0.25 gpm appeared to be more negative (more underregistration) than observed in the initial DMS tests, but none of the test results were beyond the accuracy tolerance at any of the flow rates. The county had some odd variations in the repeat tests at some flow rates, particularly at 2 gpm. The standard deviations for County 26 at each flow rate were among the larger values, but the results were not unusually large.

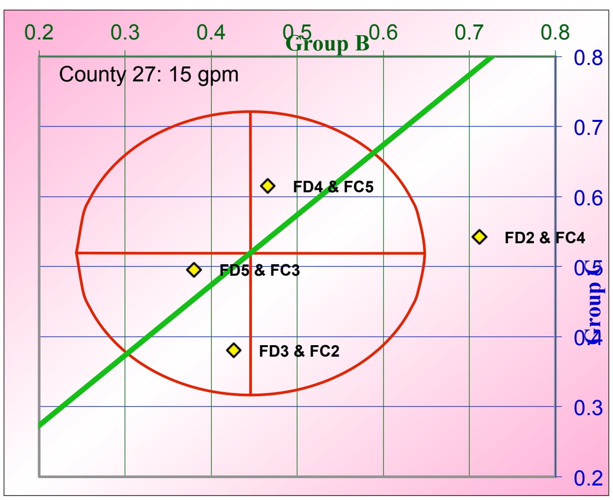


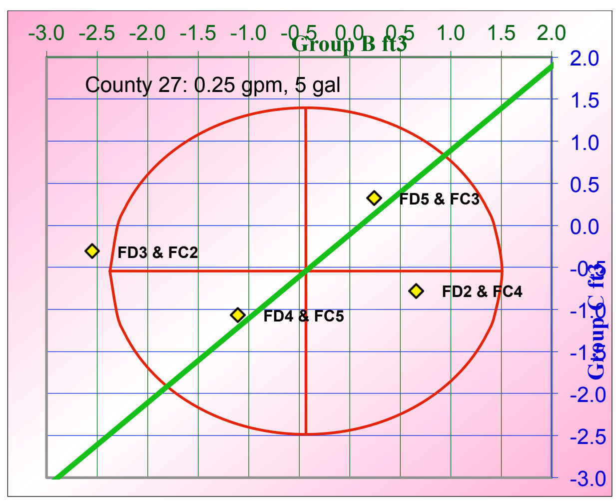
County 27

County 27 did not have a Ford test bench. Instead, the meters were connected using pipe connectors and hoses. The reference standards were metal neck-type volume standards. Tests were run at 15 and 0.25 gpm; no tests were run at 2gpm. The laboratory tended to have a positive bias at 15 gpm compared to the DMS results. The offset for the median values (0.45,0.52) of the two groups of meters at 15 gpm was among the larger median offsets observed, but which was fairly typical for a large number of county laboratories. However, none of the meters tested failed the accuracy or repeatability tolerances. The median offset from DMS at 0.25 gpm was relatively small and in good agreement with DMS. The repeatability of the test results was typical when compared to the other labs.



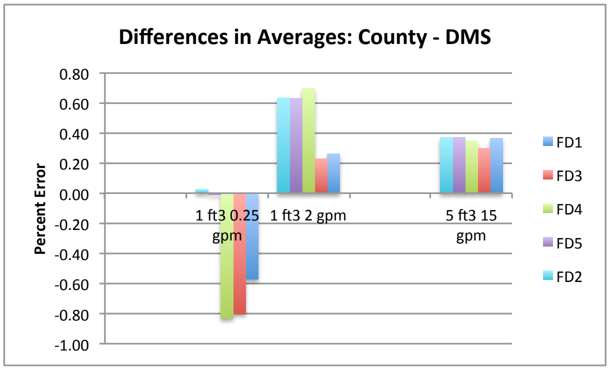


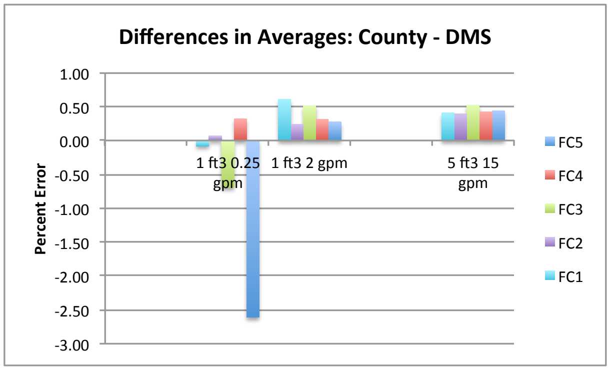


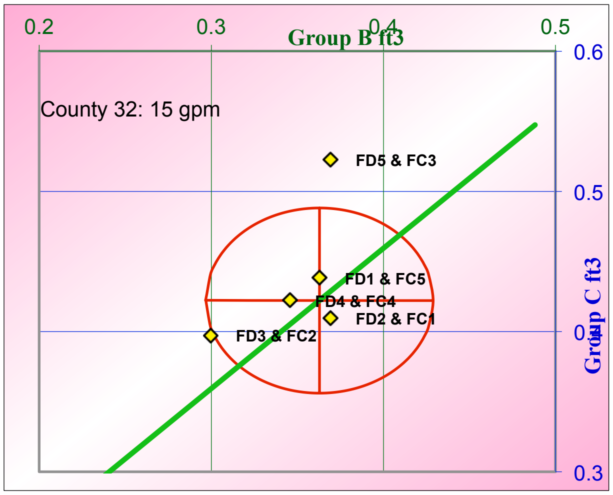


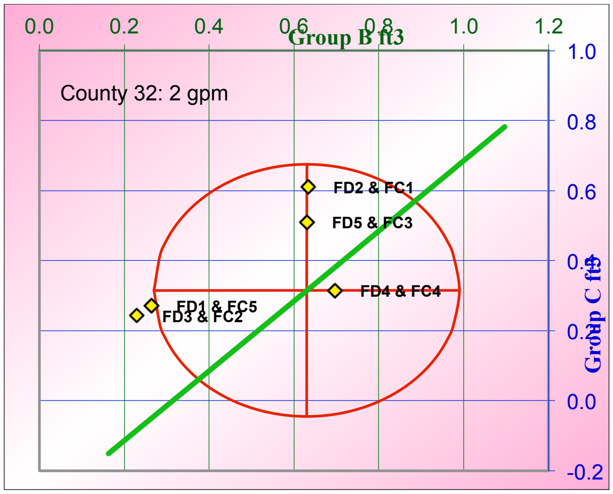
County 32

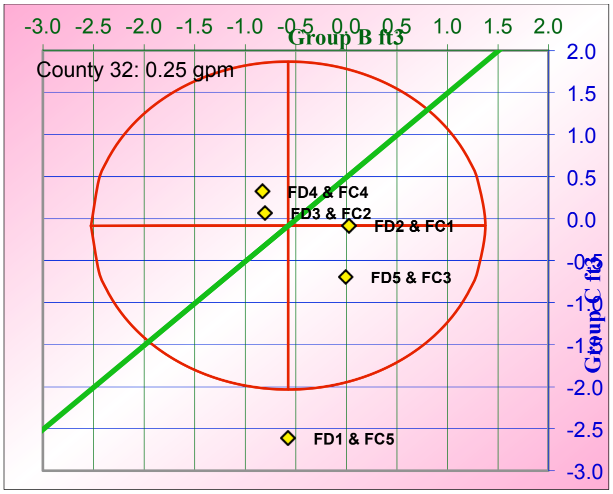
County 32 has a Ford test bench and uses supply tanks and a pumping system to recirculate water for the tests. County 32 had an offset from DMS at 15 gpm for the round-robin tests (0.36, 0.42) that was typical for many of the county labs. The lab had a relatively large median offset from DMS for one group of meters at the flow rate of 2 gpm (0.63, 0.32), but no meters failed tests at this laboratory at this flow rate. The county failed meter FC5 on two of three tests at 0.25 gpm, but this meter tended to have large negative errors at this flow rate. Hence, the test results from this laboratory were reasonably consistent with results from other labs for this meter. The differences bar chart below for meter FC5 shows a rather large difference from the DMS values at 0.25 gpm, but this is not unusual considering the test results for this meter as it was cycled through the other labs.









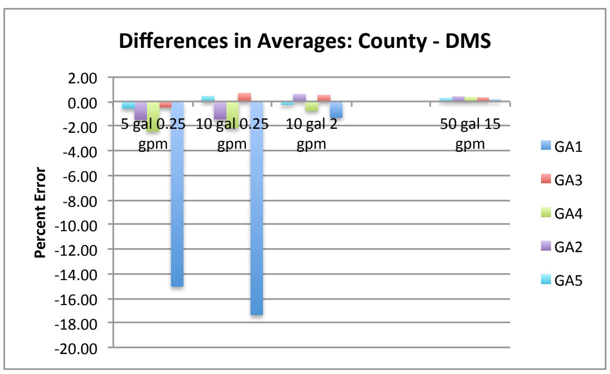


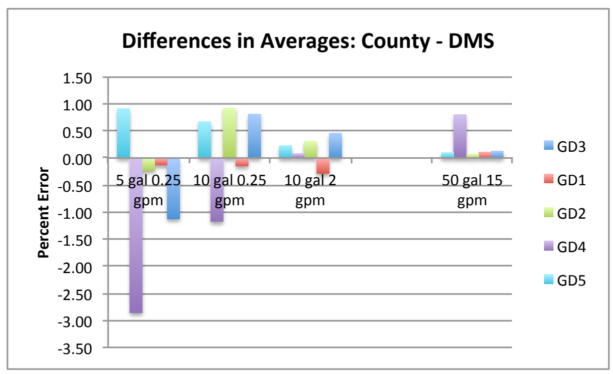
-3.0 -2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0
Group B ft3
County 32: 0.25 gpm
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
Group C ft3
FD4 & FC4
FD3 & FC2
FD2 & FC1
FD5 & FC3
FD1 & FC5

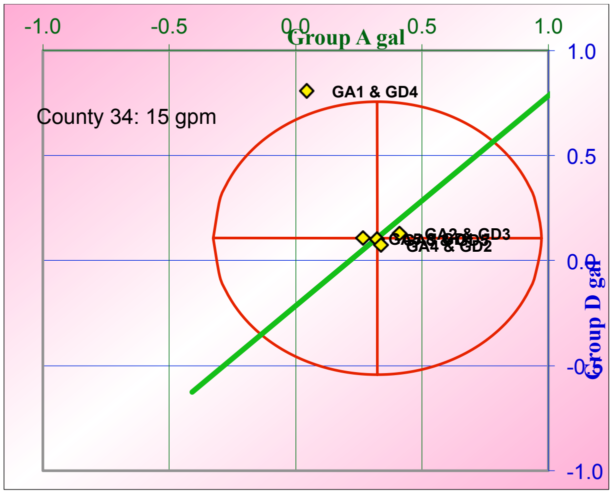
County 34

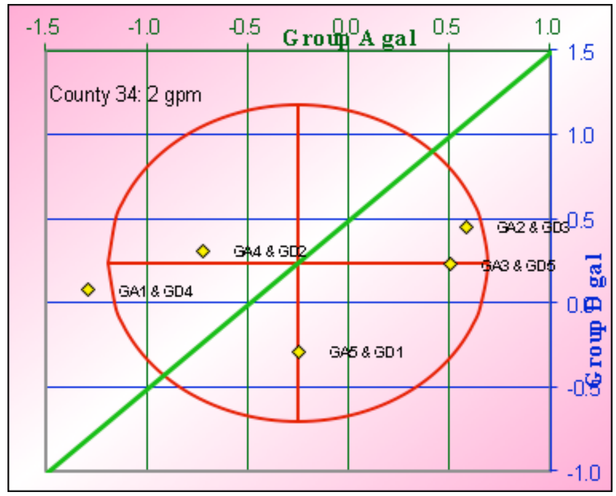
County 34 has a Ford test bench with a capacity of testing four meters at a time. The county has supply tanks and a pumping system to recirculate water for the tests. The flow rates for several of the minimum flow rate tests was slightly below 0.25 gpm, specifically, the flow rates for the tests were 0.25, 0.26, 0.24, 0.23, 0.22, and 0.25 gpm. One meter, GA1, tested at the minimum flow rate in this laboratory had errors that ranged from -8.5% to -26.5%. The flow rates below 0.25 gpm may have contributed to the unusually large minus errors. This county had larger variations in the test results compared to the other county labs, even at the flow rate of 15 gpm. Three meters failed the repeatability tolerance at the minimum flow rate. The large variations observed in the test results are most likely due to characteristics of the laboratory test facility or test procedure than due to the performance of the meters.

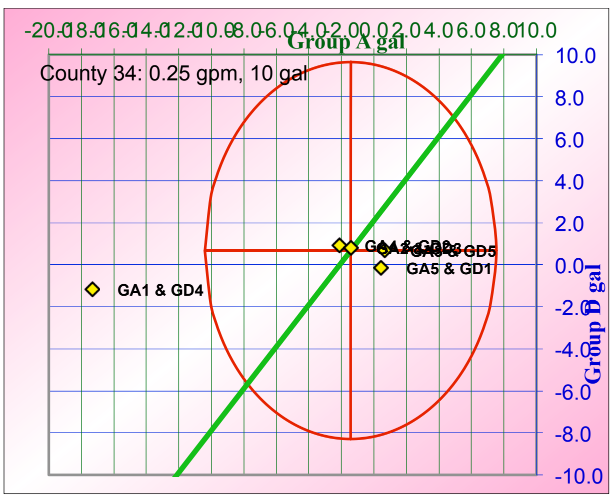
The median offsets at 15 and 2 gpm were not unusual, (0.32, 0.11) and (-0.25, 0.23) respectively; however the median offsets at 2 gpm were not in the same direction or by about the same amount for the two groups of meters, which indicate some inconsistency in the test results. The causes for the large variations in individual test results must be explored further. The county must also check the flow rate at which the minimum flow-rate tests are performed to ensure that the flow rate is at least 0.25 gpm.

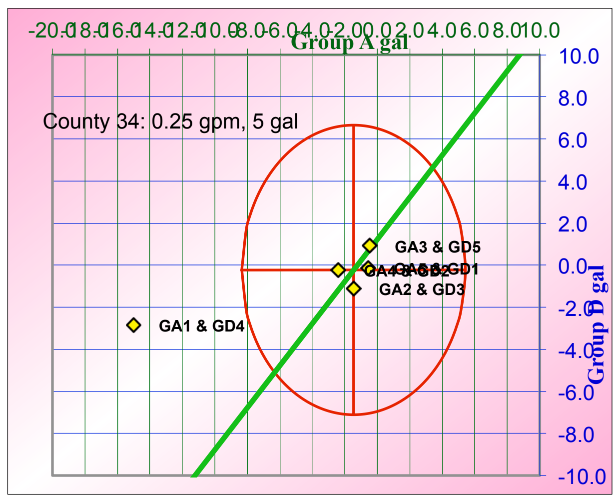





County 34: 15 gpm
Group A gal
Group D gal
GA1 & GD4
GA2 & GD3
GA4 & GD2


County 34: 2 gpm
Group A gal
Group D gal
GA2 & GD3
GA4 & GD2
GA3 & GD5
GA1 & GD4
GA5 & GD1


County 34: 0.25 gpm, 10 gal
Group A gal
Group D gal
GA5 & GD1
GA1 & GD4


County 34: 0.25 gpm, 5 gal
Group A gal
Group D gal
GA3 & GD5
GA2 & GD3
GA1 & GD4

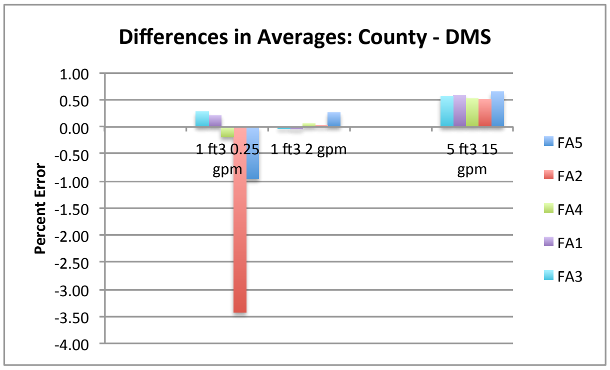
County 35

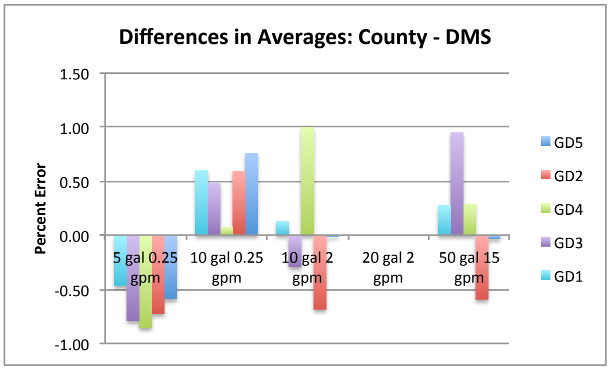
County 35 has a Ford test bench. The county tested one group of meters indicating in gallons and one in cubic feet. The county was among the labs that had the highest median offset (0.28, 0.57) from DMS at the flow rate of 15 gpm; however, the offset was significantly greater for one group of meters than the other. The median offset at 2 gpm was small. At 0.25 gpm, the median offset was fairly large for one group of meters than the other. However, at the minimum flow rate, the Youden plots are not as sensitive to median offsets due to the larger variations in test results at the minimum flow rate.

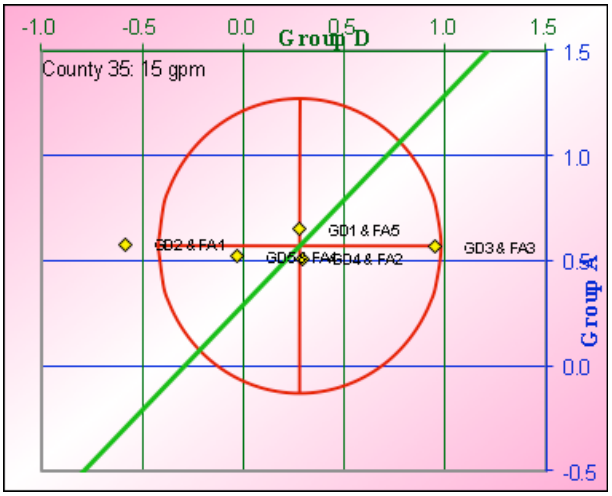
The county had two out-of-tolerance test results at the minimum flow rate for one meter. This is not unusual, because the accuracy of the meter appeared to change in the direction of greater underregistration as the survey progressed. Other labs also had some out-of-tolerance results at the minimum flow rate.

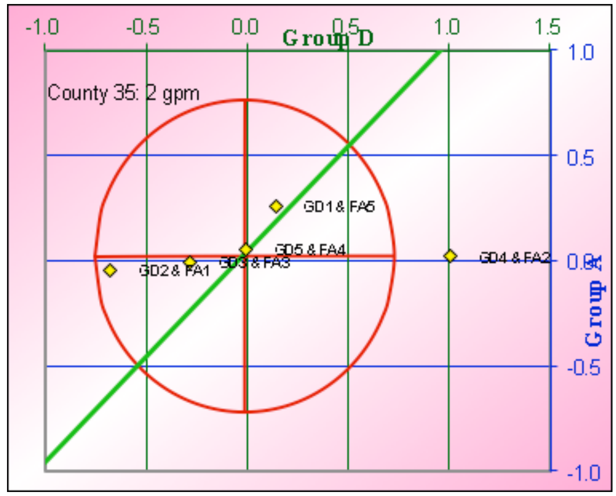
County 35 had several meters for which its test results were higher (greater overregistration) than the results for other county labs that tested the same meters.

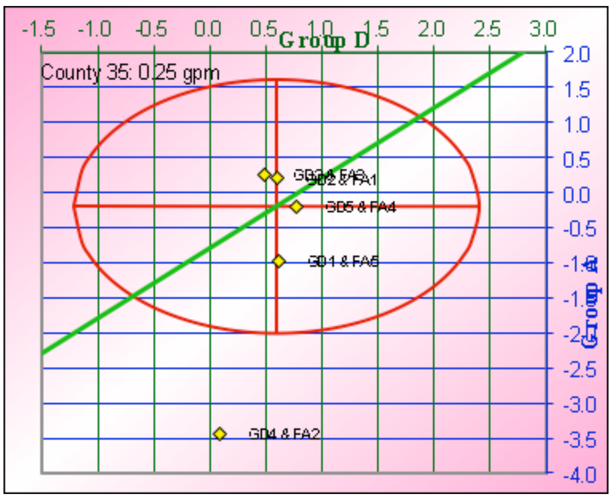
Overall, the standard deviations in the test results for this county were consistent with most of the other labs. However, the standard deviations at 0.25 gpm were among the largest for the county labs.






County 35: 15 gpm
Group D
Group A
GD1 & FA5
GD2 & FA1
GD3 & FA3
GD4 & FA2


County 35: 2 gpm
Group D
Group A
GD1 & FA5
GD2 & FA1
GD3 & FA3
GD4 & FA2
GD5 & FA4

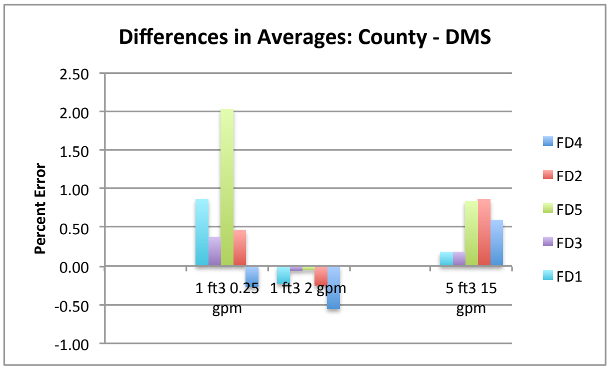

County 35: 0.25 gpm
Group D
Group A
GD2 & FA1
GD5 & FA4
GD1 & FA5
GD4 & FA2

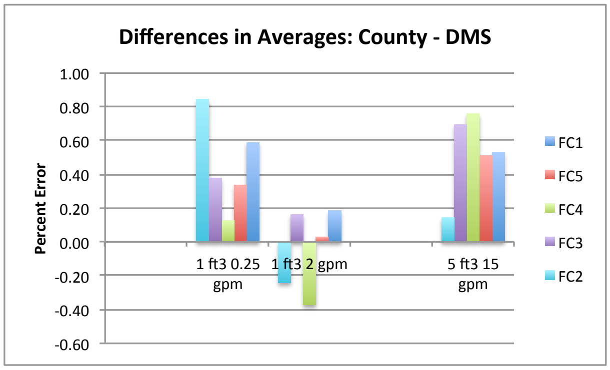
County 43

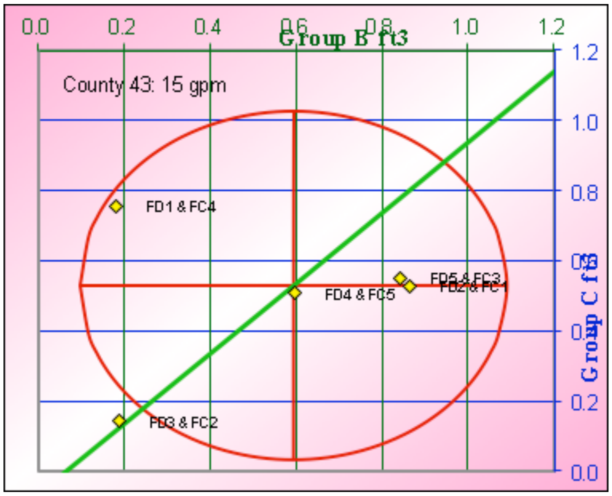
County 43 did not have a Ford test bench. The meters were tested outdoors and connected with pipes. The inlet and discharge lines were comprised of hoses. The reference volume standards were neck-type volume standards, but the larger standard was an unusual configuration. The test results tended to have a large variability, which implies that the test setup is not adequate.

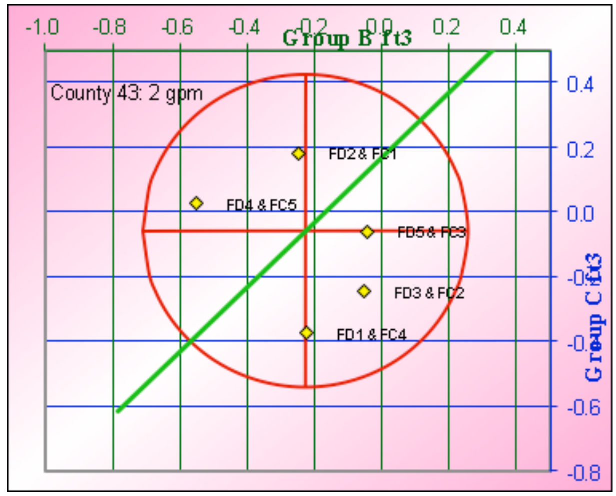
The median offset from DMS at 15 gpm (0.60, 0.53) was among the largest for the county labs. However, at 2 gpm, the median offset from DMS was negative (-0.23, -0.06). At 0.25 gpm, the median offset from DMS was positive (0.46, 0.45). The county also had several meters fail for overregistration at the flow rate of 0.25 gpm, which is different from the test results of other labs on these meters. One meter also failed the repeatability tolerance at 15 gpm, but this is probably due to the test setup rather than the meter. The inconsistency in the test results indicates problems in the test setup.

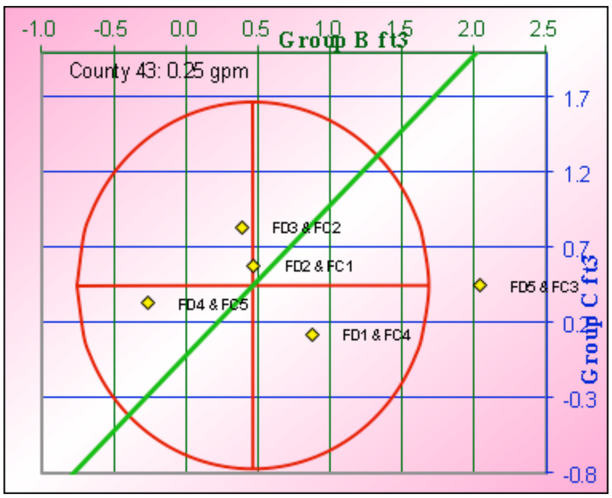
The standard deviation for the test results at 0.25 gpm was the second largest for the county labs. The individual test results for the meters tested show peculiar variations for several of the meters tested. The method of testing meters in this county should be improved.





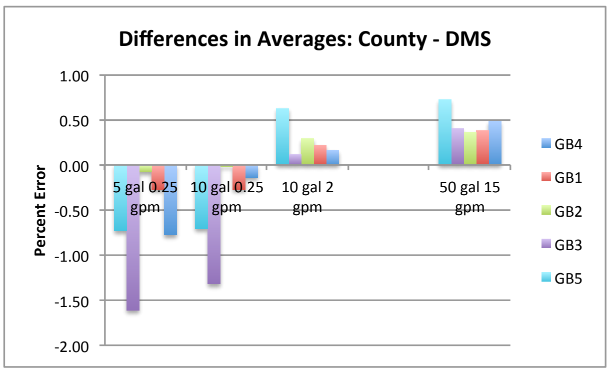

County 43: 15 gpm
Group B ft3
Group C ft3
FD1 & FC4
FD5 & FC3
FD2 & FC1
FD4 & FC5
FD3 & FC2

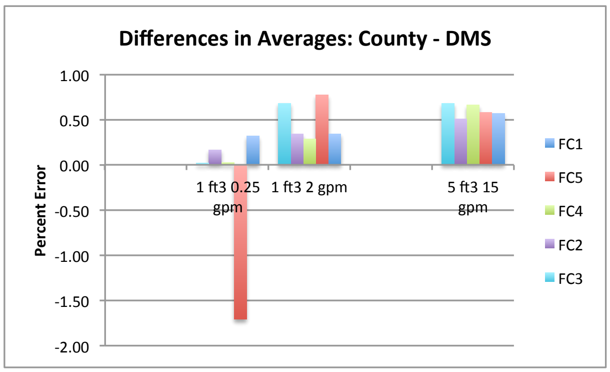

County 43: 2 gpm
Group B ft3
Group C ft3
FD2 & FC1
FD4 & FC5
FD5 & FC3
FD3 & FC2
FD1 & FC4

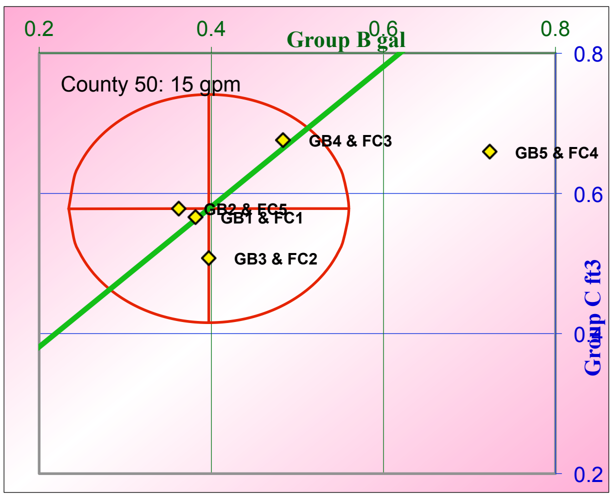

County 43: 0.25 gpm
Group B ft3
Group C ft3
FD3 & FC2
FD2 & FC1
FD5 & FC3
FD4 & FC5
FD1 & FC4

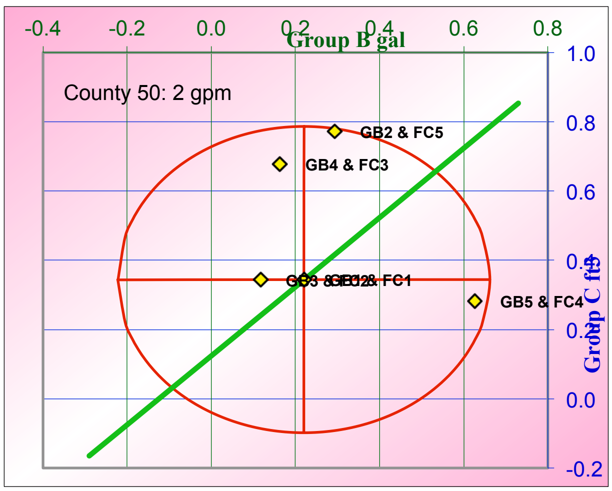
County 50

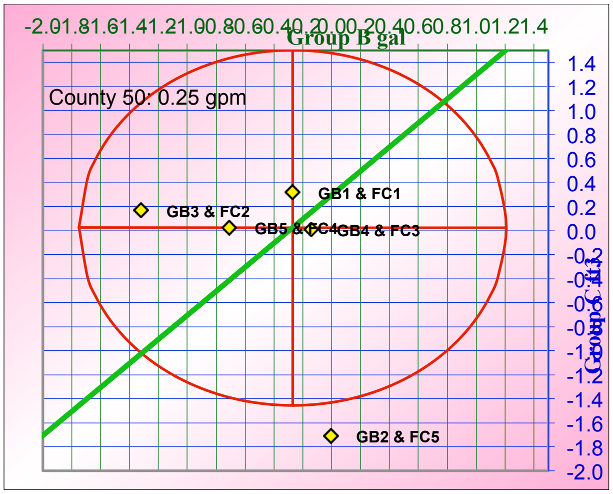
County 50 has a Ford test bench. The county tested one group of meters indicating in gallons and one in cubic feet. On occasion, the test official would stop and start the flow of water several times to stop the test draft on the nominal graduation for the test draft. The laboratory used city water for the tests, i.e., water was not recirculated. The lab had one of the larger median offsets (0.40, 0.58) from DMS for tests at the 15 gpm. The median offsets were significantly less at 2 gpm (0.22, 0.35) and at 0.25 gpm (-0.58, -0.08). The repeatability of test results is comparable or smaller than other county laboratories. Overall, the results for County 50 were typical for the county labs, but the median offset from DMS for tests at 15 gpm are significant. One meter, FC5, was rejected for underregistration at 0.25 gpm, but the results were consistent with those for other labs.









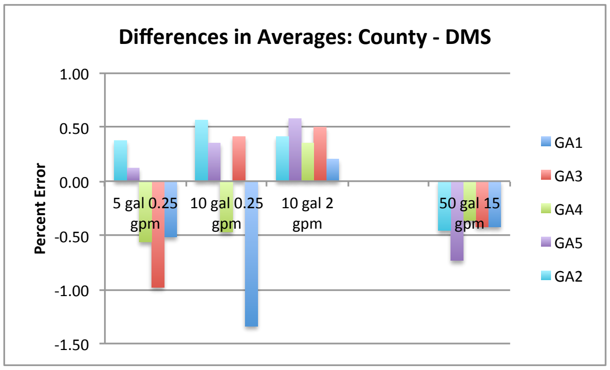

Group B gal
County 50: 0.25 gpm
GB1 & FC1
GB3 & FC2
GB5 & FC4
GB4 & FC3
GB2 & FC5

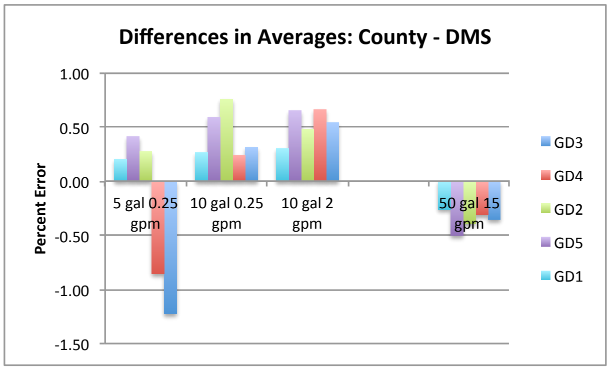
County 51

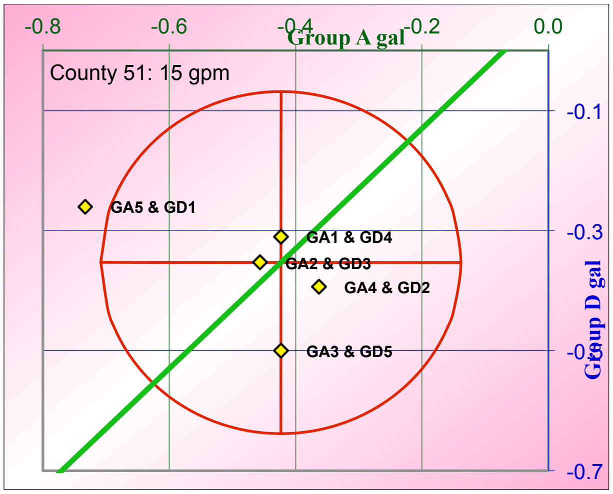
County 51 has a Ford test bench with a capacity to test a large number of meters simultaneously. All of the meters were installed at the discharge end of the test bench. The lab used city water for the tests, i.e., water was not recirculated. The county had the only negative offset from the DMS test results at 15 gpm and the median offset was fairly significant (-0.43, -0.35). The test lab had good temperature control, city water was used for all tests, and the person conducting the tests was careful and meticulous. There wasn't anything in the test facility or the test process that could be identified as the source of the offset compared to the results of other county labs and DMS. The water level in the reference tank varied on occasion from the reference graduation, but the observed variations appeared to be typical to those observed in other laboratories.

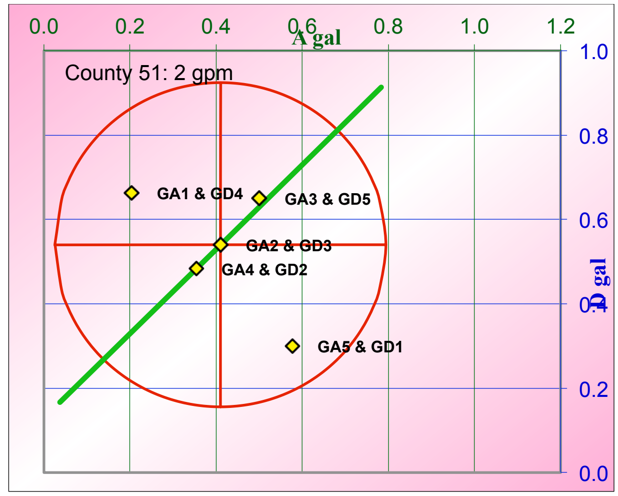
The county had a large number of rejected meters compared to other laboratories, particularly for tests at 15 gpm. There were two meters that failed the repeatability tolerance in this laboratory. Overall, the repeatability (standard deviation) of test results at each flow rate is typical for other county labs. However, the combination of the negative offset and the usual variation in the individual test results were enough to generate out of tolerance values for three meters. The three meters that were found to be out of tolerance at 15 gpm were found to underregister according to test results from other labs, but none of the other county labs had out-of-tolerance results for these particular meters at 15 gpm. Additionally, the significant negative offset from DMS and the other county labs existed for all of the meters in the two groups tested by this laboratory.

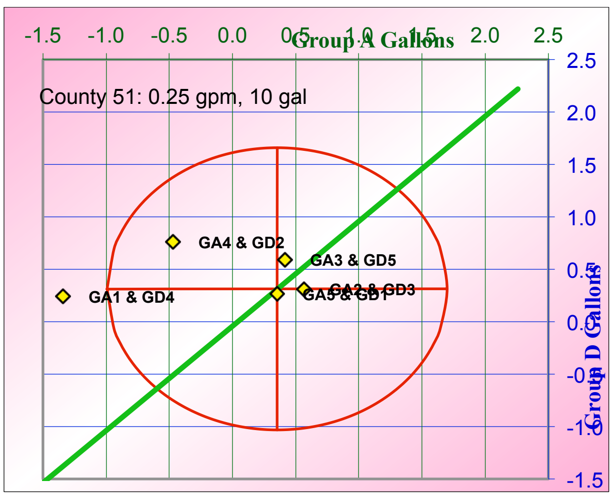
The laboratory had a significant, but positive, median offset (0.41, 0.54) from DMS for tests run at 2 gpm. The amount and change in the direction of the offset is unusual. A different reference tank was used for the tests at 2 gpm than at 15 gpm. Still, there wasn't anything obvious in the test facility, the test process or the reference standards that explains the offsets or the change in direction of the offsets for the 15- and 2-gpm tests.

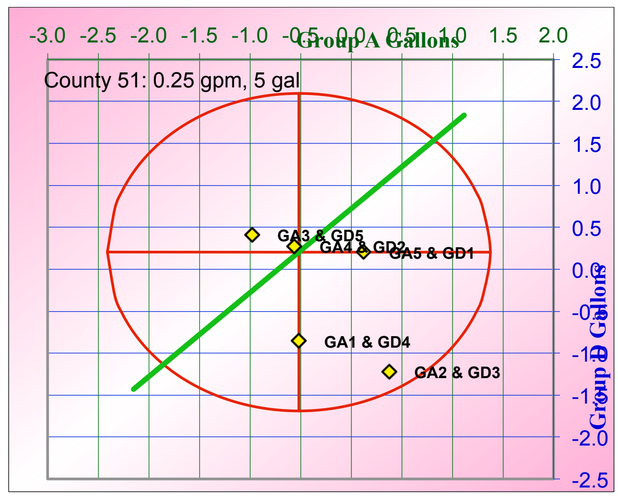





Group A gal
Group D gal
County 51: 15 gpm
GA5 & GD1
GA1 & GD4
GA2 & GD3
GA4 & GD2
GA3 & GD5
-0.8
-0.6
-0.4
-0.2
0.0
-0.1
-0.3
-0.7


A gal
D gal
County 51: 2 gpm
GA1 & GD4
GA3 & GD5
GA2 & GD3
GA4 & GD2
GA5 & GD1
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0.0
0.2
0.6
0.8
1.0


Group A Gallons
Group D Gallons
County 51: 0.25 gpm, 10 gal
GA4 & GD2
GA3 & GD5
GA1 & GD4
GA5 & GD1
-1.5
-1.0
-0.5
0.0
2.0
2.5
1.5
-1.5

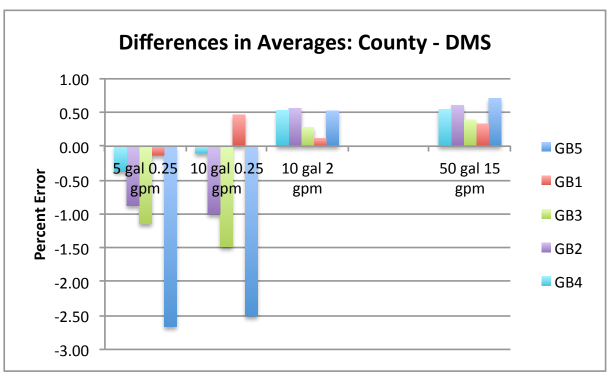

Group A Gallons
Group D Gallons
County 51: 0.25 gpm, 5 gal
GA3 & GD5
GA4 & GD2
GA5 & GD1
GA1 & GD4
GA2 & GD3
-3.0
-2.5
-2.0
-1.5
-1.0
1.5
2.0
2.5
1.0
0.5
-2.0
-2.5

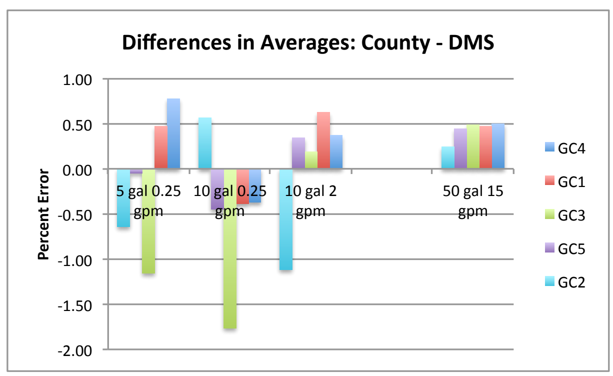
County 52

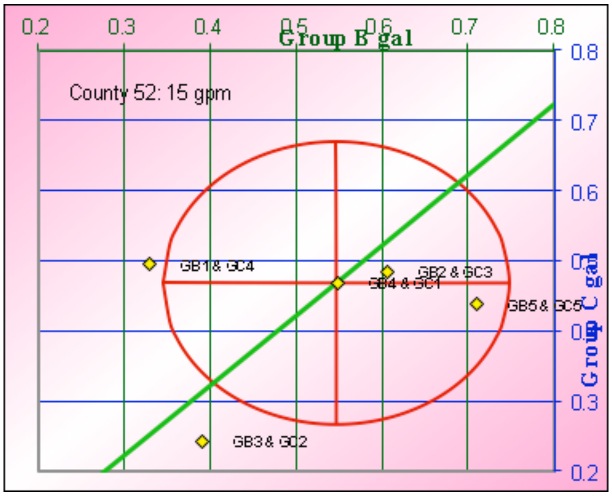
County 52 has a Ford test bench and uses city water to test the water meters. While the median offset (0.55, 0.47) from the DMS values at 15 gpm is among the largest for the counties, it is similar to the values for several other counties. There was a positive offset of the median values at 2 gpm (0.53, 0.34). There were significant negative offsets at the flow rate of 0.25 gpm for both test drafts (10 and 5 gal), but these offsets might well be have been shifted negative due to the performance characteristics of some of the meters in the two groups of meters.

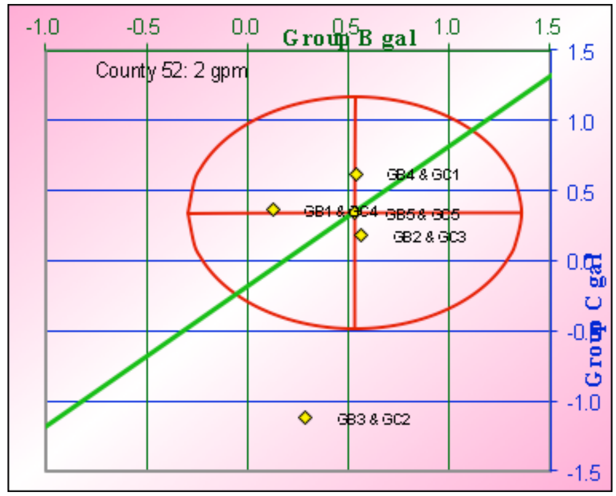
There are some variations in individual test results that look peculiar. For meter GC1 at 2 gpm, one test result is significantly different in the direction of overregistration. The range of the test results for this meter at 0.25 gpm for the 5-gal test is also large for three of the labs. County 52 also had a large positive (overregistration) value for GC2 at 0.25 gpm for the 10-gal test draft. This variation resulted in an out-of-tolerance condition for repeatability for meter GC2. There was also a large variation in test results for the 5-gal test draft. Similarly, there is a large positive test result for meter GC4 at 0.25 gpm for the 5-gal test draft. The test process should be examined to see if anything could be identified as the cause of these variations.

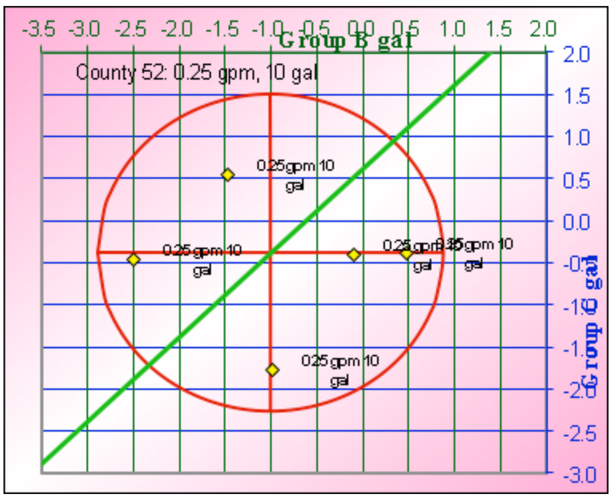
Overall, the standard deviations for this county were consistent with many of the other county labs, but the standard deviation at the flow rate of 0.25 gpm for the 10-gal test draft is one of the largest standards deviations for the county labs.

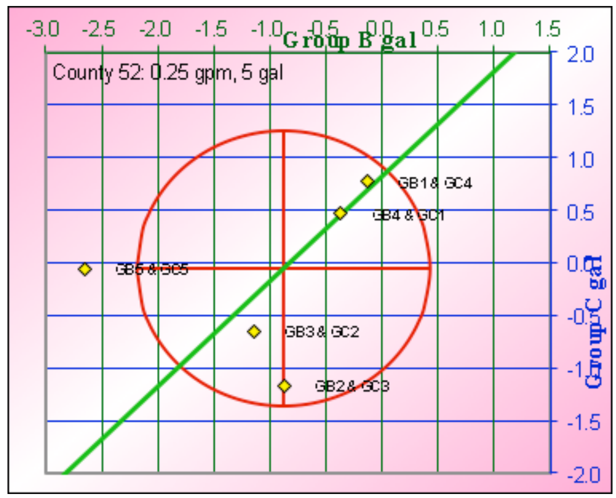





County 52: 15 gpm
Group B gal
Group C gal
GB1 & GC4
GB2 & GC3
GB4 & GC1
GB5 & GC5
GB3 & GC2

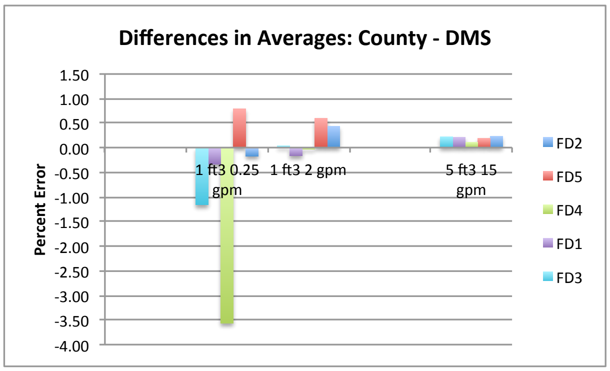

County 52: 2 gpm
Group B gal
Group C gal
GB4 & GC1
GB1 & GC4
GB5 & GC5
GB2 & GC3
GB3 & GC2

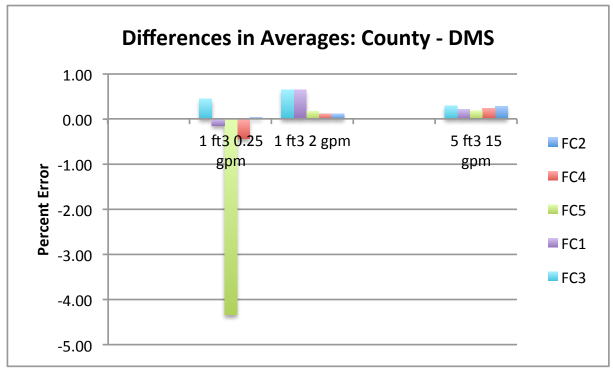

County 52: 0.25 gpm, 10 gal
Group B gal
Group C gal
0.25gpm 10 gal

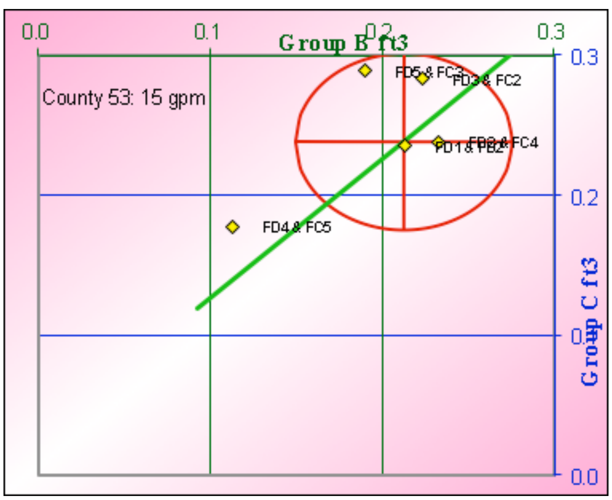

County 52: 0.25 gpm, 5 gal
Group B gal
Group C gal
GB1 & GC4
GB4 & GC1
GB5 & GC5
GB3 & GC2
GB2 & GC3

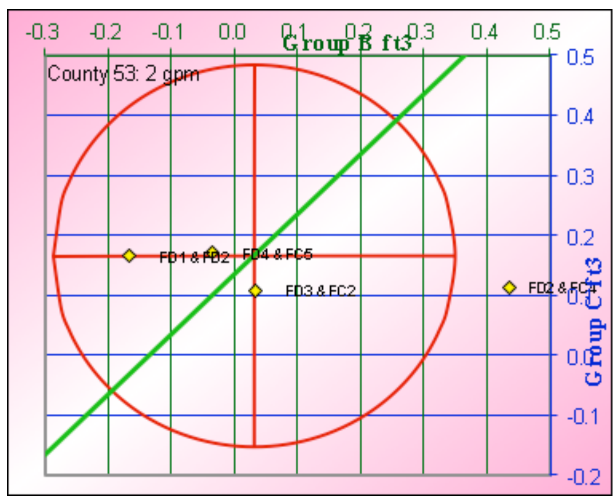
County 53

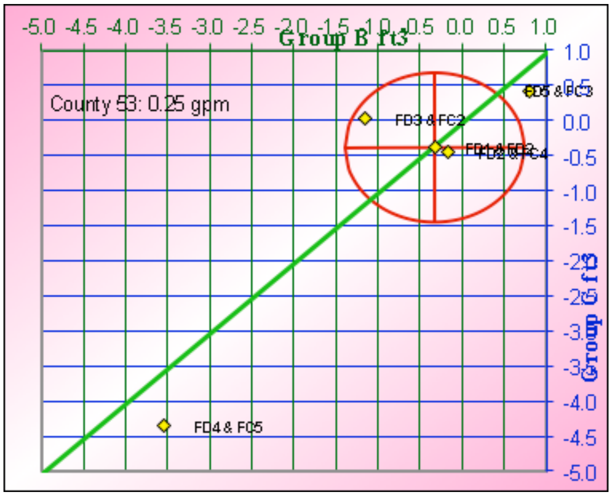
County 53 has a Ford test bench and uses supply tanks and a pumping system to recirculate water for the tests. The county results agreed reasonably well with the DMS results. The standard deviations were typical of the other county labs. The county had two meters with out-of-tolerance results, but it appears that the accuracy of the meter changed at the minimum flow rate during the survey so that the test results appear to reflect the performance of the meters at the times they were tested.









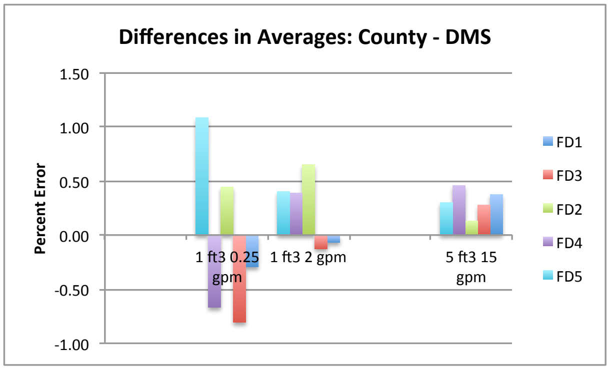


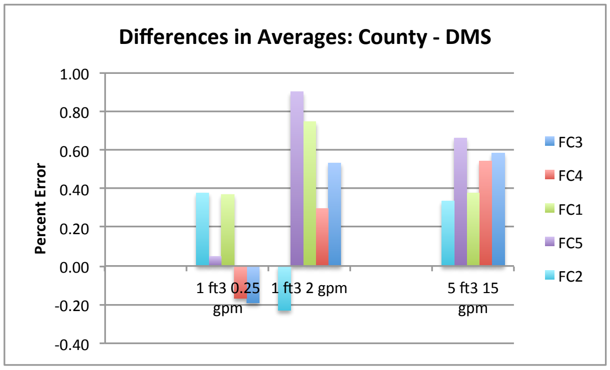
Group B ft3
Group C ft3
County 53: 0.25 gpm
FD5 & FC3
FD3 & FC2
FD1 & FD2
FD2 & FC4
FD4 & FC5

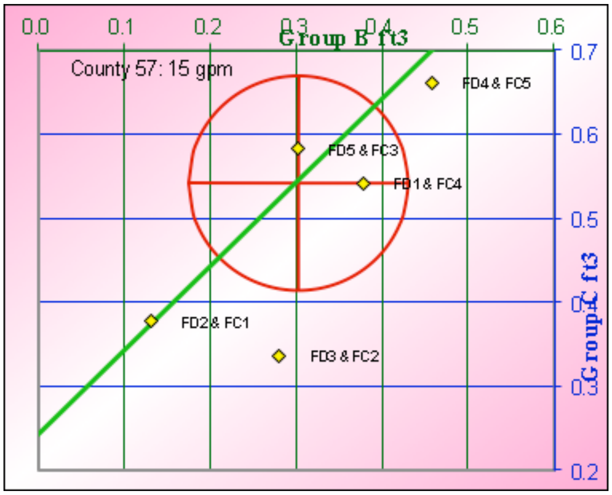
County 57

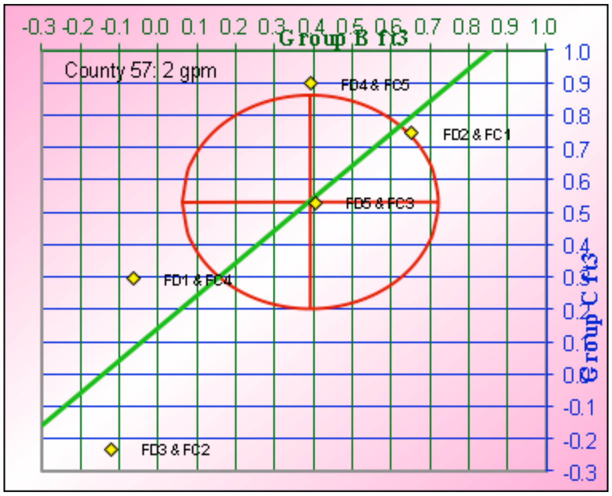
County 57 has a Ford test bench and uses a supply tank and a pumping system to recirculate water for the tests. The median offsets from DMS for the flow rates of 15 and 2 gpm were significantly positive (toward overregistration), but consistent with the results for several other labs. The median values are (0.30, 0.54) and (0.39, 0.53). The median offset at 0.25 gpm was small. Despite the positive offsets for the 15- and 2-gpm flow rates, only one meter, FC1, failed the accuracy tolerance with an error of +1.56%. Three meters failed the repeatability test at 15 gpm. Although an incorrect procedure was used for the first test, even if the first test was omitted from the analysis, there is still a significant amount of variation in the last two tests at 15 gpm. If the first test were omitted, two meters would still fail the repeatability tolerance. The cause of the variations in the test results at 15 gpm should be investigated.

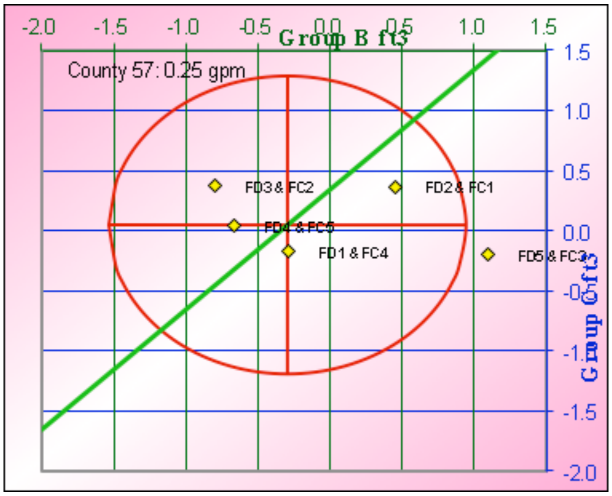
County 57 has one of the largest standard deviations at 15 gpm. The repeatability (standard deviations) at the 2- and 0.25-gpm flow rates is typical for the counties.









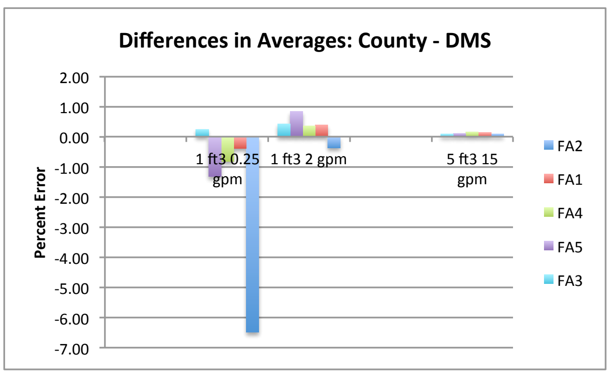


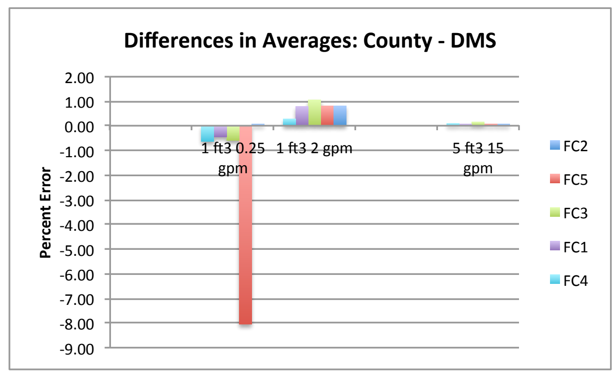
Group B ft3
County 57: 0.25 gpm
FD3 & FC2
FD2 & FC1
FD4 & FC5
FD1 & FC4
FD5 & FC3
Group C ft3
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5

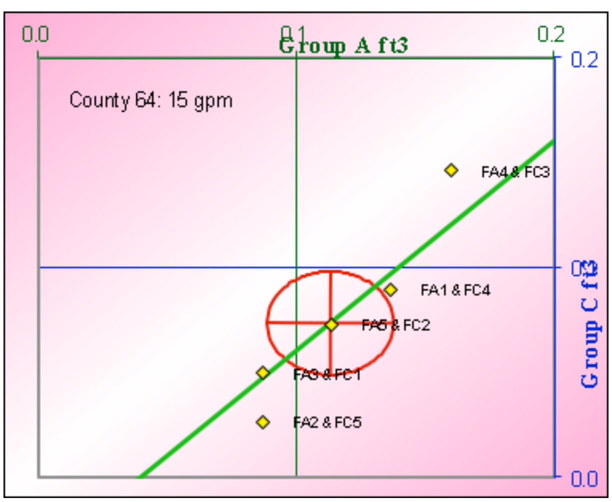
County 64

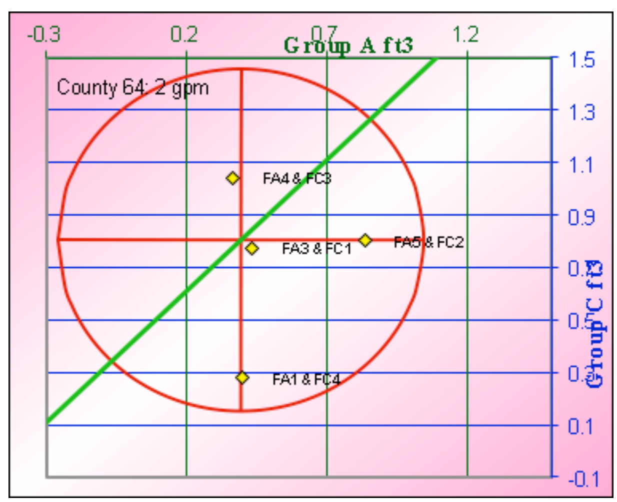
County 64 has a Ford test bench and uses a supply tank and a pumping system to recirculate water for the tests. The county agreed well with DMS for the tests at 15 gpm. The median offset at 2 gpm (0.39, 0.81) was one of the larger offsets for the county labs. At 0.25 gpm, the offset (-0.82, -0.59) was significant relative to the DMS results. However, the two meters, FA2 and FC5, that failed the accuracy tests at 0.25 gpm also failed for underregistration in other labs. Based on the test results for other meters in these two groups of meters, it is likely that the large underregistration errors are due to the performance of these particular meters. The other meters in these groups did not show a significant difference in the test results for this lab compared to the results of other labs.

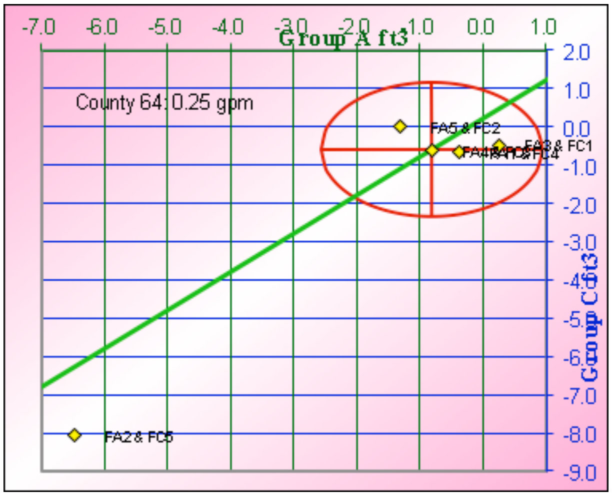
The standard deviations for County 64 are consistent or smaller than for the other labs.







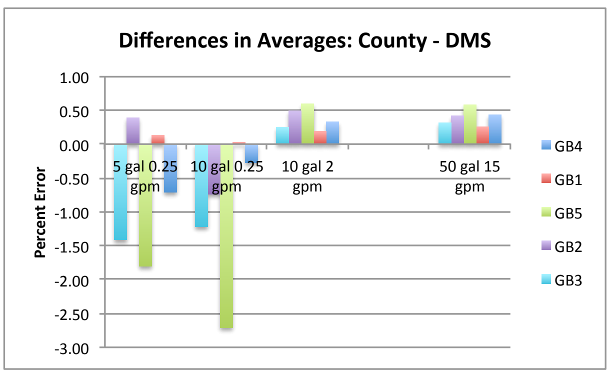


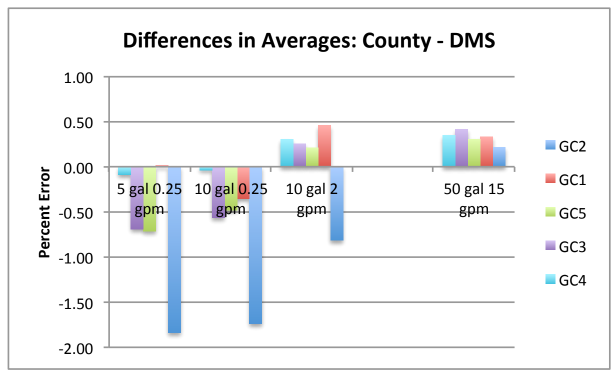


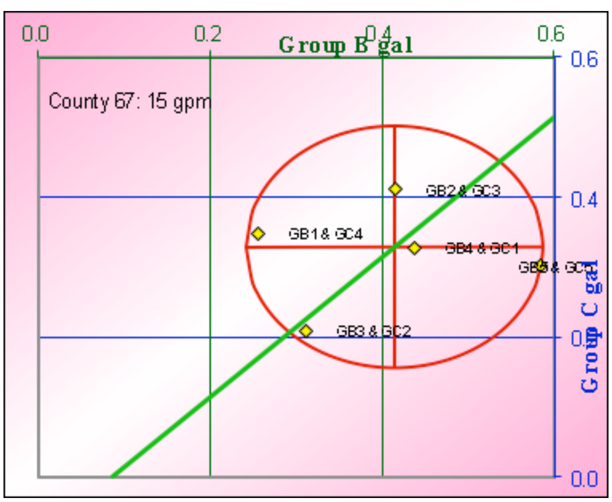
Group A ft3
Group C ft3
County 64: 0.25 gpm
FA5 & FC2
FA3 & FC1
FA2 & FC5
-7.0
-6.0
-5.0
-4.0
-3.0
-2.0
-1.0
0.0
1.0
2.0
-8.0
-9.0

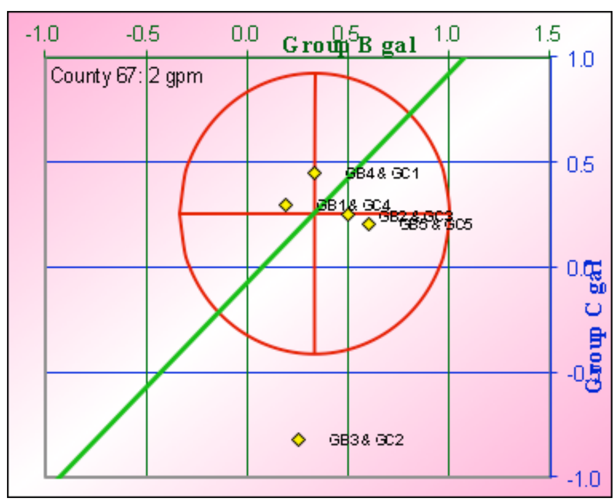
County 67

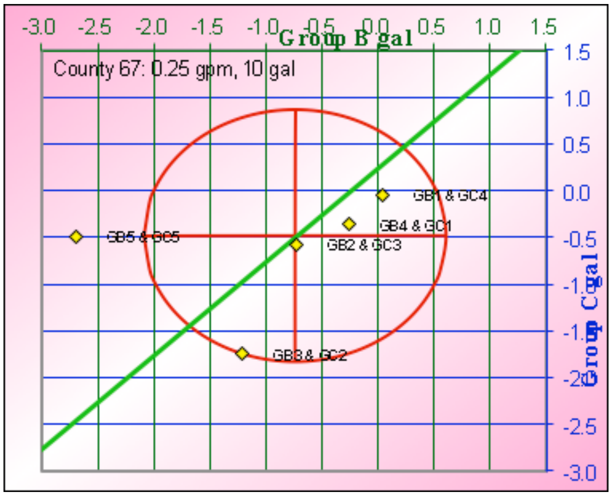
County 67 has a Ford test bench and uses city water to test the meters, that is, recirculated water is not used. The test bench was installed outdoors. The median offset from DMS results (0.42, 0.33) at 15 gpm was about in the middle of the offsets observed for the counties. The median offset at 2 gpm for was relatively small. The median offsets at 0.25 gpm for the 10-gal and the 5-gal test drafts [(-0.74, -0.48) and (-0.71. -0.69), respectively] were negative (more underregistration) compared to the DMS results. The county had one of the larger standard deviations in the test results at the flow rate of 0.25 gpm for the 5-gal test draft. However, the standard deviation at the flow rate of 0.25 gpm for the 10-gal test draft was relatively small compared to the other counties. The county had one meter, GB2, fail the repeatability tolerance at 15 gpm. The variation in the results for this meter was relatively large compared to the other meters tested at 15 gpm. The laboratory also had some significant variation in the test results for meter GB3 at 15 gpm, but the range did not exceed the repeatability tolerance. None of the meters failed the accuracy tolerances. Although the test bench was installed outdoors, the test results for the county were typical of the results for the county laboratories.

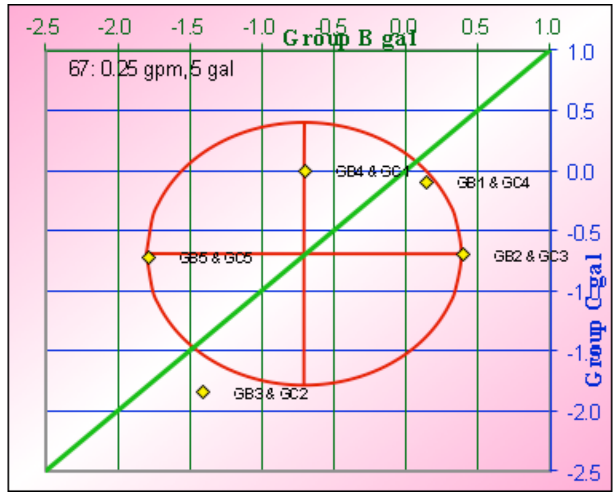








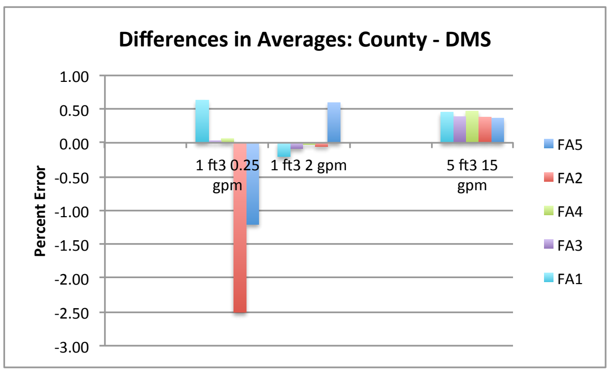

Group B gal
Group C gal
County 67: 0.25 gpm, 10 gal
GB1 & GC4
GB4 & GC1
GB2 & GC3
GB5 & GC5
GB3 & GC2

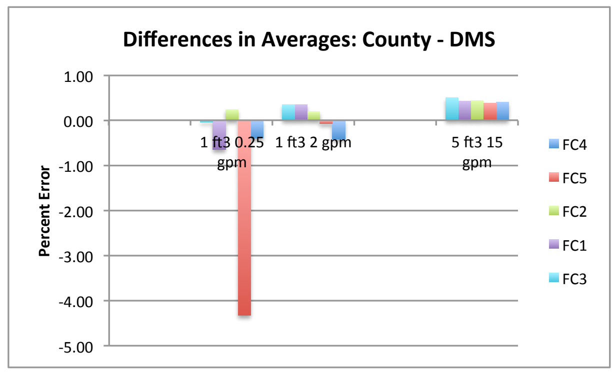

Group B gal
Group C gal
67: 0.25 gpm, 5 gal
GB4 & GC1
GB1 & GC4
GB5 & GC5
GB2 & GC3
GB3 & GC2

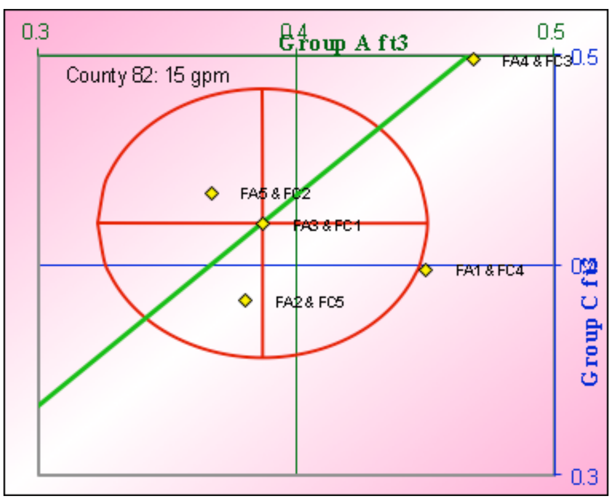
County 82

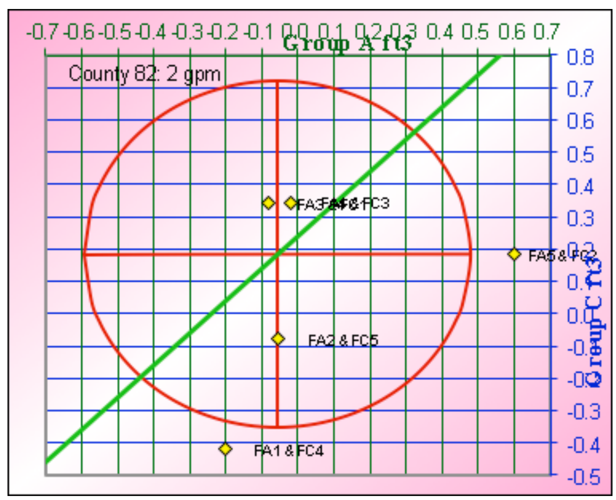
County 82 has a Ford test bench and uses a supply tank and a pumping system to recirculate water for the tests. The median offset (0.37, 0.42) for County 82 from the average DMS values at 15 gpm was consistent with many other county labs. The median offsets were relatively small for the flow rates of 2 and 0.25 gpm. County 82 had out-of-tolerance results for meter FC5, which several other labs also determined. These out-of-tolerance results are probably due to the performance of the meter.

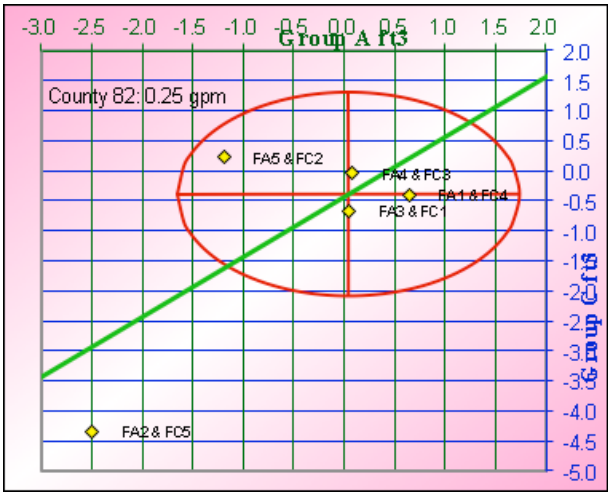
The repeatability (standard deviations) for this lab at each flow rate is typical of the results from the other county labs.









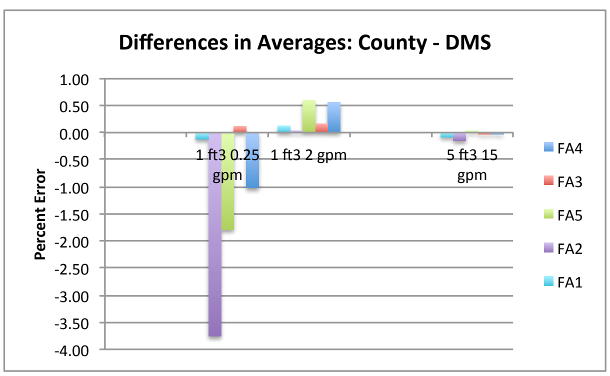

Group A ft3
Group C ft3
County 82: 0.25 gpm
FA5 & FC2
FA4 & FC3
FA1 & FC4
FA3 & FC1
FA2 & FC5

County 85

County 85 has a Ford test bench and used city water as the water supply. The test results at the flow rates of 15 and 2 gpm agreed well with the DMS results. The test results at 0.25 gpm varied from essentially agreement with DMS on two meters, but with some differences on the other meters. Meter FA2 failed the accuracy tolerance for two tests at 0.25 gpm; however, the accuracy of the meter appears to have changed during the survey. Consequently, some of the average difference for this meter from the initial DMS average value is understandable. The out-of-tolerance results at 0.25 gpm are consistent with the results of the lab that tested the meter before County 85. Nevertheless, the DMS values for this meter at the minimum flow rate were still significantly different (about 2%) than the results obtained by County 85.

County 85 had an out-of-tolerance result for meter FA2 at 15 gpm. This result was unusually far off from the other two tests. The results of two of the 15-gpm tests for meter FA2 agreed well with the results of the other labs, but the third test result is inconsistent. The meter would fail the repeatability tolerance, but this is probably due to something in the test process, rather than due to meter performance.

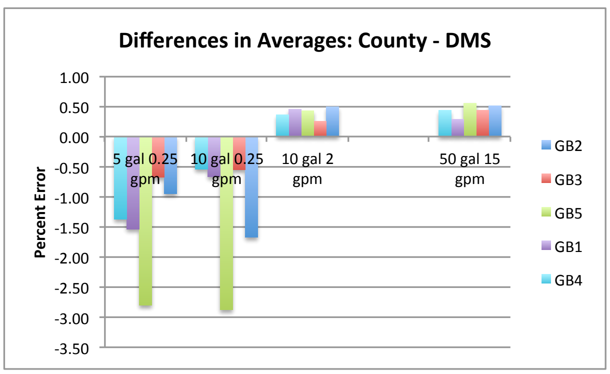
The standard deviations for all of the flow rates were among the largest standard deviations for the counties. The cause of the large variations in the test results should be explored with the objective to reduce the variation in the test results.

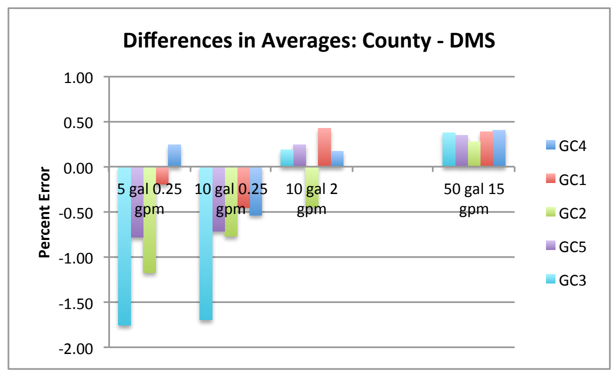


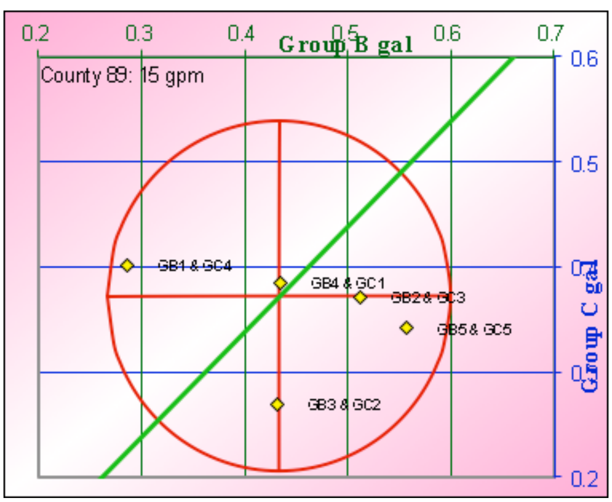
County 89

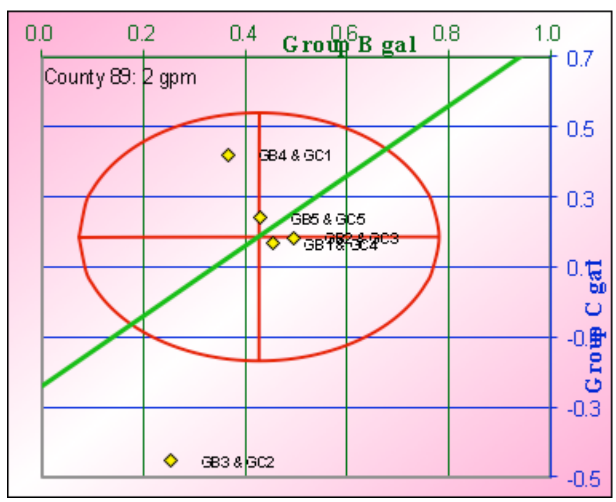
County 89 has a Ford test bench and uses a supply tank and a pumping system to recirculate water for the tests. The median offset (0.43, 0.37) from DMS at 15 gpm was significant, but typical for a large number of county labs. The median offset at 2 gpm (0.43, 0.19) was somewhat large, but not unusual compared to the other county labs. The median offset (-0.67, -0.71) at 0.25 gpm for the 10-gal test draft was significant, but not unusual. The median offset (-1.38, -0.78) at 0.25 gpm for the 5-gal test draft was one of the largest for this flow rate and test draft. Despite these offsets, none of the meters failed the accuracy tolerances at any of the flow rates.

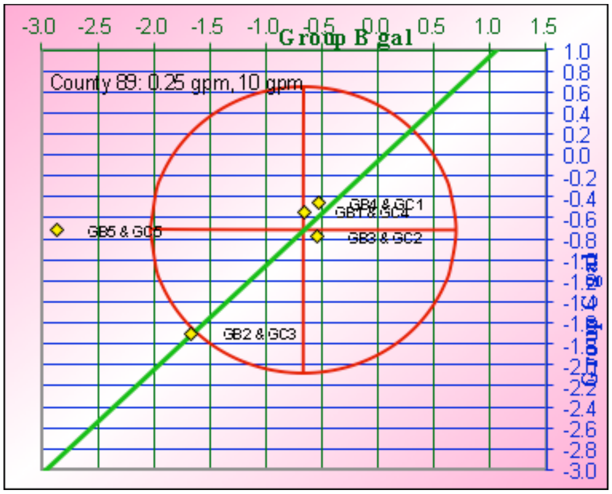
The standard deviations for the lab are typical for the county labs, although the standard deviation at 0.25 gpm and the 5-gal test draft was one of the largest for the county labs. Nevertheless, none of the meters failed the repeatability tolerances.

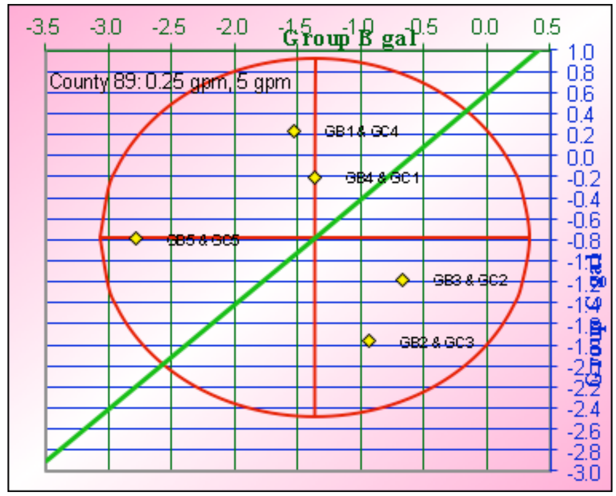








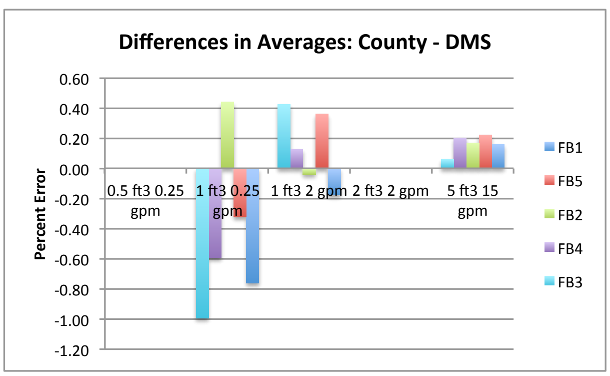

Group B gal
County 89: 0.25 gpm, 10 gpm
GB4 & GC1
GB1 & GC4
GB3 & GC2
GB5 & GC5
GB2 & GC3


Group B gal
County 89: 0.25 gpm, 5 gpm
GB1 & GC4
GB4 & GC1
GB5 & GC5
GB3 & GC2
GB2 & GC3

County 93

County 93 has a Ford test bench and used city water as the water supply. Two of the flow rates for the tests at the minimum flow rate were below 0.25 gpm. When the flow rate was increased for the last minimum flow rate test, the meter errors were less than when the flow rates were below 0.25 gpm. Nevertheless, none of the meters failed accuracy or repeatability tests. However, the change in meter accuracy when the flow rate was increased above the minimum of 0.25 gpm, the standard deviation for the laboratory at the minimum flow rate was one of the largest for the counties.

Overall, the offsets of the test results at 15 gpm were about 0.2% or less. At the flow rate of 2 gpm, the differences in test results were both positive and negative relative to the DMS results. At the minimum flow rate, four of the five meter errors were more negative than the DMS results, but not to any extreme. Overall, the results of the tests agreed well with the DMS results.

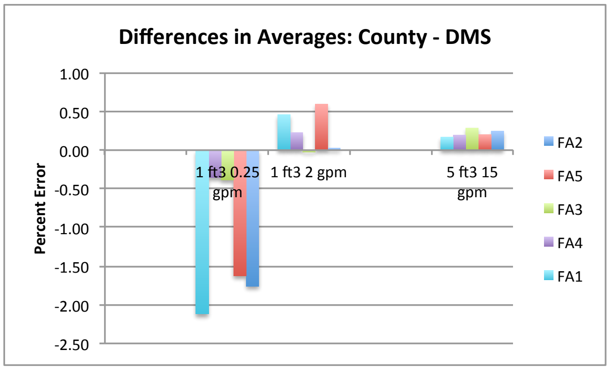


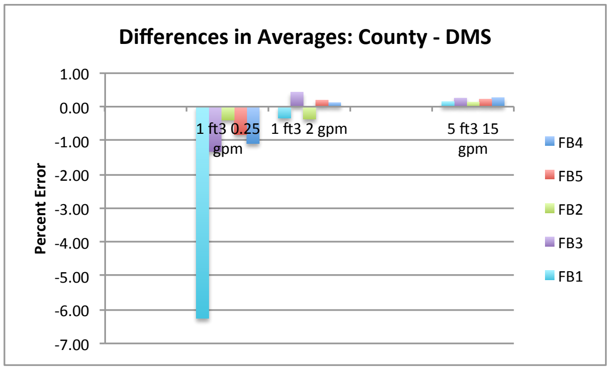
County 94

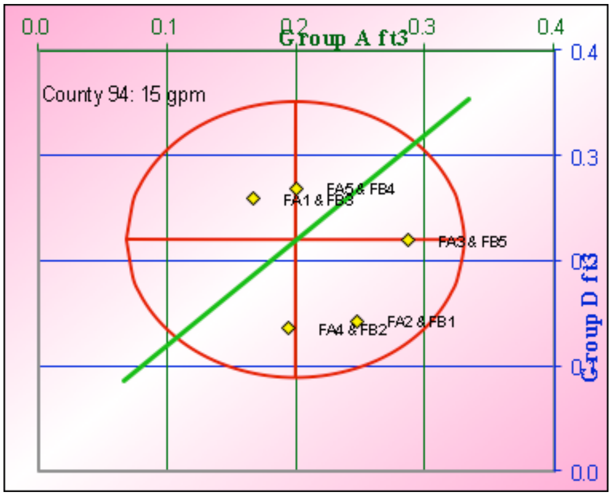
County 94 has a Ford test bench and uses a supply tank and a pumping system to recirculate water for the tests. The median offsets for County 94 at the flow rates of 15 and 2 gpm were small, which indicates good agreement with the initial DMS results. The median offset (-1.62, -1.09) at 0.25 gpm for the 1-ft^3 test draft was the largest for the county labs. However, only one meter, FB1, had test results outside the accuracy tolerance at the 0.25-gpm flow rate. The county lab (County 7) that tested meter FB1 after County 94 also found the meter to be out of tolerance for underregistration. However, when DMS tested the meter at the conclusion of the survey, the test results for the meter at the flow rate of 0.25 gpm were well within tolerance. It isn't clear if the rather large underregistration errors are due to the laboratory facility or due to the performance of the meter.

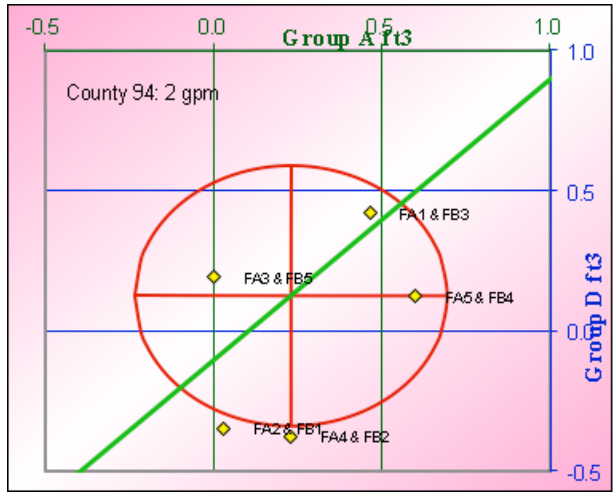
In general, the test results for County 94 on the FA group of meters were not unusual. However, the test results for meter FA1 at 0.25 gpm were lower than the other labs. The accuracy of meter FA2 at 0.25 gpm appears to have changed (toward more underregistration) during the survey, so County 94 would be expected to obtain results that would be more negative (more underregistration) than the initial DMS test results.

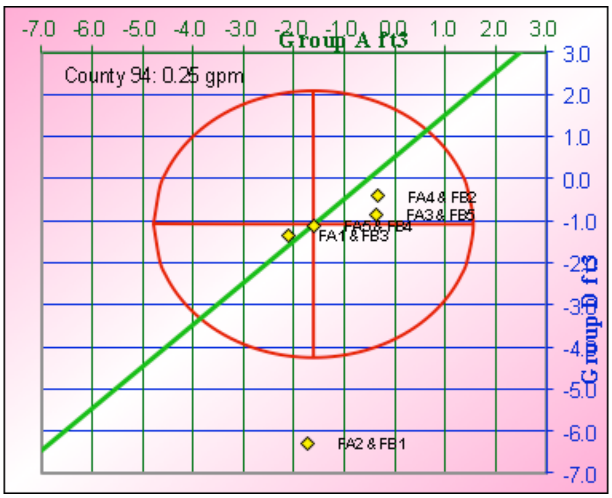
The accuracy of meter FB3 may have changed at the flow rate of 0.25 gpm during the survey, because the last four labs to test the meter had significant underregistration errors compared to the labs that tested this meter earlier in the survey. The results for meter FB4 at 0.25 gpm were also lower (more underregistration) for the last four labs that tested the meter compared to the results from the manufacturer and the initial tests by DMS.






County 94: 15 gpm
Group A ft3
Group D ft3
FA5 & FB4
FA1 & FB3
FA3 & FB5
FA4 & FB2
FA2 & FB1


County 94: 2 gpm
Group A ft3
Group D ft3
FA1 & FB3
FA3 & FB5
FA5 & FB4
FA2 & FB1
FA4 & FB2


County 94: 0.25 gpm
Group A ft3
Group D ft3
FA4 & FB2
FA3 & FB5
FA5 & FB4
FA1 & FB3
FA2 & FB1

Potential Sources of Error

Reading Errors

Reading errors occurred relatively frequently, but the frequency of reading errors varied from lab to lab. Many labs did not have any reading errors, but others had from one to five reading errors for all of the sets of tests. Some of the people who ran the tests in some of the county labs were relatively inexperienced in water meter testing. In other labs, the test official had many years of experience. However, even some of the experienced people made reading and recording errors. Not all of the reading errors resulted in an out-of-tolerance conditions for the tests. Nevertheless, the frequency of reading errors is a major concern.

The registers on some of the meters contributed to some of the reading errors. In particular, one brand of meter register made the change in the smallest displayed digit of the register with the transition beginning between 6 and 7 on the outer dial and completed the transition between 8 and 9 on the outer dial. If the test official was not aware of the point of transition in the dial readings, reading errors often occurred when the start or end readings were after the transition was completed, but before the dial indicator passed the zero graduation.

A number of these errors might have been detected and corrected if all of the county officials had computed the meter errors for the tests conducted for this survey. Some counties have a policy to retest all meters that failed the initial test. The policy was that if a meter passed the retest, the meter would be passed. Under this policy, a retest of the meters would effectively eliminate a reading error, because it is unlikely that a reading error will occur twice on the same meter in two independent tests.

Since three tests were performed on each meter at each flow rate, the existence of reading errors could be detected. For example, if in one test a meter had a meter error of -10%, but if the same meter had a +10% error on the next test at the same flow rate and test draft size, this clearly indicated that there was a reading or recording error, which was corrected in the data analysis for this survey. However, in the normal test process in the county laboratories, only one test is conducted on each meter at each flow rate. Consequently, many of these reading errors might not be detected.

Care must be taken to minimize the number of reading or recording errors that occur when testing water meters. The following courses of action are offered for consideration.

1. When training a new employee to test water meters, both the testing official and the training official should independently read each meter under test and then compare readings to ensure that the new employee is reading and recording the readings correctly.
2. The errors for meters should be calculated before the water meters are removed from the test bench. Ideally, the meter errors for each test should be computed

before the next run begins, so that if unusual meter errors are observed, at least the final reading of the meter can be verified to ensure that the recorded reading is correct.

3. The testing official should be cognizant that reading and recording errors are possible. The testing official should develop his or her own technique to check readings and minimize errors. The most common reading and recording errors observed were:
    a. Recording one number above or below the correct number in one of the digits;
    b. Recording a number that is off by one-half of the smallest division on the register, e.g., recording a 6 instead of a 1 or an 8 instead of a 3; or
    c. Transposing numbers, e.g., recording 30 instead of 03.

To help identify potential reading errors due to recording one digit (or half division) above or below the actual number, the table below has been created to show the magnitude that these types of reading errors will translate into the values computed as meter errors for specific sizes of test drafts. If meter errors appear regularly similar to the values associated with the reading errors illustrated below, the test official should consider that the apparent meter error might be due to a reading or recording error and double check the readings.

Test Draft (ft^3)	Reading Error	% Error	Test Draft (gallons)	Reading Error	% Error
1	0.001	-0.1	5	0.01	-0.2
1	0.005	-0.5	5	0.05	-1
1	0.01	-1	5	0.1	-2
1	0.05	-5	5	0.5	-10
1	0.1	-10	5	1	-20
1	0.5	-50			
1	1	-100	10	0.01	-0.1
			10	0.05	-0.5
2	0.001	-0.05	10	0.1	-1
2	0.005	-0.25	10	0.5	-5
2	0.01	-0.5	10	1	-10
2	0.05	-2.5			
2	0.1	-5			
2	0.5	-25	50	0.01	-0.02
2	1	-50	50	0.05	-0.1
			50	0.1	-0.2
5	0.001	-0.02	50	0.5	-1
5	0.005	-0.1	50	1	-2
5	0.01	-0.2			
5	0.05	-1			
5	0.1	-2	100	0.01	-0.01

Test Draft (ft^3)	Reading Error	% Error	Test Draft (gallons)	Reading Error	% Error
5	0.5	-10	100	0.05	-0.05
5	1	-20	100	0.1	-0.1
			100	0.5	-0.5
10	0.001	-0.01	100	1	-1
10	0.005	-0.05			
10	0.01	-0.1	20	0.01	-0.05
10	0.05	-0.5	20	0.05	-0.25
10	0.1	-1	20	0.1	-0.5
10	0.5	-5	20	0.5	-2.5
10	1	-10	20	1	-5

Parallax and Eccentricity Errors

The test technician must position his or her eye directly above the test index sweep hand and perpendicular to the dial face to eliminate the effects of parallax. Since the sweep hand is located a small distance above the dial face, a reading error may occur if the technician is reading the sweep hand at an angle other than perpendicular to the dial face. Depending upon the angle and the position of the sweep hand, parallax may increase or decrease the reading of the meter. Parallax errors may occur in both the start and end readings of the register.

Another potential source of error in the readings is if there is any eccentricity of the test index sweep hand relative to the graduations of the test index dial. If the shaft for the test index sweep hand is not exactly in the center of the test index dial, then this can contribute to errors (due to variations in the movement) in the meter indications. This situation is exacerbated when test drafts represent only 50% of one revolution of the test index.

The Reference Tanks

The volume reference standards used in the labs that Ford test benches are typically two metal vertical cylinders with an external glass tube and graduated scale plate that runs almost the total height of the tanks. The capacity of the large tank is typically 10 ft^3 and is certified by the state metrologist at the capacities of 5 ft^3, 10 ft^3, 50 gal, and 100 gal. The smaller tank has a capacity of 10 gal and is calibrated at 1 ft^3, 5 gal, and 10 gal, which are the test draft sizes used to test water meters. The large tank has a diameter of approximately 25.75 in; the smaller tank has a diameter of approximately 8.75 in.

The specified method of test using the Ford test bench is to deliver water until the water level in the reference tanks reach the desired certified graduation on the tank. The test officials are instructed to use only the certified graduations on the tanks, because the tanks are not considered to be linear throughout the range of the graduated scale. Consequently, the objective is to stop the flow of water through the water meters in the test bench when the water levels in the reference tanks are on the certified graduations for the specified test drafts.

When observing the tests being performed in different laboratories, it was noticed that the water levels in the tanks were frequently slightly higher or lower than the reference graduation. The largest variations in the water levels were at 15 gpm when delivered into the large reference tank and at 2 gpm when delivered into the smaller reference tank. The variations in the water level were much less at the flow rate of 0.25 gpm when delivered into the smaller reference tank, because the slow flow rate made it easier to stop the deliveries on the reference graduations. Nevertheless, the reference volume used to test the water meters was accepted to be the nominal value of the graduation on which the goal was to stop the flow of water. This deviation in the water level in the tank from the desired reference graduation is considered to be one of the most significant sources of errors and variations in the test process. Some of the larger deviations from the reference graduation that were observed were at least 0.1 in or 2 to 3 mm. Most of the deviations, when they were observable, were probably about 1 mm. The extent of the deviations of the water level from the reference graduations varied from laboratory to laboratory. To estimate the potential impact of the deviations of the water level from the reference graduations, the potential difference in the actual volume of water in the reference tank was calculated as a percentage of the nominal volume of the test drafts used to test water meters. These volumes are converted into percent of the volumes of the test drafts used to test water meters and shown in the table below. The impact of these errors may be plus or minus depending upon whether the water level is too high or too low relative to the graduation.

Deviation of Water Level from Graduation	10-gal Tank: Diameter ~8.75 inches		
	% Error in Test Draft		
	1 ft^3	5 gal	10 gal
1 mm	0.137	0.205	0.102
2 mm	0.274	0.410	0.205
3 mm	0.411	0.615	0.307

Deviation of Water Level from Graduation	10-ft^3 Tank: Diameter ~25.75 inches			
	% Error in Test Draft			
	5 ft^3	10 ft^3	50 gal	100 gal
1 mm	0.237	0.119	0.178	0.089
2 mm	0.475	0.237	0.355	0.178
3 mm	0.712	0.356	0.533	0.266

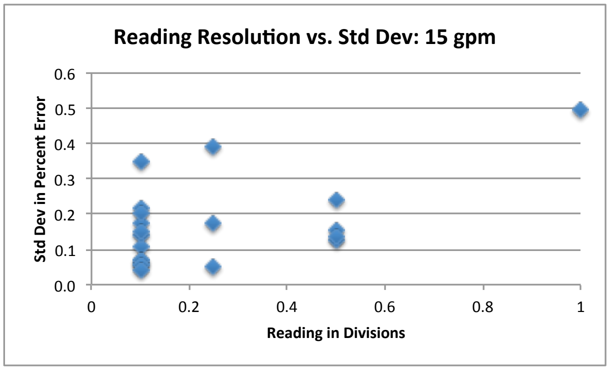
While this potential source of error is large, they must be considered relative to the accuracy tolerances of ±1.5% and +1.5% to -5.0% and the repeatability tolerances of 0.6%, 2.0% and 4.0%. The potential errors arising from not stopping exactly on the reference graduation could be significant, so efforts must be made to reduce these errors as much as practicably possible. Consideration should be given to using higher resolution reference volume standards, such as metal neck-type standards as described in NIST Handbook 105-3 or to use gravimetric test methods with scales that have sufficient resolution to reduce errors to determine the actual volume of water delivered through the meters. The advantage of these latter types of standards is that the water level does not have to be stopped specifically on a graduation representing the test draft, because the actual volume delivered can be compared to the meter readings.

Resolution of Meter Readings

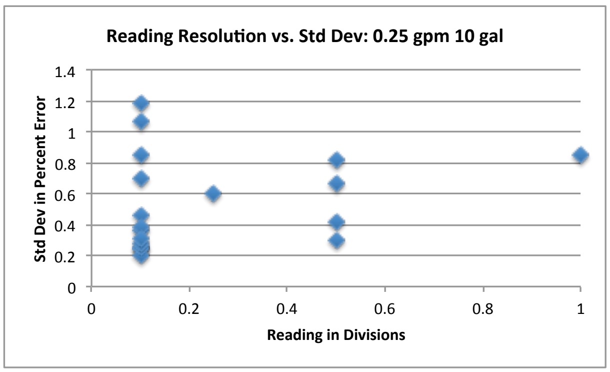
One suggestion is that as the size of the test draft decreases, the resolution of the meter registers and the uncertainty associated with reading the meter registers become a larger percentage of the test draft. The uncertainty associated with reading the registers has been estimated to be from one-third to one-half of the smallest division of the registers. Consider that the smallest divisions of the registers are 0.1 gal and 0.01 ft^3. Some of the registers have marks for one-half of the smallest division, but for this discussion, the values of 0.1 gal and 0.01 ft^3 are used for this discussion.

One of the county test officials read the meters to the nearest graduated division. Several others read the registers to ¼ division and ½ division. The remainder read the registers to 0.1 division. For meters that indicated in gallons, the round-off error can be a significant part of the tolerance, especially for small test drafts. When rounding gallon registers to the nearest 0.1 gal, this can introduce a rounding error up to 0.05 gal to both the start and ending reading for a test. This rounding error could be 0.1 gal on the difference in the start and end readings for 5- and 10-gal test drafts. This rounding error could have an effect of 2% on a 5-gal test draft and 1% on a 10-gal test draft. For meters indicating in cubic feet, the round off error of 0.005 ft^3 on the start and end readings could introduce an error of 0.01 ft^3 on the difference in the readings and have an effect of 1% on a 1-ft^3 test draft. These rounding errors can be significant. The rounding error can be reduced by recording readings to 0.1 division, which is 0.01 gal and 0.001 ft^3, which is recommended. However, reading to 0.1 division does not eliminate the uncertainty associated with a reading, because different people may read the estimated 0.1 division differently. Still, reading the registers to 0.1 division will reduce the uncertainty associated with the round-off error in the readings. It is recommended that, when testing water meters, the water meters should be read to 0.1 division to reduce the possibility that the test results are affected by rounding the meter indications to the nearest division.

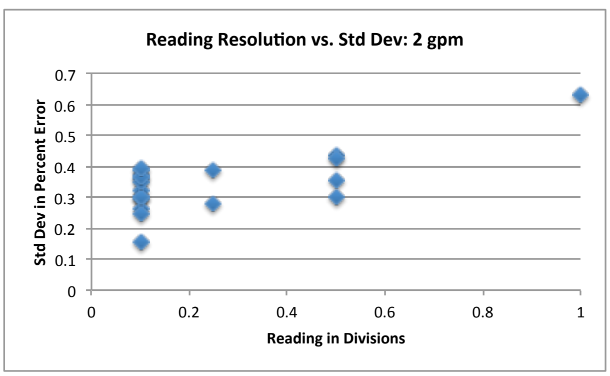
If the round-off error were a significant variable in the process to determine the meter error, one would expect that the resolution of the reading to 1d, 0.5d, 0.25d, and 0,1d (where d is the value of a division) should correlate with the standard deviations for the laboratories. Plotting the county standard deviations against the resolution of the readings does not show any correlation in the test results. The charts and correlation coefficients are provided below.



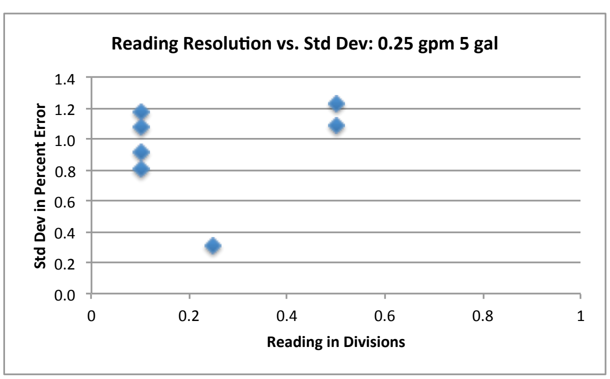
Correlation Coefficient = 0.56



Correlation Coefficient = 0.24



Correlation Coefficient = 0.71



Correlation Coefficient = 0.22

At two California county labs, three people read the meters independently so that the variations in reading could be studied. There were 155 sets of readings for three people and 20 sets of readings for two people to compare. The pooled standard deviation for the 175 sets of readings is 0.11 divisions. Using plus and minus three standard deviations as the width of the distribution, this gives a range of readings of ±0.033 gal or 0.0033ft^3. For test drafts of 1 ft^3, 10 gal and 5 gal the following table shows the uncertainty in the test result as a percent of the test draft.

	Uncertainty in Test Draft Due to Reading Variability		
Reading Variation	1 ft^3	10 gal	5 gal
0.0033 ft^3	0.33%		
0.033 gal		0.33%	0.66%

There were seven counties that tested meters with gallon registers with test drafts of 10 gal and 5 gal. The standard deviations in percent meter error for the test results for these test drafts are shown below along with a calculated uncertainty in percent meter error based upon ±3 standard deviations to allow comparison with the table above.

County	SD for 0.25 gpm, 10 gal	SD for 0.25 gpm, 5 gal	3 SD for 0.25 gpm, 10 gal	3 SD for 0.25 gpm, 5 gal	Ratio of SDs 5 to 10 gal drafts
6	1.069	0.807	3.21	2.42	75%
34	1.896	3.044	5.69	9.13	160%
35	0.671	1.095	2.01	3.29	163%
51	0.303	1.235	0.91	3.71	408%
52	0.848	1.080	2.54	3.24	127%
67	0.204	0.922	0.61	2.77	452%
89	0.282	1.176	0.85	3.53	417%

A review of the repeatability (standard deviations) of county test results does not show that the counties that rounded the meter readings to the nearest division had any larger standard deviations than those counties that read to 0.1 divisions. Based upon the reading variability alone, one would expect the uncertainty for the 5-gal test draft to be 0.3% to 0.6% greater than the uncertainty for the 10-gal test drafts. In five of the nine county labs, the uncertainty for the 5-gal test drafts increased much more than these amounts compared to the 10-gal test drafts. These results indicate that other factors are affecting the test results for 5-gal test drafts at the minimum flow rate.

Effect of Round-Off Errors on Meter Readings

When meter readings are rounded off to the nearest one-half of a division, there are four possible rounding possibilities for both the start and end readings of the meter test. If the meter reading is in the first quarter of the distance from one graduation to the next, the reading will be rounded down to the lower division (graduation). If the reading is between one-quarter to one-half of the distance from one graduation to the next, the reading will be rounded up to one-half. From one-half to three-quarters, the reading will be rounded down to one-half. From three-quarters to the higher division, the reading will be rounded up to the higher division. Hence, there are four possible rounding scenarios for the start reading and four possible rounding scenarios for the end reading. This means that there are 16 possible combinations for rounding. There is a one in 16 chance that the starting and ending round-off errors will be in opposite directions on the extreme readings (i.e., the start reading will round down to the lower graduation and the end reading will round up to the higher graduation) and create the largest impact on the test results. Similarly, there is a one in 16 chance that the rounding errors will be in the same direction at the extreme readings and cancel out when the start meter reading is subtracted from the end reading. In the other 14 combinations, there will be differing round-off effects, but they will be between the two examples of the extremes.

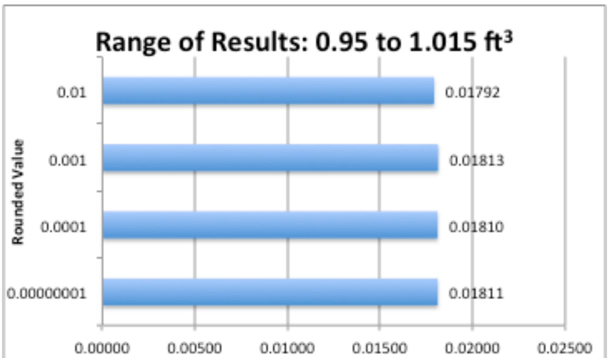
To evaluate the effect of the round-off errors on the water meter indications on the test results of the water meter survey, models of test results were created and then rounded off to see what the effect was on the variations of the test results as measured by calculating the standard deviations. Random numbers were generated to simulate the test results of meters indicating in cubic feet for the minimum flow rate with a test draft size of 1 ft^3. Each set of random numbers consisted on 15 numbers to simulate the test results of five meters tested three times. Two ranges of the test results were used to generate random numbers to simulate the test results. The first range was the entire tolerance, which corresponds to meter indications between 0.95 ft^3 and 1.015 ft^3. The range of the second set of simulated test results in a smaller range of 0.98 to 1.01 ft^3. Six sets of random numbers were generated for each range of simulated test results and the numbers were rounded off to 0.000001 (actually not rounded at all, but computed to the resolution of the computer), 0.0001, 0.001, 0.01 and 0.1 ft^3. The round off to 0.01 ft^3 is rounded more than what was done by any of the county laboratories. The greatest round-off value used by a county was to 0.005 ft^3, so the round-off error in the models to 0.01 ft^3 shows an effect greater than was experienced in the survey. Most of the laboratories read the meters to 0.001 ft^3.

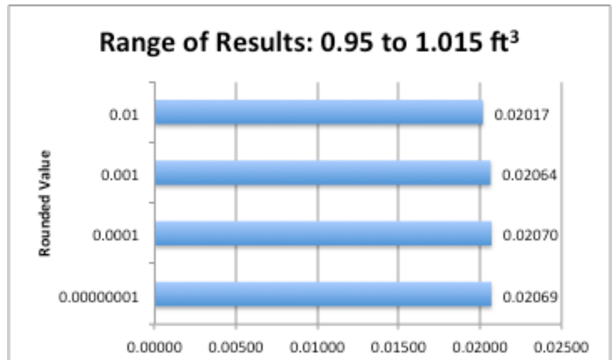
Considering the range of values used in the models, rounding results to 0.1 ft^3 resulted in numbers for all 15 readings of 1.0 ft^3, which is obvious. The standard deviations for the other rounded values did not vary excessively. Only the rounded values to 0.01 ft^3 had some variation from the other rounded values, but the difference is not great enough to explain the actual variations observed in test results obtained in the survey. Consequently, the "granularity" issue does not explain the variations observed in the survey for the small test draft sizes.

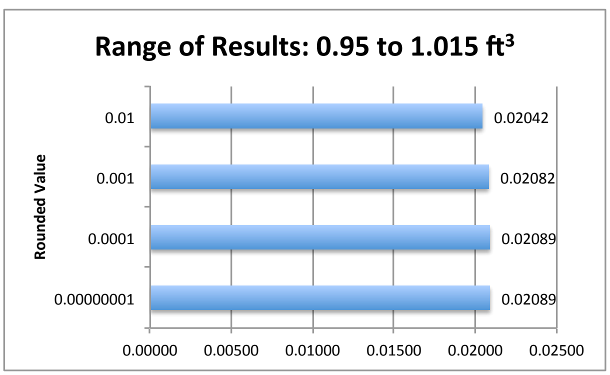
Charts showing the standard deviations for each set of rounded test results from 0.000001 ft^3 to 0.01 ft^3 are shown on the following two pages. One can see that when readings are rounded to 0.01 ft^3, the standard deviation may be slightly larger or slightly smaller than the standard deviations when the readings are taken to more decimal places. These results are due to the fact that individual meter readings may be rounded up or rounded down when rounding to 0.01ft^3. Even then, the effect of the round off on the standard deviation is relatively small.

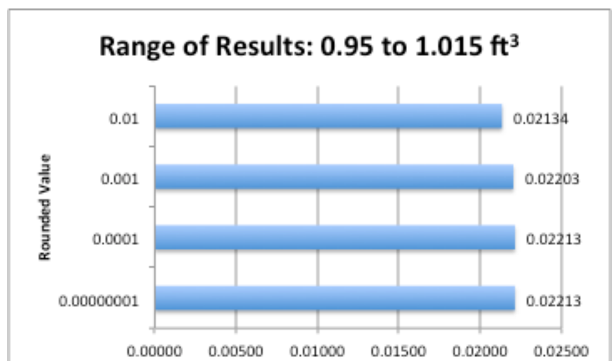
One will also notice that the effect of the round-off error is greater when the range of test results is smaller. This is logical, because as the range in the test results gets smaller, then the round-off error becomes a larger percentage of the variation of the test results. However, as the variation gets smaller, the variation in test results due to the round-off error remains “small” compared to the tolerance for tests at the minimum flow rate. Nevertheless, the round-off error can have can effect on the “pass/fail” decision of a meter if the error in the meter is at one of the tolerance limits.

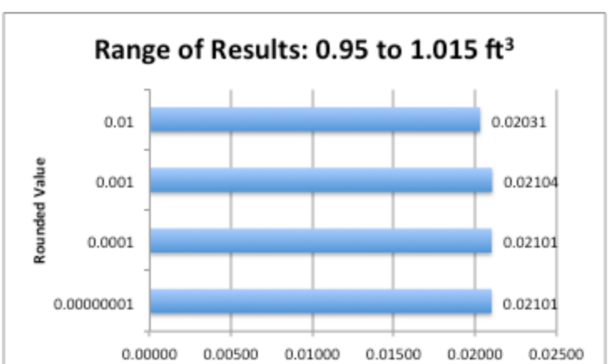
The charts below represent a range of test results between 0.95 and 1.015 ft^3.

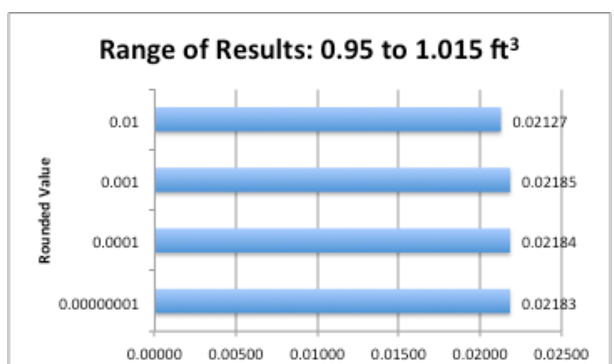




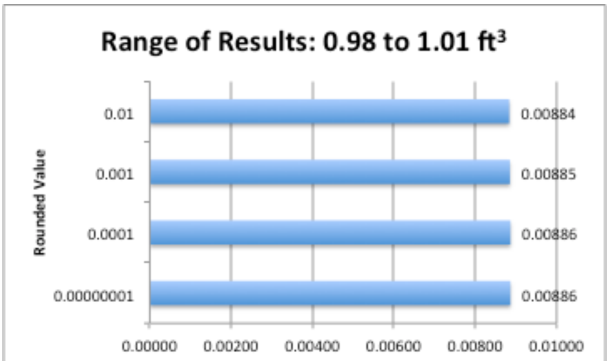


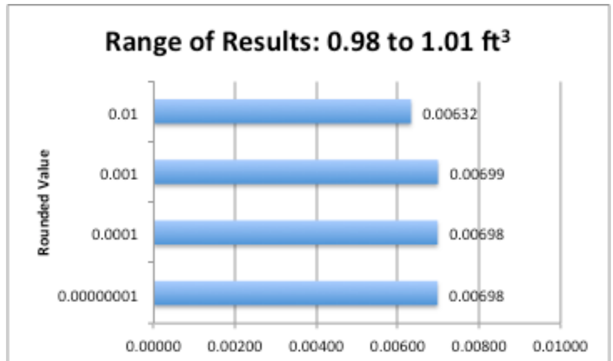


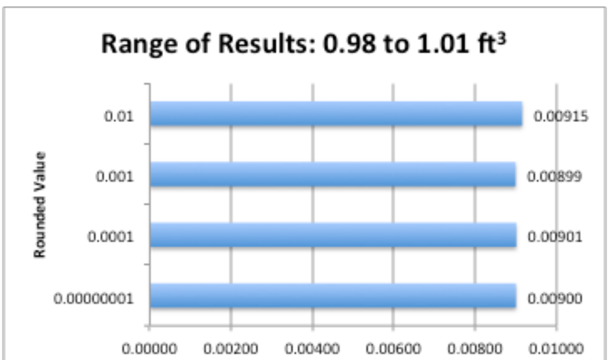


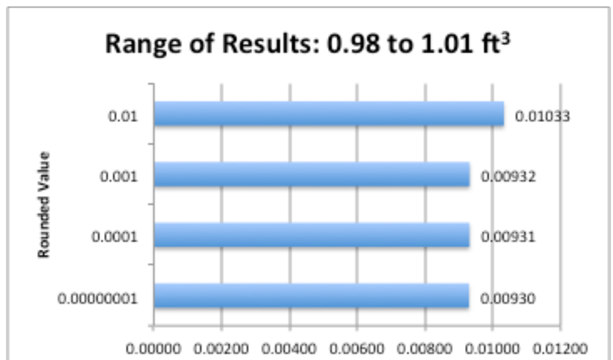


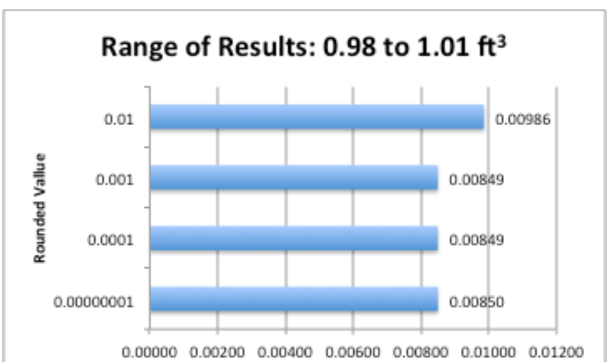
The charts below represent a range in test results of 0.98 to 1.01 ft^3.

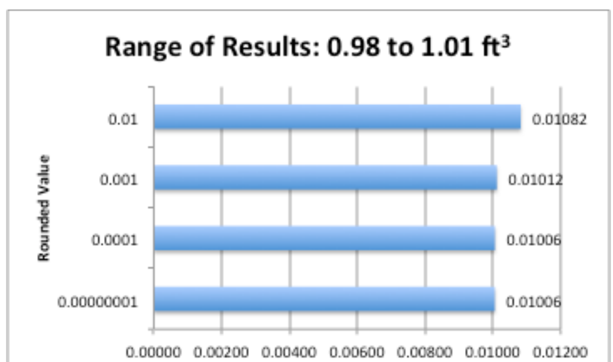












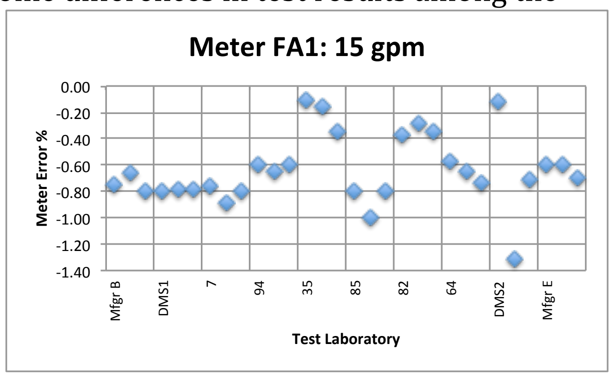
Granularity Issues

There are several issues in which a lack of granularity or resolution can influence the accuracy and repeatability results. Several issues have been discussed, namely, the inability to stop all water deliveries into the reference tanks exactly on the reference graduations, the round-off errors associated with meter readings, and parallax and eccentricity errors associated with the meter registers. The combination of several of these variables can have a significant impact on the test results. Consequently, care must be taken is all aspects of the test procedure to keep these potential sources of error as small as possible.

Interpretation of Test Results

One objective of this survey is to assess whether or not there are significant differences in the test results for water meters when tested by different laboratories. Whenever repeat measurements are made on the same meter (or any object), there will be some variation in the test results provided that the measurements are made to an adequate resolution. In the case of meters, some of the variation is due to the repeatability of the meter, the repeatability of the person and laboratory performing the measurements, and there may be differences in test results from one laboratory to another. Hence, the data must be analyzed in an effort to determine (1) if there are significant differences from laboratory to laboratory and (2) whether or not those differences are significant relative to the tolerances for the water meters.

By examining any one of the charts of the individual test results for the water meters used in the survey, one can see that there are variations in the test results, both within the test results for each laboratory and that there are some differences in test results among the different laboratories. The chart to the right is an example. There are two types of variation of particular interest. The first is the difference in the meter accuracy (i.e., the meter error) as determined by each laboratory. The second is the amount of variation that exists in the test results for each laboratory. In the latter case, the issue is whether or not the amount of variation in the test results (i.e., the repeatability of the test results, usually measured by the range in the results of three consecutive tests at each flow rate for each test draft) is different from laboratory to laboratory. If there are differences from laboratory to laboratory, one would like to know if the differences are simply within the expected limits of variability for the meter errors and the range based upon the performance characteristics of the meters and the test systems or if the differences are the result of variations in the laboratory facilities and test procedures.



As part of the survey, the test processes used by the California counties were witnessed by either Henry Oppermann of Weights and Measures Consulting, or Paul Jordan or Daniel Parks of the California Division of Measurement Standards. If there were any unusual characteristics of the test systems or test procedures used in any of the county laboratories that might cause differences in the test results, these were noted so that any unique characteristics could be considered when analyzing the data to identify possible causes for any significant differences in test results.

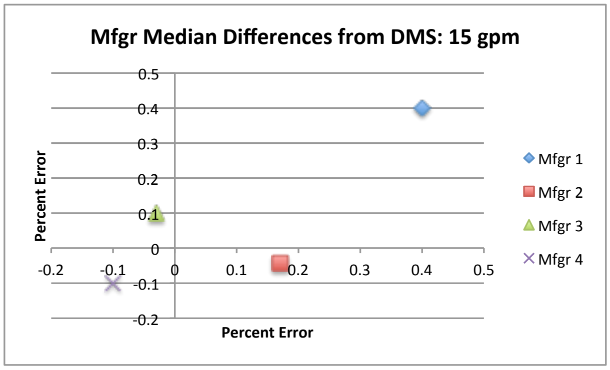
Statistical Concepts Used in the Data Analysis

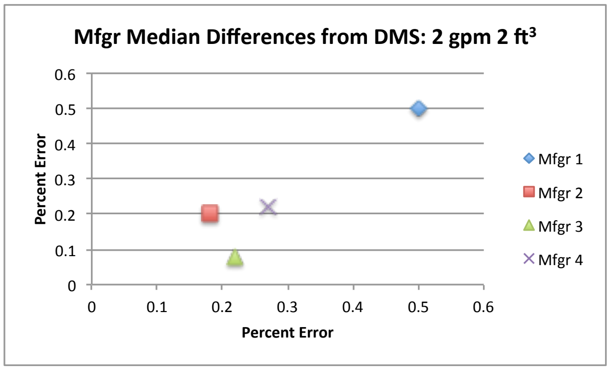
Typically, any measuring instrument will have performance results that resemble a normal distribution, that is, the average error for a meter at a particular flow rate will be the center of the normal distribution and then the variation in the individual test results for the meter error is measured by the standard deviation of the variation of the individual test results. Meters of the same design will usually have a similar performance curve, that is, the accuracy of a meter varies somewhat over the range of flows that the meter measures the water. However, the average error and the variation of the measurement results will often vary over the range of the flow rates that the meter is capable of measuring. The water meters (and any meter) will have performance at a given flow rate that can be defined by the mean of the meter error and the standard deviation of the variation of the test results at that flow rate. One can think of the performance characteristics for the performance curve of a meter as being represented by a different normal distribution at each flow rate at which the meter is tested. Since three repeat tests were conduced on each water meter at each flow rate in each laboratory, the three repeat tests represent samples of test results taken from the normal distribution of the population of test results for that meter at each flow rate. If the accuracies of the meters do not change during the survey, then one would expect that the test results of each laboratory should agree within the repeatability of the meters, the test facilities and the test procedures, i.e., within the uncertainties of the meters, test facilities and test processes. Usually these uncertainties vary from laboratory to laboratory, but since the same laboratories tested the same meters, the variability characteristics of each meter are common to the laboratories that tested the same meters. Furthermore, one can expect that meters from the same manufacturer will have similar performance characteristics.

To assess whether or not there are differences in the test results from one laboratory to another, one must have an estimate of the uncertainty associated with each test result. Since each laboratory ran three repeat tests on each meter at each flow rate, the average error for the three repeat measurements at each flow rate is the laboratory's estimate of the mean of the meter's normal distribution for its population of measurement results. The standard deviation for the three repeat tests is an estimate of the width of the normal distribution for the population of measurement results. These estimates of the means and standard deviations of each meter's performance characteristics have a rather large uncertainty, since only three measurements were made to determine the performance characteristics of each meter. However, the tolerances established for meters take into consideration the uncertainty associated with accuracy estimates of individual test results and the repeatability tolerances (expressed in range values) for the meters. Hence, the goal is to set the tolerances are set large enough to allow different laboratories to conduct individual tests on meters to determine if the meters are accurate within the specified tolerance and to reject meters whose accuracy falls outside the tolerance limits. Similarly, the tolerances for repeatability are established so that the sampling of repeat tests from the normal distribution of each meter's normal distribution generally fall within the tolerance for the range of the sample of measurements.

The estimates of the mean and standard deviation values of the normal distribution of each meters performance characteristics may be complicated, because there may be differences between the within-series (short-term) and between-series (long-term) standard deviations when testing meters. This appears to be the case with the water meters used in the survey, which will be illustrated later. However, this information is critical in an effort to identify when differences in test results from different laboratories may be differences due to the test facilities and test procedures or when the differences may be expected and acceptable based upon the typical differences in meter performance and acceptable laboratory facilities and test procedures.

Comparison of DMS and Manufacturer Test Results

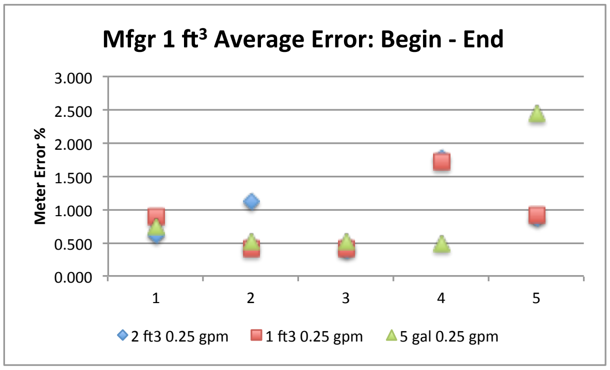


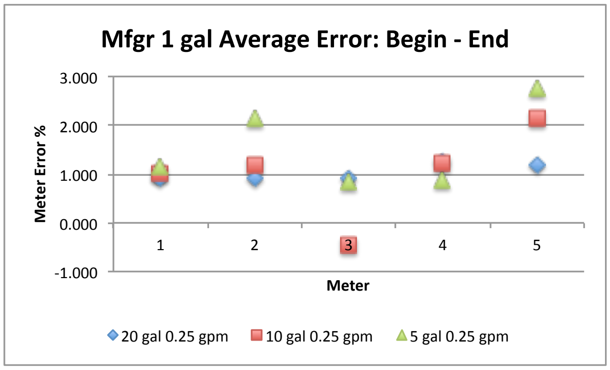


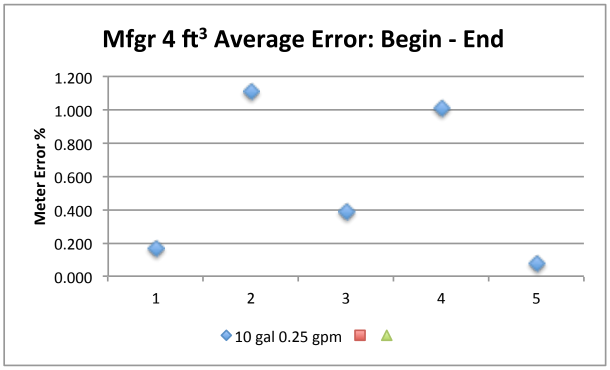
As mentioned in the sections "Manufacturer and DMS Test Results at Start of Survey" and "Manufacturer and DMS Test Results at End of Survey," the results for manufacturer 1 at the flow rates of 15 gpm and 2 gpm tended to be about 0.5% different from DMS (see the charts at the right). The results from the other manufacturers had differences significantly smaller. Manufacturer 1 should investigate the causes of these differences, because they are larger than expected based upon the results of other manufacturers.

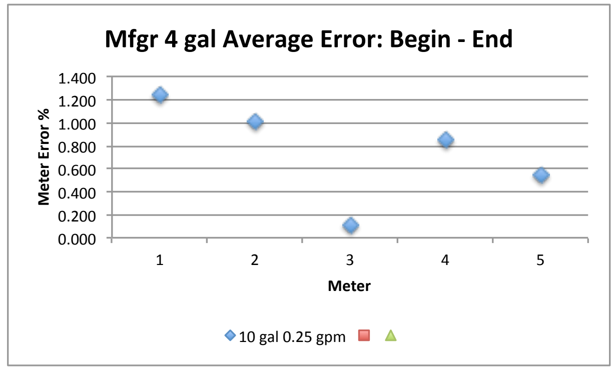
Changes in Meter Accuracy

Several meters appeared to change accuracy during the survey, as indicated in the section titled, "Comparison of Manufacturer Results: Beginning and End." The meters from manufacturer 1 tended to underregister to a greater extent at the end of the survey than at the beginning of the survey. The test results for manufacturer 4 also tended to show that several meters appear to have changed accuracy (see the charts below).

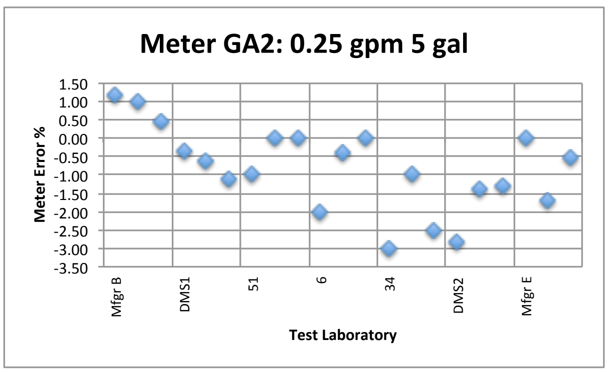


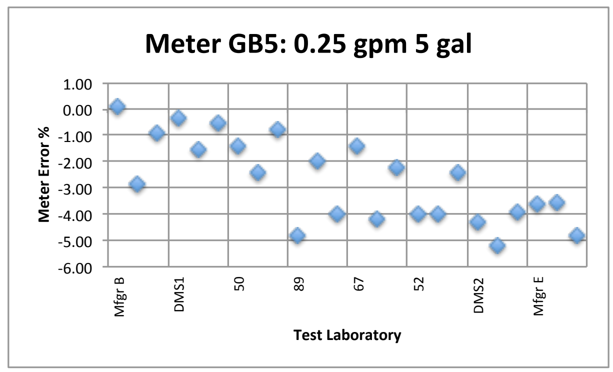






A trend in the test results when graphed in the sequence of testing also indicates when the accuracy of a meter has changed over time. Below are examples of charts for the individual test results on meters that show a change in meter accuracy over time.



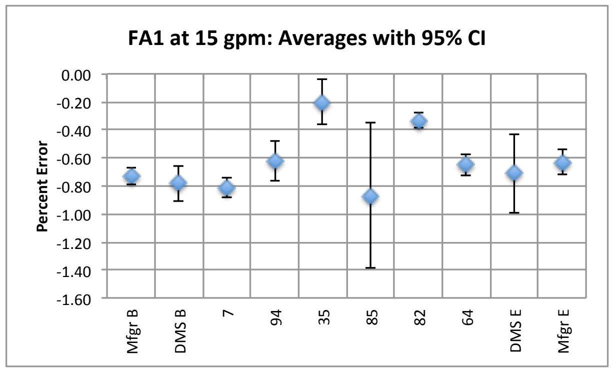


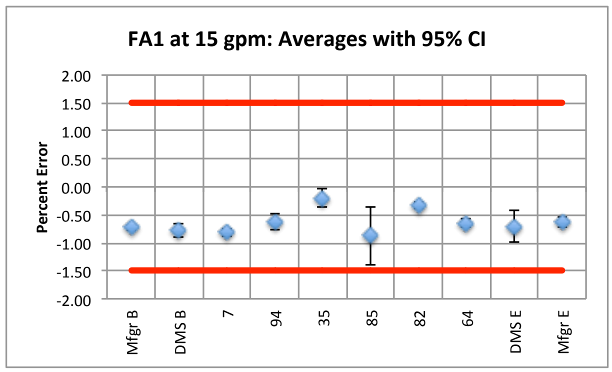
Obviously, it is necessary to consider whether or not the accuracy of a meter was changing during the survey when evaluating agreement among the laboratories for these meters. The variation in the test results for the meters does not appear to have changed even though the accuracy of some meters changed during the survey.

Within-Series Standard Deviations

To compare measurement results, it is not sufficient to have just the value that was determined by the measurement process; one must also have an estimate of the uncertainty associated with the measurement value. Furthermore, to compare measurement results, it is more useful to compare the average results of several measurements to the average results from other laboratories because the average is a better estimate of the characteristic one is trying to determine than the result of a single measurement. Additionally, the uncertainty associated with the average of several values is smaller than the uncertainty associated with individual measurements. Consequently, the average meter error for the three repeat measurements for each laboratory was computed and the within-series standard deviations calculated for each meter at each flow rate and for each size test draft, when applicable. The within-series standard deviations for all of the meters tested at the same flow rate and size test draft were pooled in an effort to obtain a better estimate of the standard deviation of the parent normal distribution for the meters that were tested at each flow rate and test draft size. These pooled within-series standard deviations were used to calculate error bars at a 95% confidence level for the test results for each laboratory. The statistical concept is that if the values determined by each laboratory for the percent meter error are graphed with error bars representing 95% confidence intervals, then if the error bars overlap one can conclude that the measurement results agree. This is why the average values for each meter error as determined by each laboratory was graphed with error bars based upon the pooled, within-series standard deviation computed for each laboratory (see the section titled, "Average Errors and Error Bars"). This approach is one way to determine if the results from laboratories agree or disagree with each other at the 95% confidence level. However, my conclusion is that the within-series standard deviations frequently underestimate the standard deviation of the parent normal distribution that represents the performance characteristics of the meters. Consequently, most of the uncertainty error bars are too small.

One must also ask that if results differ from one laboratory to another, are the differences significant relative to the tolerances that apply to the water meters?





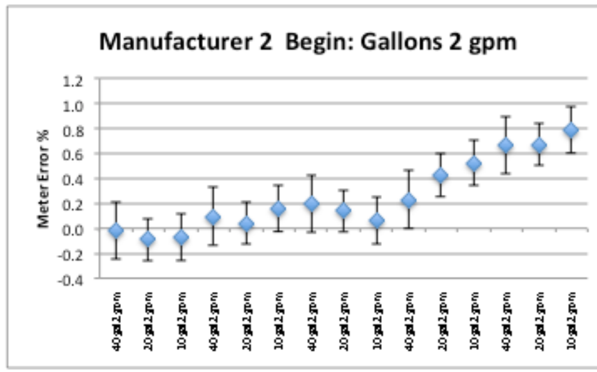
To evaluate whether or not results from different laboratories agree and whether or not the differences in test results are significant relative to the tolerances are why the average values for the three tests at each flow rate and each test draft were plotted on the charts in the section, "Average Errors and Error Bars." At the right are two charts for the test results of meter FA1 when tested at 15 gpm. In the upper chart, the variations in the lengths of the error bars are significant. Some of the error bars for some laboratories do not overlap. If one has confidence that the error bars are valid, then a typical conclusion would be that the results for some of the laboratories are different from the other laboratories. However, I believe that many of the error bars are too small, because the within-series standard deviations significantly underestimate the standard deviation of the parent normal distribution for the meters that were tested.

The next question is, "Even if the results differ from laboratory to laboratory, are the differences significant relative to the tolerances?" The test results must be evaluated for each flow rate and test draft, which is why the charts for each meter for each flow rate are included in this report. In most cases, we see that the variations from laboratory to laboratory are relatively small compared to the tolerances for water meters. However, there is more information to be considered.

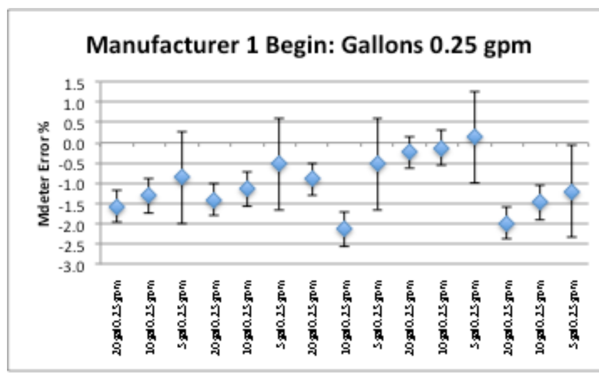
Test Results for the Same Flow Rates But Different Sizes of Test Drafts

The manufacturers ran extensive tests on their meters at the beginning and the end of the survey. Three of the manufacturers ran three tests at three different sizes of test drafts at the flow rates of 2 gpm and 0.25 gpm. The results from the manufacturers' tests provide the most extensive test results on each meter and are valuable because of the relatively large amount of data generated.

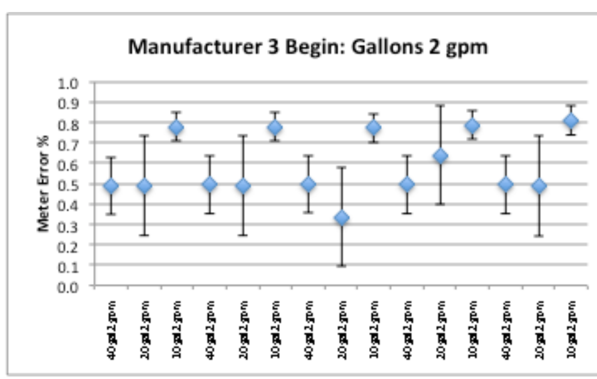
It is assumed that the manufacturers are satisfied that their test systems are quality systems and operated by competent technicians. Consequently, the results from the manufacturer's tests can be used as a benchmark to estimate the level of accuracy and repeatability that can be expected on water meters.



If one studies the manufacturers' results for tests at the beginning and end of the survey for the different test draft sizes at the same flow rates, one will see that most of the error bands overlap. The chart at the right shows results that are expected. Please remember that each group of three sequential values represents one meter and that five meters are represented in the graph.

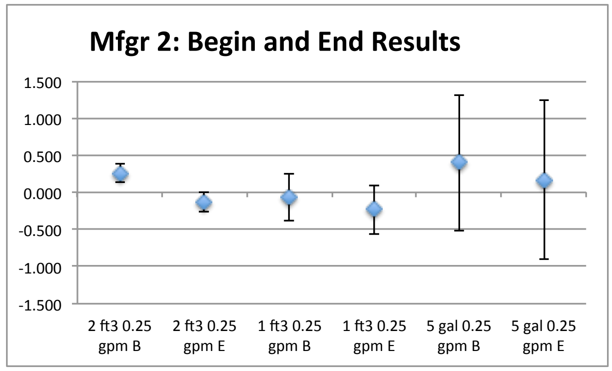


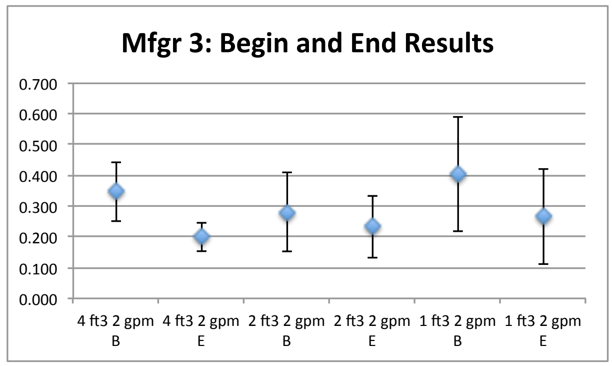
The next chart apparently shows an inconsistency in the test results for the third meter when tested at 0.25 gpm for the 10-gal test draft. The uncertainty band for the average test result does not overlap the uncertainties for the other two test draft sizes. However, if the uncertainty bands are too small based upon the pooled, within-series standard deviations, then the uncertainty is underestimated. If the uncertainty is known to be larger, then the uncertainty bands (error bars) might overlap.



The chart at the right shows some very odd results. The results for all five meters at the 10-gal test draft are unusually consistent and offset from the other test results. The unusual consistency resulted in very small uncertainty bands. These unusual results were not duplicated when the manufacturer tested these same meters at the end of the survey. A logical conclusion is that there is something wrong with this set of test results.

Beginning and End Test Results





There are two more pieces of information that imply that the within-series standard deviation does not include the effect of the between-series standard deviation. The comparison of the beginning and end test results for manufacturers often show differences beyond the error bars, even when the charts of the test results from all laboratories do not show any evidence that the accuracies of meters have changed. In the chart at the right, the error bars for the beginning and end values for the meter tested at 0.25 gpm with a 2-ft^3 test draft do not overlap.

In the next chart, the error bars do not overlap for the beginning and end values at 2 gpm for the 4-ft^3 test draft. If the meters didn't change accuracy during the survey, one would expect that the error bars would overlap. However, the values do not overlap by small amounts. Since the confidence interval is based on a 95% level, one expects that 5% of the test results may not overlap. However, another explanation is that the within-series standard deviations do not adequately capture the between-series variations, so the error bars (i.e., uncertainty limits) are understated. The large variations in the error bars also imply that the within-series standard deviations do not adequately represent the standard deviation of the parent normal distribution that represents the performance characteristics of the meters.

F-Tests for Standard Deviations

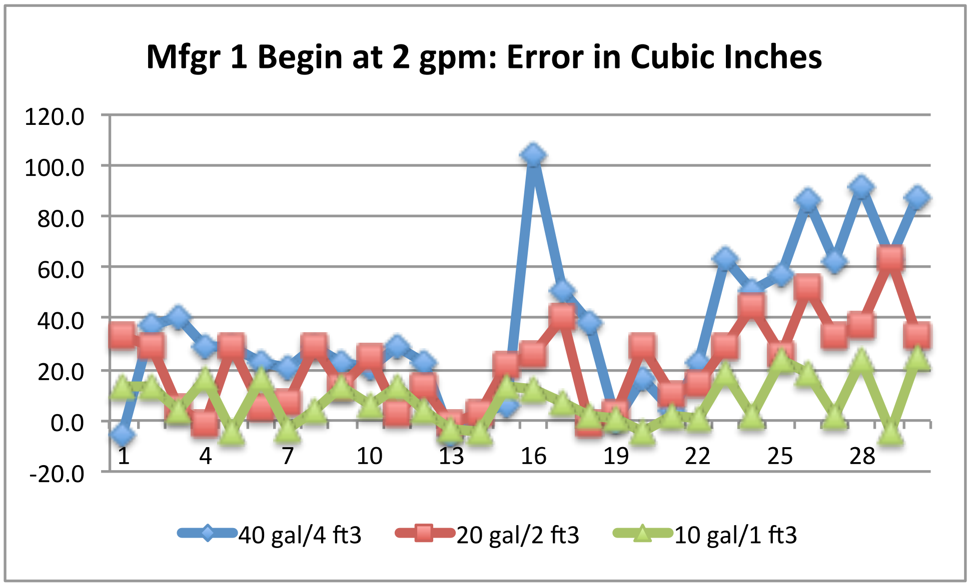
The final piece of information that indicates that the within-series standard deviations do not include the effects of the between-series standard deviations is the number of F-test comparisons of standard deviations for the same flow rates, but for different test draft sizes. The F-test results reported in the section, "Repeatability Expressed in Units of Volume," showed that 9 out of 72 F-test comparisons failed the F-test at a 95% confidence level. This represents 12.5% failures, when one would expect only about 5% failures. The DMS F-tests also failed at the rate of 12.5%. These results indicate that the F-test comparisons indicate a problem with the standard deviation values.

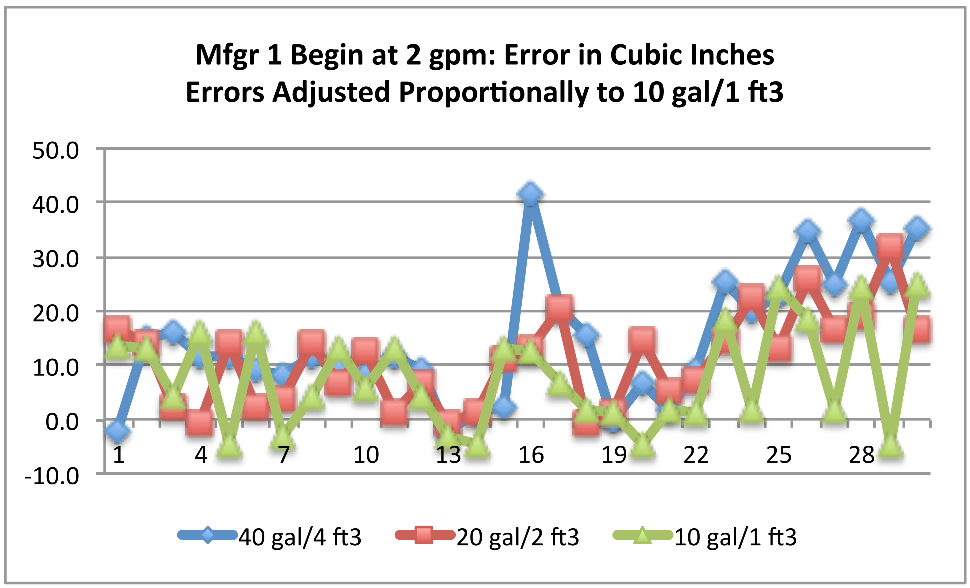
Evaluation of Within- and Between-Series Standard Deviations

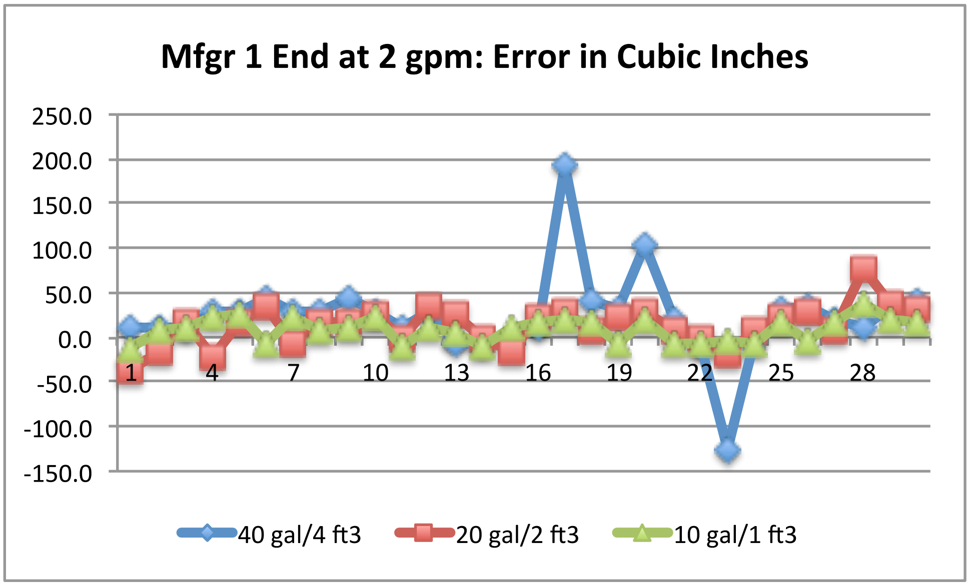
It appears that the pooled within-series standard deviations do not provide a good estimate of the standard deviation for the parent normal distribution for the meters performance characteristics. A better estimate of the combined within- and between-series standard deviations are needed to assess when differences in results for accuracy and repeatability among laboratories is needed.

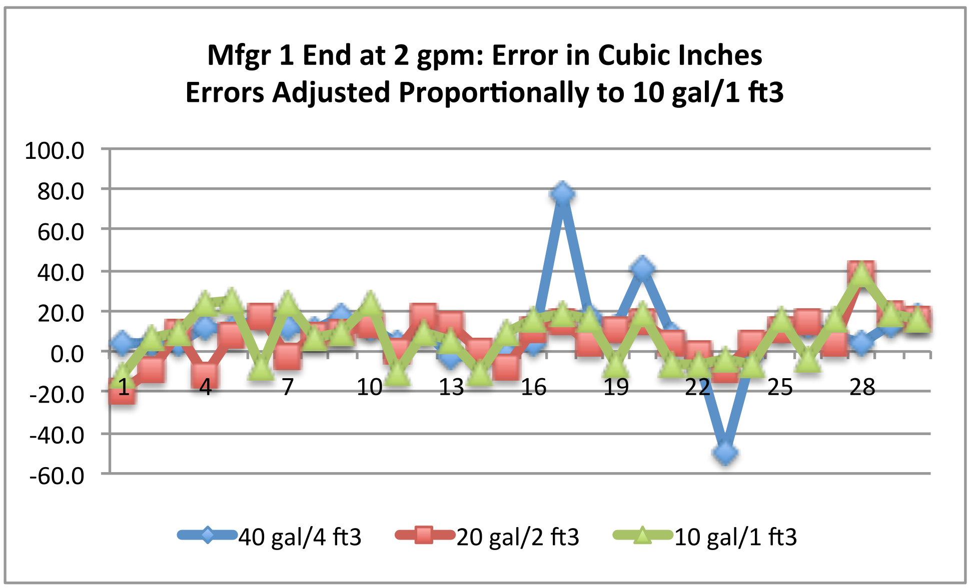
The instances where the error bars for the manufacturers' results do not overlap for the same flow, but different test draft sizes, are not logical. Typically, the accuracy performance of meters is composed primarily of two components: the errors associated with starting and stopping the flow of liquid through a meter and the steady-state inaccuracy when the meters are at a constant flow rate. Since the tests of water meters require a considerable period of time, the errors associated with the starting and stopping of the flow should be small compared to the steady-state inaccuracy at a constant flow rate.

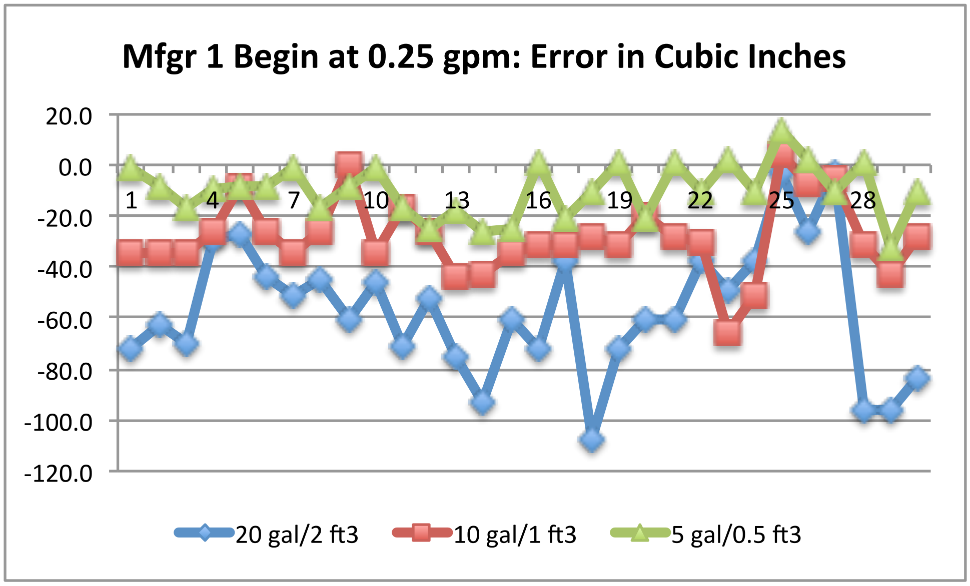
We can see that this is true for water meters if we look at meter errors for different test draft sizes at the same flow rate. Below, four pairs of charts (beginning and end) show the meter errors as determined by the manufacturers at the same flow rates, but for different test draft sizes. Two pairs of graphs are for the 2-gpm flow rate (beginning and end) and the other two pairs are at 0.25 gpm (beginning and end). The first chart of each pair shows the meter errors in cubic inches for each meter and each test run. Each chart includes meters indicating in gallons and cubic feet. The second chart of each pair shows the meter errors adjusted proportionally to the test draft size of 10 gal and 1 ft^3 for the flow rates of 2 gpm and 0.25 gpm. The purposes of this exercise are (1) to demonstrate that the meter errors in cubic inches are proportional to the sizes of the test drafts, and (2) to pool the standard deviations for all three test drafts when the errors are adjusted to the test draft size of 10 gal and 1 ft^3. These latter pooled standard deviations can be used to provide an estimate of the combined within- and between-series standard deviations that can be used to perform the F-tests for all of the test drafts when adjusted back to the original test draft sizes. The appropriateness of this analysis can be argued, but when the standard deviations for the adjusted test drafts are used in the denominator of the F-tests when applied separately for the manufacturers' beginning and end results for meters indicating in gallons and cubic feet, the number of F-tests that fail are 4 out of 72 or 5.6%. This failure rate is very close to the 5% that is expected when calculating the F-test at the 95% confidence level.

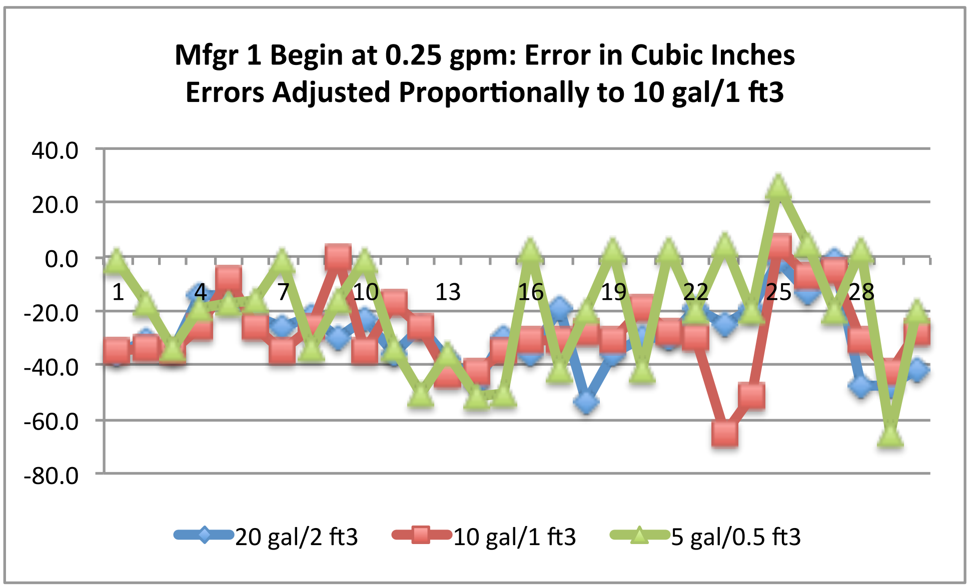

Mfgr 1 Begin at 2 gpm: Error in Cubic Inches
120.0
100.0
80.0
60.0
40.0
20.0
0.0
-20.0
1
4
7
10
13
16
19
22
25
28
40 gal/4 ft3
20 gal/2 ft3
10 gal/1 ft3

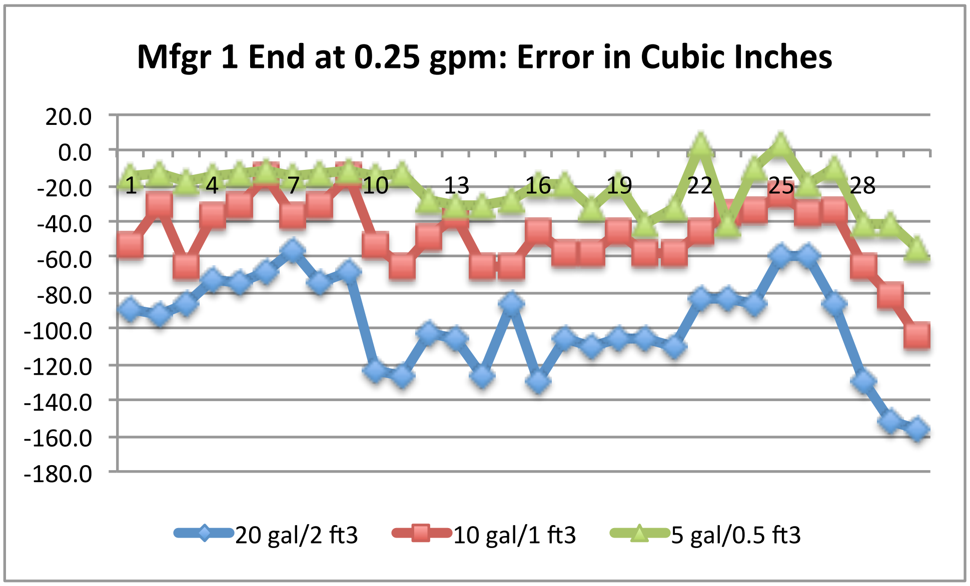

Mfgr 1 Begin at 2 gpm: Error in Cubic Inches
Errors Adjusted Proportionally to 10 gal/1 ft3
50.0
40.0
30.0
20.0
10.0
0.0
-10.0
1
4
7
10
13
16
19
22
25
28
40 gal/4 ft3
20 gal/2 ft3
10 gal/1 ft3

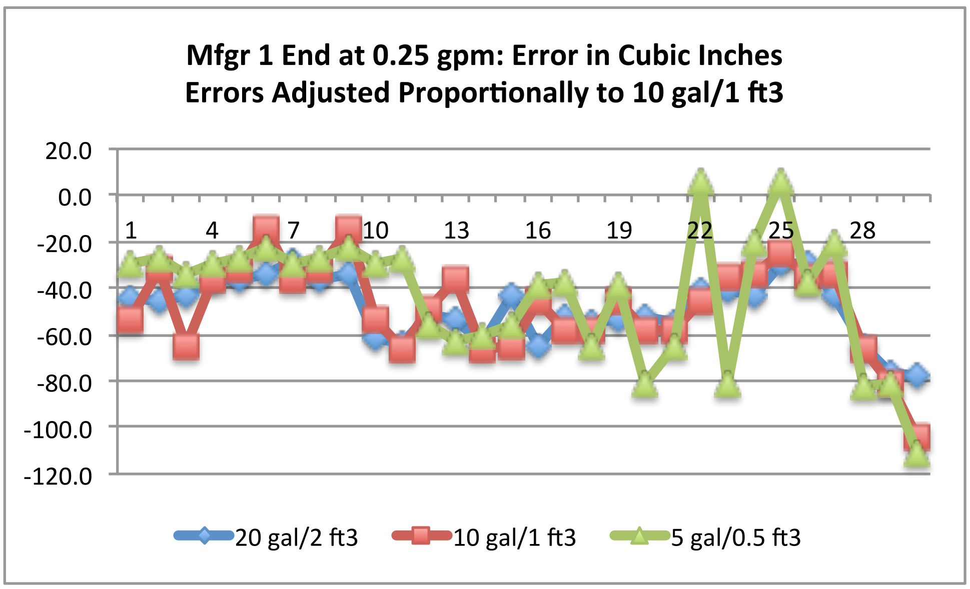

Mfgr 1 End at 2 gpm: Error in Cubic Inches
250.0
200.0
150.0
100.0
50.0
0.0
-50.0
-100.0
-150.0
1
4
7
10
13
16
19
22
25
28
40 gal/4 ft3
20 gal/2 ft3
10 gal/1 ft3

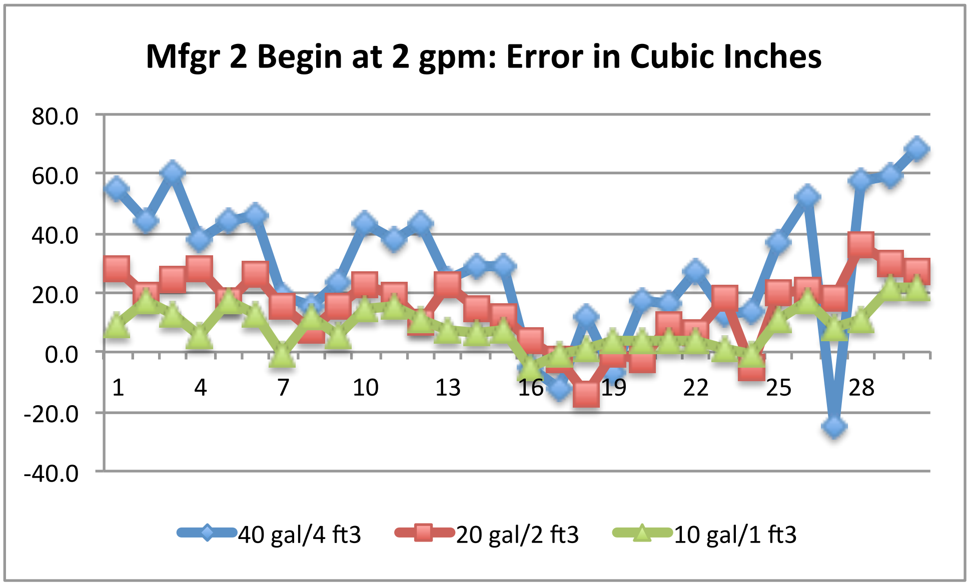

Mfgr 1 End at 2 gpm: Error in Cubic Inches
Errors Adjusted Proportionally to 10 gal/1 ft3
100.0
80.0
60.0
40.0
20.0
0.0
-20.0
-40.0
-60.0
1
4
7
10
13
16
19
22
25
28
40 gal/4 ft3
20 gal/2 ft3
10 gal/1 ft3

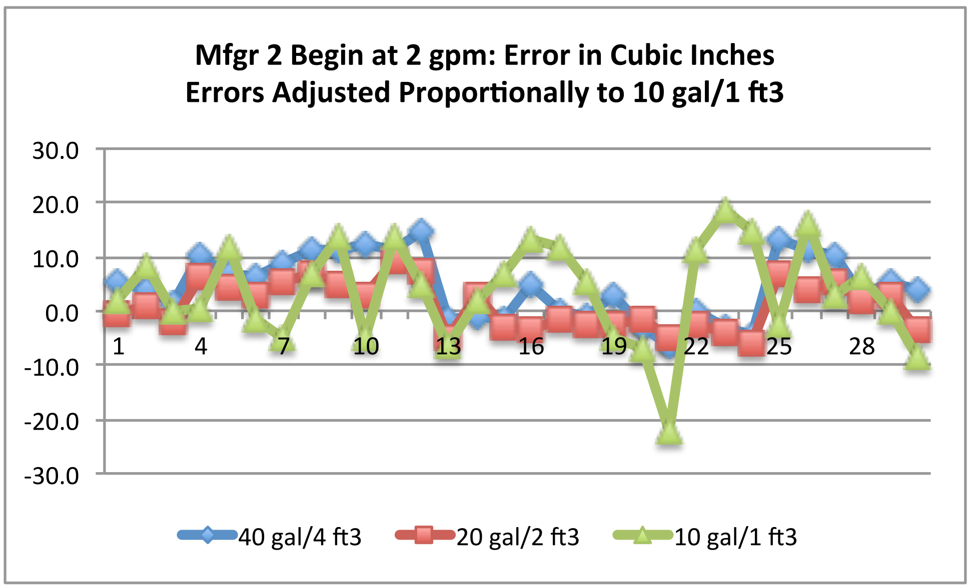

Mfgr 1 Begin at 0.25 gpm: Error in Cubic Inches
20.0
0.0
-20.0
-40.0
-60.0
-80.0
-100.0
-120.0
1
4
7
10
13
16
19
22
25
28
20 gal/2 ft3
10 gal/1 ft3
5 gal/0.5 ft3

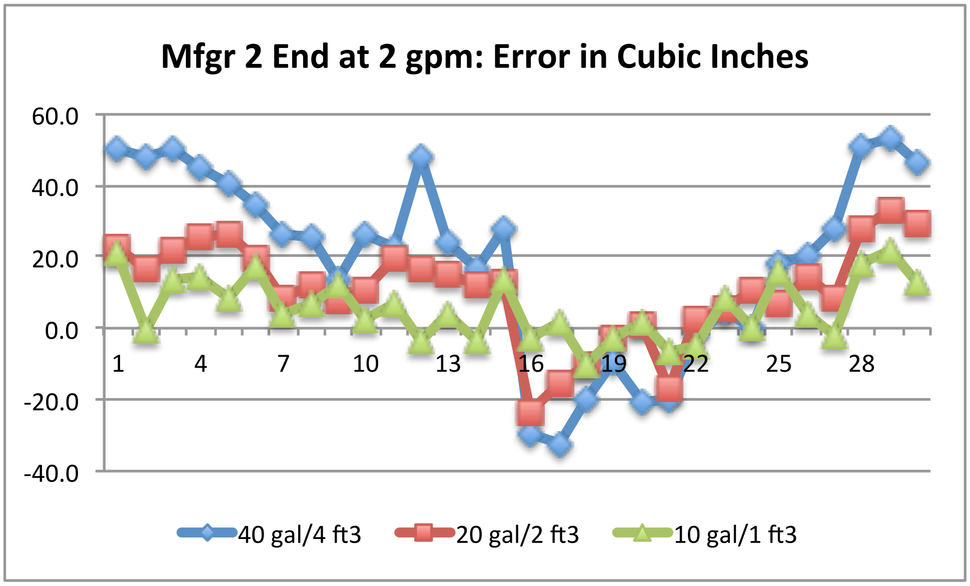

Mfgr 1 Begin at 0.25 gpm: Error in Cubic Inches
Errors Adjusted Proportionally to 10 gal/1 ft3
40.0
20.0
0.0
-20.0
-40.0
-60.0
-80.0
1
4
7
10
13
16
19
22
25
28
20 gal/2 ft3
10 gal/1 ft3
5 gal/0.5 ft3

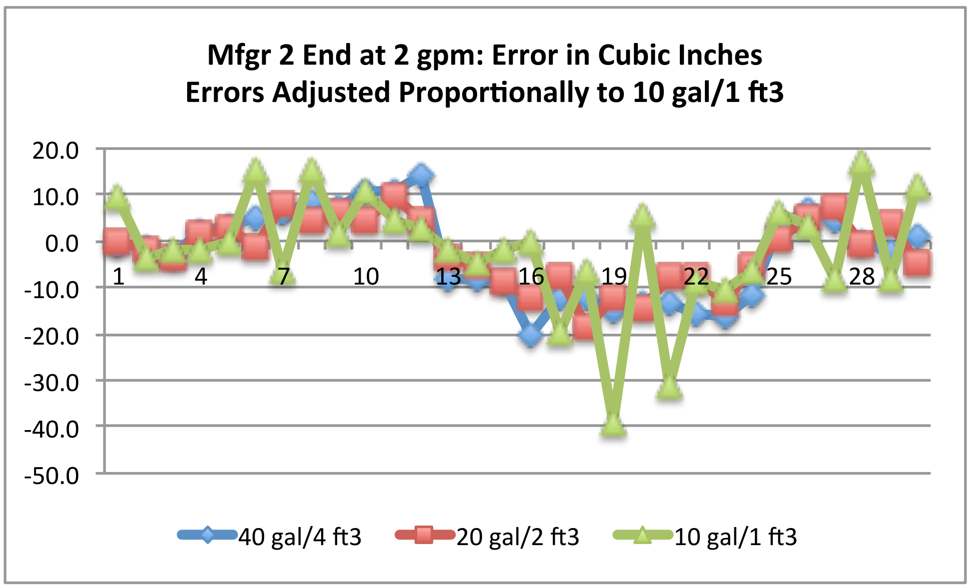

Mfgr 1 End at 0.25 gpm: Error in Cubic Inches
20.0
0.0
-20.0
-40.0
-60.0
-80.0
-100.0
-120.0
-140.0
-160.0
-180.0
1
4
7
10
13
16
19
22
25
28
20 gal/2 ft3
10 gal/1 ft3
5 gal/0.5 ft3

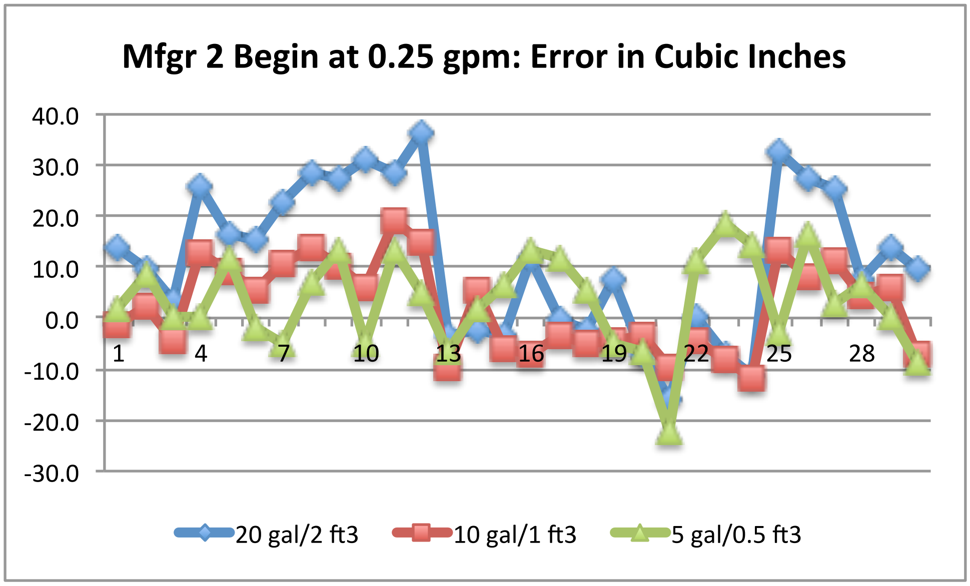

Mfgr 1 End at 0.25 gpm: Error in Cubic Inches
Errors Adjusted Proportionally to 10 gal/1 ft3
20.0
0.0
-20.0
-40.0
-60.0
-80.0
-100.0
-120.0
1
4
7
10
13
16
19
22
25
28
20 gal/2 ft3
10 gal/1 ft3
5 gal/0.5 ft3

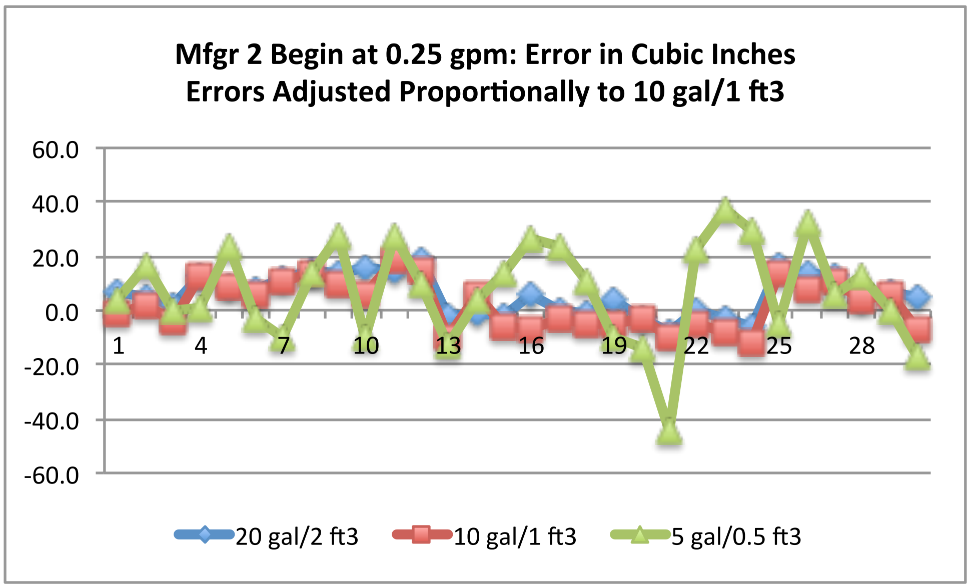

Mfgr 2 Begin at 2 gpm: Error in Cubic Inches
80.0
60.0
40.0
20.0
0.0
-20.0
-40.0
1
4
7
10
13
16
19
22
25
28
40 gal/4 ft3
20 gal/2 ft3
10 gal/1 ft3

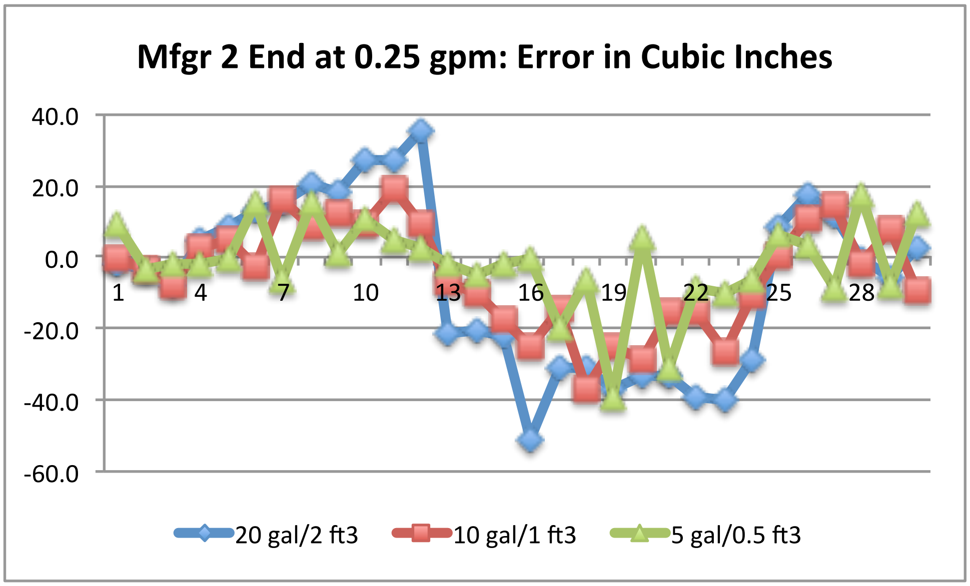

Mfgr 2 Begin at 2 gpm: Error in Cubic Inches
Errors Adjusted Proportionally to 10 gal/1 ft3
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
1
4
7
10
13
16
19
22
25
28
40 gal/4 ft3
20 gal/2 ft3
10 gal/1 ft3

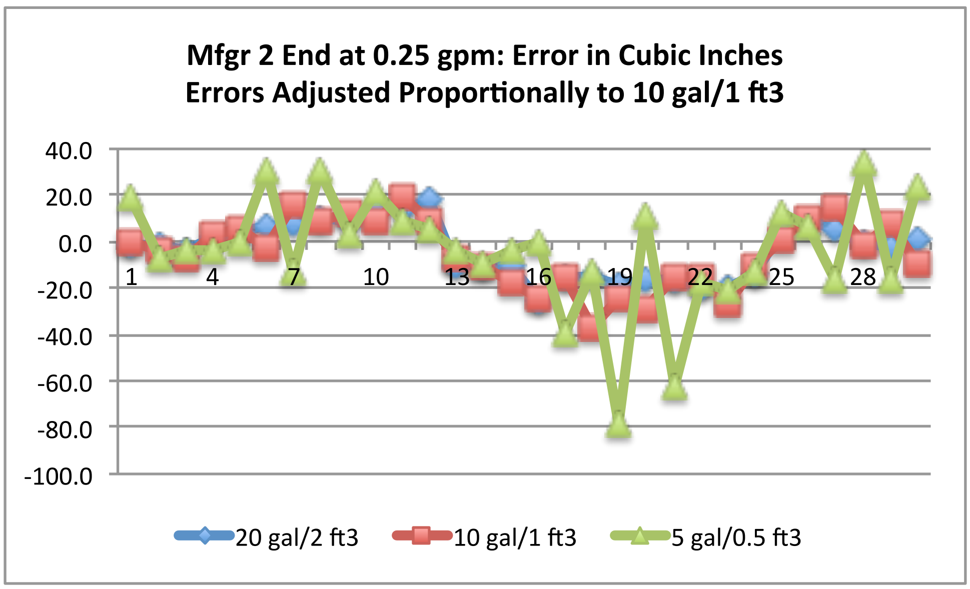

Mfgr 2 End at 2 gpm: Error in Cubic Inches
60.0
40.0
20.0
0.0
-20.0
-40.0
1
4
7
10
13
16
19
22
25
28
40 gal/4 ft3
20 gal/2 ft3
10 gal/1 ft3

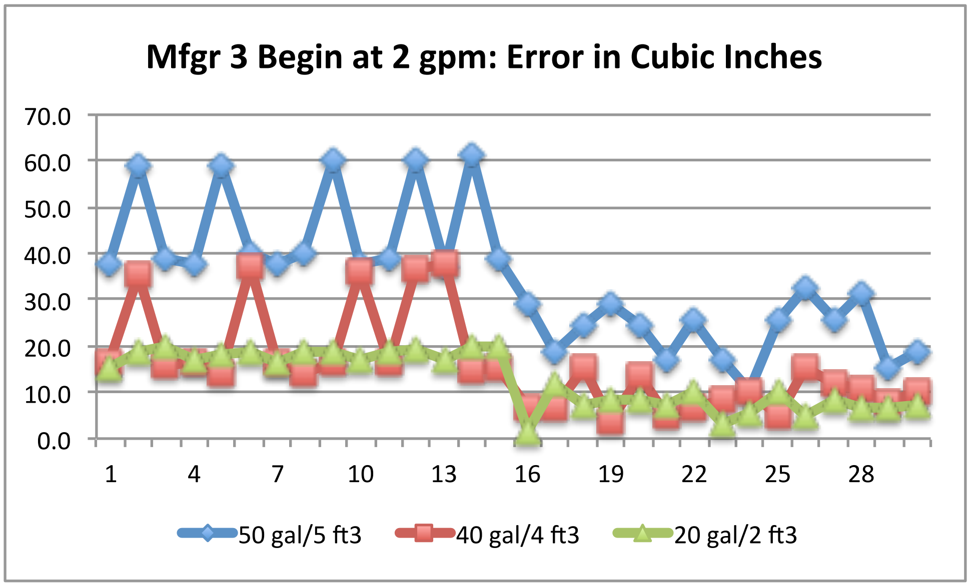

Mfgr 2 End at 2 gpm: Error in Cubic Inches
Errors Adjusted Proportionally to 10 gal/1 ft3
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
1
4
7
10
13
16
19
22
25
28
40 gal/4 ft3
20 gal/2 ft3
10 gal/1 ft3

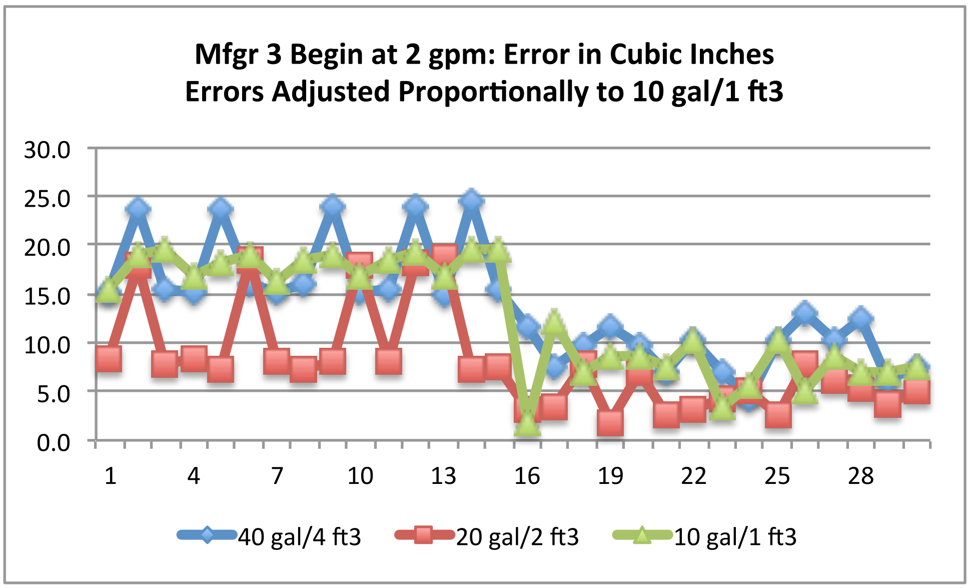

Mfgr 2 Begin at 0.25 gpm: Error in Cubic Inches
40.0
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
1
4
7
10
13
16
19
22
25
28
20 gal/2 ft3
10 gal/1 ft3
5 gal/0.5 ft3

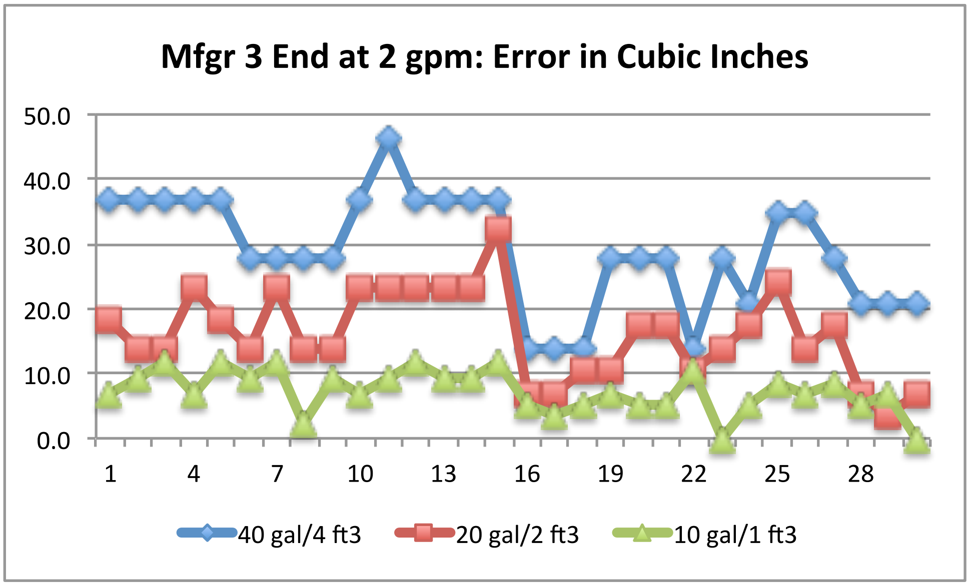

Mfgr 2 Begin at 0.25 gpm: Error in Cubic Inches
Errors Adjusted Proportionally to 10 gal/1 ft3
60.0
40.0
20.0
0.0
-20.0
-40.0
-60.0
1
4
7
10
13
16
19
22
25
28
20 gal/2 ft3
10 gal/1 ft3
5 gal/0.5 ft3

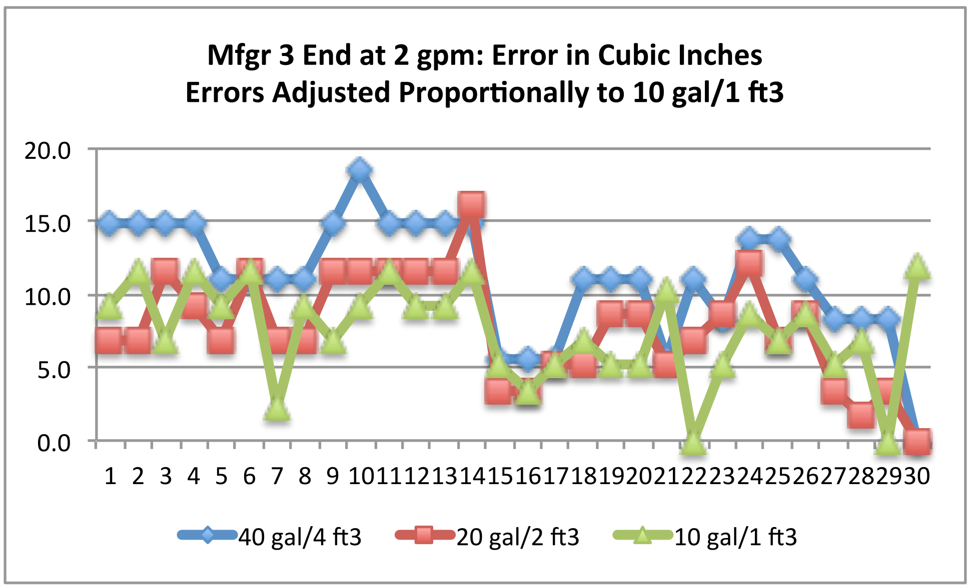

Mfgr 2 End at 0.25 gpm: Error in Cubic Inches
40.0
20.0
0.0
-20.0
-40.0
-60.0
1
4
7
10
13
16
19
22
25
28
20 gal/2 ft3
10 gal/1 ft3
5 gal/0.5 ft3

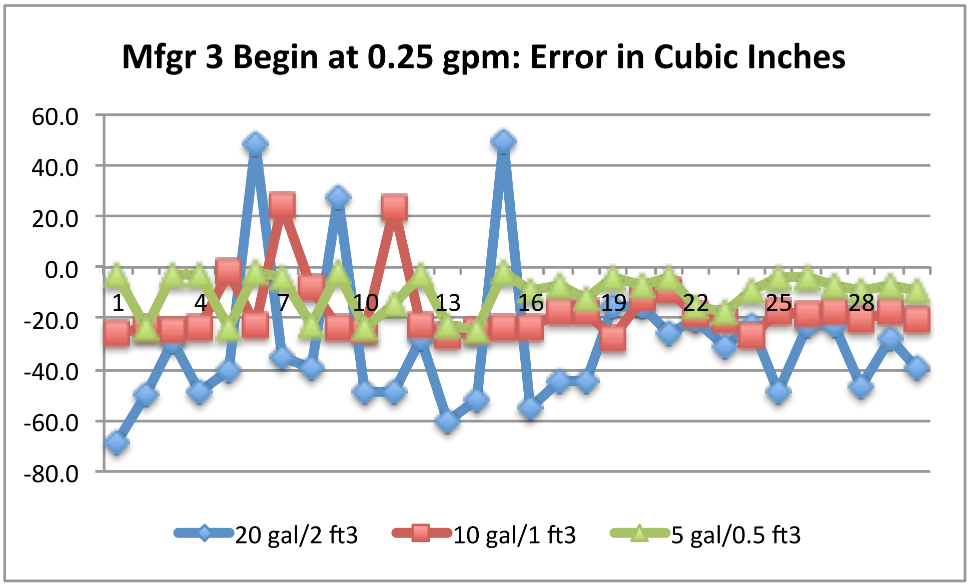

Mfgr 2 End at 0.25 gpm: Error in Cubic Inches
Errors Adjusted Proportionally to 10 gal/1 ft3
40.0
20.0
0.0
-20.0
-40.0
-60.0
-80.0
-100.0
1
4
7
10
13
16
19
22
25
28
20 gal/2 ft3
10 gal/1 ft3
5 gal/0.5 ft3

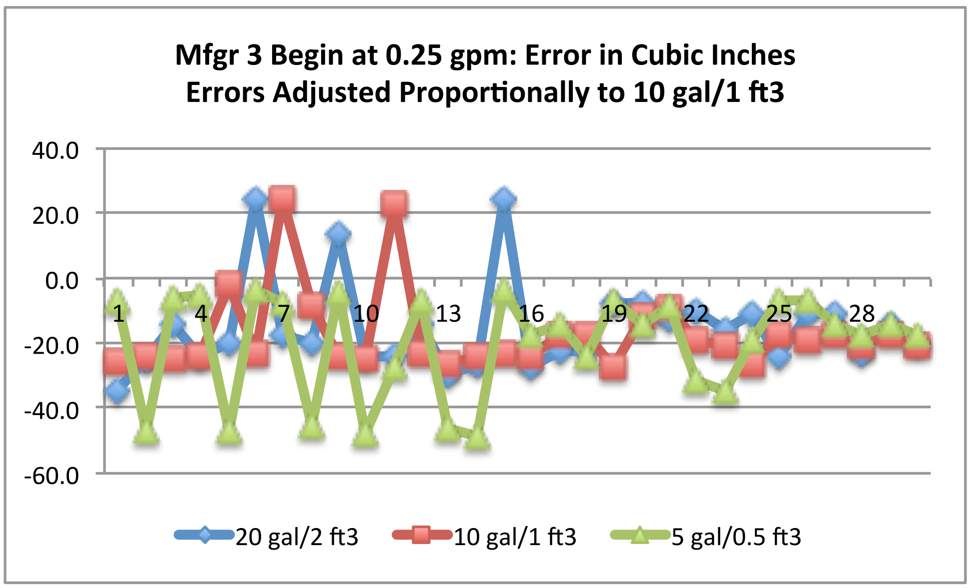

Mfgr 3 Begin at 2 gpm: Error in Cubic Inches
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1
4
7
10
13
16
19
22
25
28
50 gal/5 ft3
40 gal/4 ft3
20 gal/2 ft3

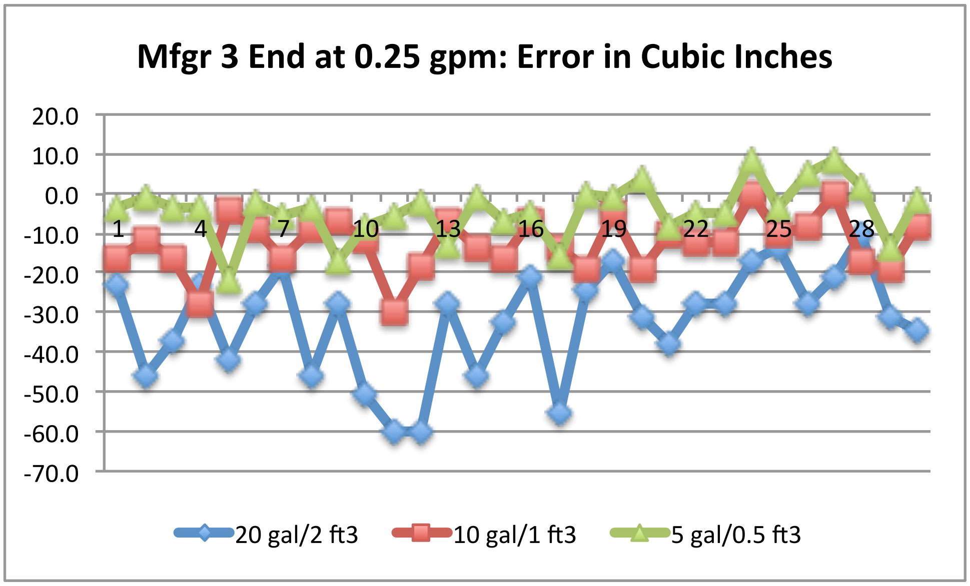

Mfgr 3 Begin at 2 gpm: Error in Cubic Inches
Errors Adjusted Proportionally to 10 gal/1 ft3
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1
4
7
10
13
16
19
22
25
28
40 gal/4 ft3
20 gal/2 ft3
10 gal/1 ft3

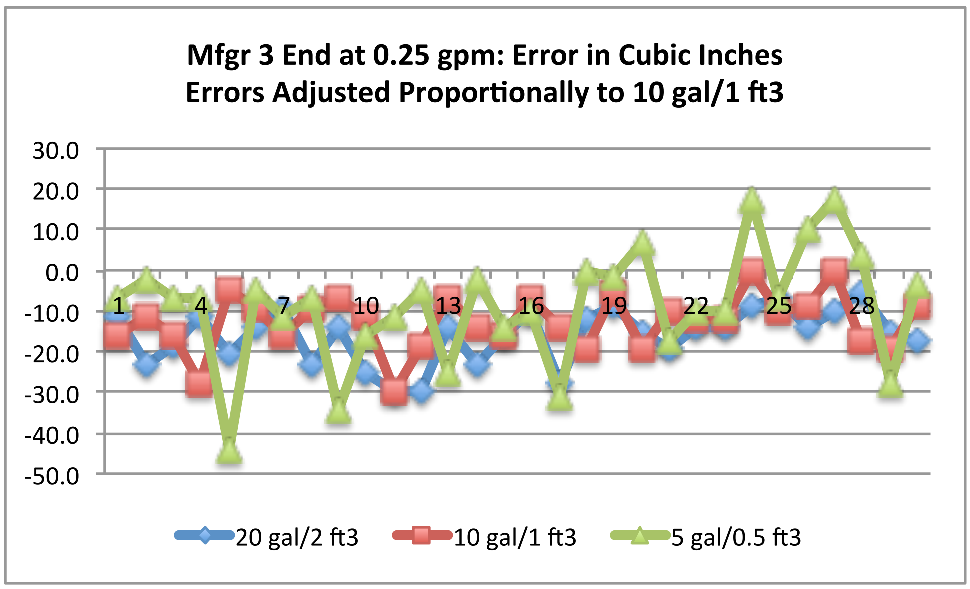

Mfgr 3 End at 2 gpm: Error in Cubic Inches
50.0
40.0
30.0
20.0
10.0
0.0
1
4
7
10
13
16
19
22
25
28
40 gal/4 ft3
20 gal/2 ft3
10 gal/1 ft3


Mfgr 3 End at 2 gpm: Error in Cubic Inches
Errors Adjusted Proportionally to 10 gal/1 ft3
20.0
15.0
10.0
5.0
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
40 gal/4 ft3
20 gal/2 ft3
10 gal/1 ft3


Mfgr 3 Begin at 0.25 gpm: Error in Cubic Inches
60.0
40.0
20.0
0.0
-20.0
-40.0
-60.0
-80.0
1
4
7
10
13
16
19
22
25
28
20 gal/2 ft3
10 gal/1 ft3
5 gal/0.5 ft3


Mfgr 3 Begin at 0.25 gpm: Error in Cubic Inches
Errors Adjusted Proportionally to 10 gal/1 ft3
40.0
20.0
0.0
-20.0
-40.0
-60.0
1
4
7
10
13
16
19
22
25
28
20 gal/2 ft3
10 gal/1 ft3
5 gal/0.5 ft3





In an effort to estimate the combined within- and between-series standard deviations, the standard deviations for the proportionally adjusted test results at each flow rate for the 10-gal and 1-ft^3 test drafts were computed. The proportionately adjusted test results for each meter were used to compute the standard deviation for each meter for each manufacturer. Then the 10 within-series standard deviations for the beginning and end test results were pooled separately and then the two pooled standard deviations for the beginning and end results were pooled. In the final step, the pooled standard deviations for the 10-gal and 1-ft^3 test drafts were scaled up and down for the other test drafts. The calculated values to estimate the combined within- and between-series standard deviations are shown in the following table in cubic inches and as a percent of the test draft using the gallon test draft size.

	2 gpm					
	40 gal/4 ft^3		20 gal/2 ft^3		10 gal/1 ft^3	
	in^3	% Test Draft	in^3	% Test Draft	in^3	% Test Draft
Mfgr 1	42.0	0.45	21.5	0.46	10.7	0.46
Mfgr 2	24.6	0.27	12.3	0.27	6.2	0.27
Mfgr 3	15.5	0.17	7.7	0.17	3.9	0.17
	0.25 gpm					
	20 gal/2 ft^3		10 gal/1 ft^3		5 gal/0.5 ft^3	
	in^3	% Test Draft	in^3	% Test Draft	in^3	% Test Draft
Mfgr 1	27.9	0.60	13.9	0.60	7.0	0.61
Mfgr 2	23.6	0.51	11.8	0.51	5.9	0.51
Mfgr 3	24.2	0.52	12.1	0.52	6.1	0.53

When the pooled standard deviation values in cubic inches are used in the denominator of the F-tests for the within-series standard deviations expressed in cubic inches for the beginning and end tests, the probability values for the F-tests are shown below. The shaded cells represent probabilities less than 5% of being the same.

Probability

	2 gpm	2 gpm	2 gpm	0.25 gpm	0.25 gpm	0.25 gpm
Meter Set	40 gal	20 gal	10 gal	20 gal	10 gal	5 gal
Mfgr Begin	0.729	0.954	0.916	1.000	0.999	0.942
Mfgr Begin	0.774	0.063	0.998	0.006	0.050	0.001
Mfgr Begin	0.991	0.829	0.473	0.944	0.901	0.003
	2 gpm	2 gpm	2 gpm	0.25 gpm	0.25 gpm	0.25 gpm
Meter Set	4 ft3	2 ft3	1 ft3	2 ft3	1 ft3	0.5 ft3
Mfgr Begin	1.000	0.999	0.890	1.000	0.933	0.120
Mfgr Begin	1.000	0.998	0.788	1.000	1.000	0.997
Mfgr Begin	1.000	0.999	0.806	0.999	0.972	0.270

Probability

	2 gpm	2 gpm	2 gpm	0.25 gpm	0.25 gpm	0.25 gpm
Meter Set	40 gal	20 gal	10 gal	20 gal	10 gal	5 gal
Mfgr End	1.000	0.999	0.460	1.000	0.921	0.282
Mfgr End	1.000	0.997	0.910	1.000	0.978	0.343
Mfgr End	0.096	0.937	0.619	1.000	0.893	0.003
	2 gpm	2 gpm	2 gpm	0.25 gpm	0.25 gpm	0.25 gpm
Meter Set	4 ft3	2 ft3	1 ft3	2 ft3	1 ft3	0.5 ft3
Mfgr End	1.000	0.990	0.251	1.000	0.975	0.145
Mfgr End	1.000	1.000	0.893	1.000	0.985	0.198
Mfgr End	0.997	0.972	0.133	0.999	1.000	0.994

As mentioned earlier, when the standard deviations for the adjusted test drafts are used in the denominator of the F-tests when applied separately for the manufacturers' beginning and end results for meters indicating in gallons and cubic feet, the number of F-tests that fail are 4 out of 72 or 5.6%. This failure rate is very close to the 5% that is expected when calculating the F-test at the 95% confidence level. These results of the F-tests give credibility to the standard deviations calculated in the exercise, but actual test data are needed to determine the combined within- and between-series standard deviations.

Evaluation of the Uncertainty Limits on the Average Test Results

Using the manufacturers' test results as a benchmark, one can assume that the uncertainty limits on the average values for each laboratory should not be less than two times the standard deviations calculated in the previous section. At the flow rate of 2 gpm, the standard deviations for the different manufacturers varied significantly. Since the variation in the test results for the manufacturers, DMS and the county labs are relatively small compared to the tolerance, no additional effort is made to analyze the results.

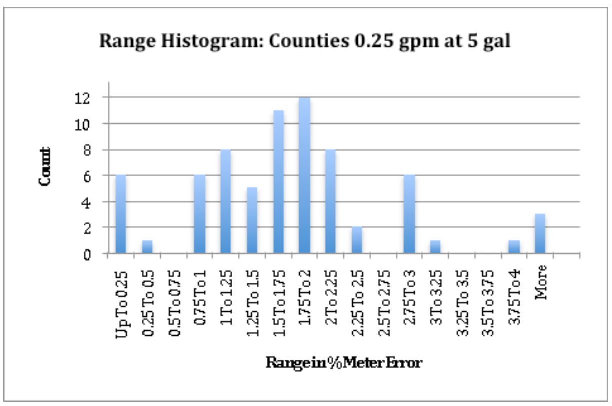
At the flow rate of 0.25 gpm, the standard deviations calculated for the three manufacturers are rather consistent; they are between 0.5% and 0.6%. Again, using a multiplier of two for the standard deviations in the previous section, this indicates that the error bars associated with the average test results for any laboratory at 0.25 gpm should not be less than about 1% at the 95% confidence level. Some laboratories may have larger uncertainties, but it is unlikely that the uncertainty limits should be less than the values calculated for the manufacturers in the previous section. If these larger uncertainty values were used, more values and error bars would overlap.

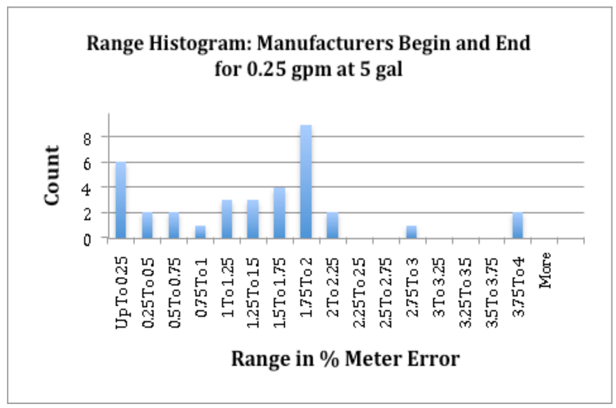
Evaluation of the Range Charts

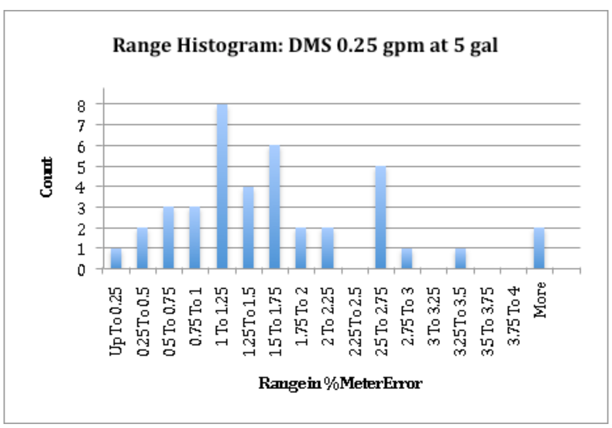
The range of the repeat test results in terms of percent meter error is used as a measure of repeatability of water meters. It is apparent from the charts in the section titled, "Range Charts," that the range in test results can vary significantly from laboratory to laboratory and from meter to meter. The ranges in test results also vary as a percent meter error for the different sizes of test drafts. The logic to establish appropriate limits on the range results is a challenge. The simplest approach is to compare the range results of the counties to the range results for the manufacturers and DMS. However, the value for the range can vary greatly, because it depends on only two values: the minimum and maximum values of the set of repeat tests. The results can vary greatly depending upon how the "sample" of three measurements happens to be drawn from the population distribution.

The "Histograms of the Range Results" provides the most helpful view of the test results for the range. At 15 gpm, there isn't much difference in the test results among the manufacturers, DMS and the county laboratories. At 2 gpm, the counties tend to exhibit greater variability in the range than do DMS and the manufacturers. However, very few of the meters exceeded the tolerance of 2% for the intermediate flow rate.

The range of the test results is greater for the county laboratories at the minimum flow rate of 0.25 gpm than it is for DMS and the manufacturers. Nevertheless, the shapes of the distributions, even for the 5-gal test draft are not greatly different for the counties, DMS and the manufacturers results. The following charts are repeated from the section titled, "Histograms of the Range Results."





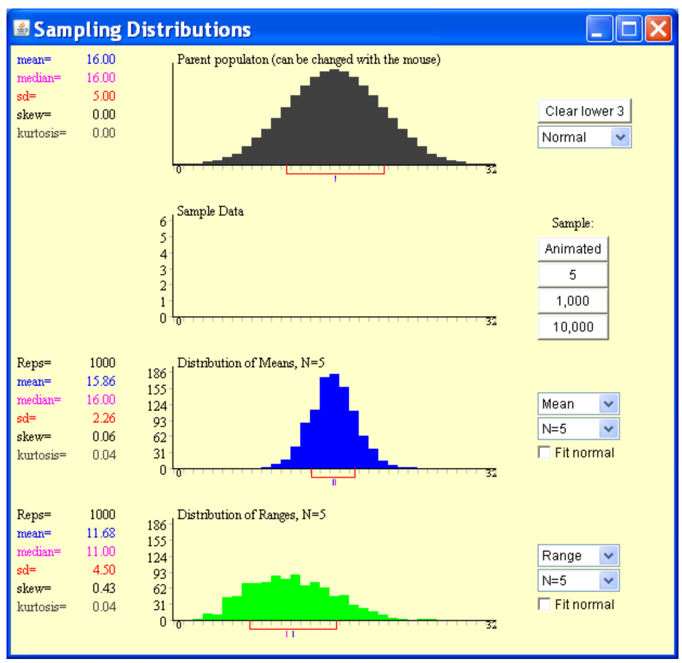


The median values for the ranges at the minimum flow rates are surprisingly similar for the counties, DMS and the manufacturers. The following table is repeated from the section. “Histograms of the Range Results.”

Meters in ft³	15 gpm at 5 ft³		2 gpm at 1 ft³		0.25 gpm at 1 ft³			
	Mean	Median	Mean	Median	Mean	Median		
Counties	0.21	0.12	0.50	0.49	0.84	0.58		
DMS	0.12	0.07	0.52	0.41	0.61	0.59		
Mfgrs	0.16	0.06	0.57	0.48	0.69	0.58		
Meters in gallons	15 gpm 50 gal		2 gpm at 10 gal		0.25 gpm at 10 gal		0.25 gpm at 5 gal	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Counties	0.26	0.19	0.58	0.50	0.93	0.50	1.94	1.60
DMS	0.20	0.13	0.49	0.41	0.69	0.59	1.67	1.47
Mfgrs	0.16	0.14	0.38	0.20	0.65	0.55	1.40	1.50

There is a helpful statistical tool on the Internet that allows one to perform sampling experiments to explore different measurement characteristics. The web site is:

http://onlinestatbook.com/stat_sim/sampling_dist/index.html.



In particular, one can see the range distribution when sampling from a normal distribution. It is interesting to note that the median of the range is more than double the standard deviation of the parent normal distribution. Additionally, the range distribution extends to the right by more than one standard deviation of the range beyond the median and mean. One can use the “between-series” standard deviation at the minimum flow rate to obtain an estimate of the range of values that can reasonably be expected for water meters.

If we use an “between-series” standard deviation of 0.55% as an estimate of the parent distribution for water meters at a flow rate of 0.25 gpm for the 5-gal test draft, then it is reasonable to expect the range of test results to easily vary up to at least 1.8%. The range histograms for the counties, DMS and the manufacturers all show a large percentage of the range results go up to about 2.25%. Consequently, one can conclude that range results up to about 2.25% at 0.25 gpm for the 5-gal test draft are reasonable simply based upon “sampling” of the parent distribution for water meters. Laboratories that had range values significantly greater than 2.25% should examine their test facilities and test procedures to see if anything in their test system is contributing to the large range of test results.

Repeatability and the Sizes of Test Drafts

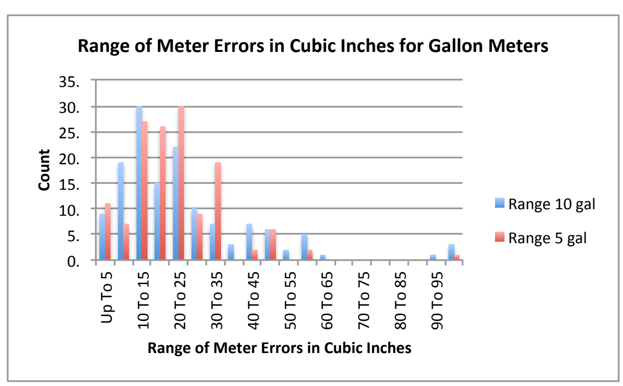
Analyses were done to explore the impact on the variation of test results when using different sizes of test drafts. The 10- and 5-gal test drafts at the minimum flow rate are of particular interest. The test results for all of the test laboratories (manufacturers, DMS and counties) were examined. The analyses show that the variations in the results for the 10- and 5-gal test results are similar. The apparent increase in variability in test results when computed as percent meter error for the 5-gal test draft is a mathematical effect due to dividing the constant variation (that is, the standard deviation in cubic inches for the 10- and 5-gal tests) by the smaller value (5-gal) when computing the percent meter error for the 5-gal test.

The pooled standard deviation for all of the laboratories for the sets of three tests for the 10-gal test draft is 16.5 in^3. The pooled standard deviation for the tests using the 5-gal test draft is 14.7 in^3. The pooled standard deviations, when calculated in cubic inches, are essentially equal.

For reference purposes, the repeatability tolerances for utility type water meters are given in the table below in both percent meter error and in cubic inches for the different sizes of test drafts.

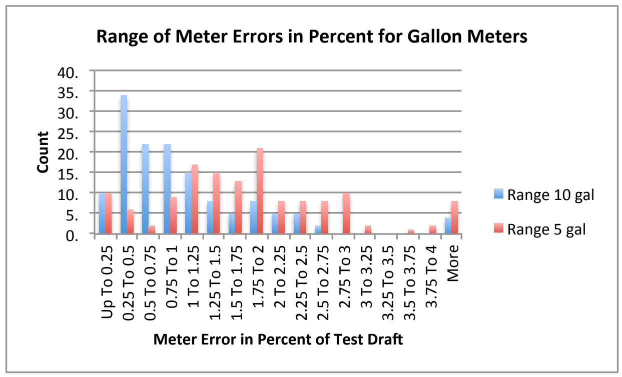
Flow Rate	Test Draft	Repeatability Tolerance	
		Range in Percent Meter Error	Range in Cubic Inches
Normal	5 ft^3	0.6%	51.8
	50 gal		69.3
Intermediate	1 ft^3	2.0%	34.6
	10 gal		46.2
Minimum	1 ft^3	4.0%	69.1
	10 gal		92.4
	5 gal		46.2

The histogram (right) for the range of test results for the 5- and 10-gal test drafts when the meter errors are stated in cubic inches for each set of three individual tests shows that the range results resemble normal distributions that are slightly skewed. This is consistent with the results of the sampling exercises that can be done using the web site,

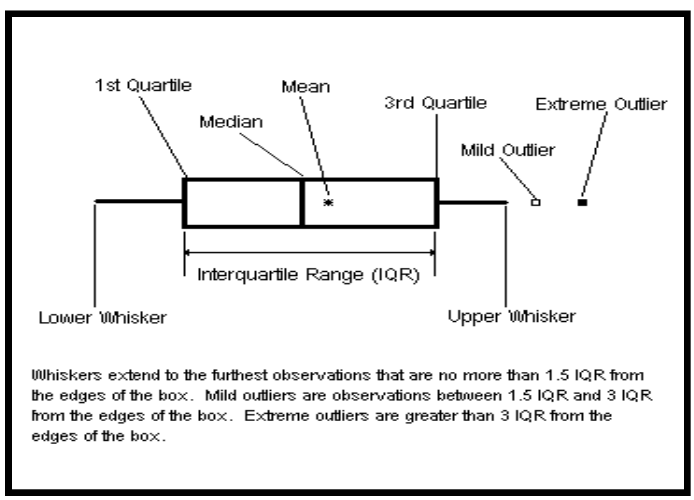


http://onlinestatbook.com/stat_sim/sampling_dist/index.html.

The histogram shows that the ranges of the test results are similar for the 5-gal test draft compared to the 10-gal test draft when plotted in cubic inches. This is expected since the pooled standard deviations (when calculated in cubic inches) for the two test drafts are essentially equal. Because the pooled standard deviations for the two test drafts are essentially equal, the 10-gal test draft effectively doubles the repeatability tolerance in cubic inches compared to the 5-gal test draft. Most of the range results are well within the repeatability tolerance for both test draft sizes. Of the 140 sets of tests (i.e., 140 sets of three repeat tests at each test draft at the minimum flow rate), three meters failed the repeatability tolerance for the 10-gal test and 5 meters failed the repeatability tolerance at the 5-gal test.

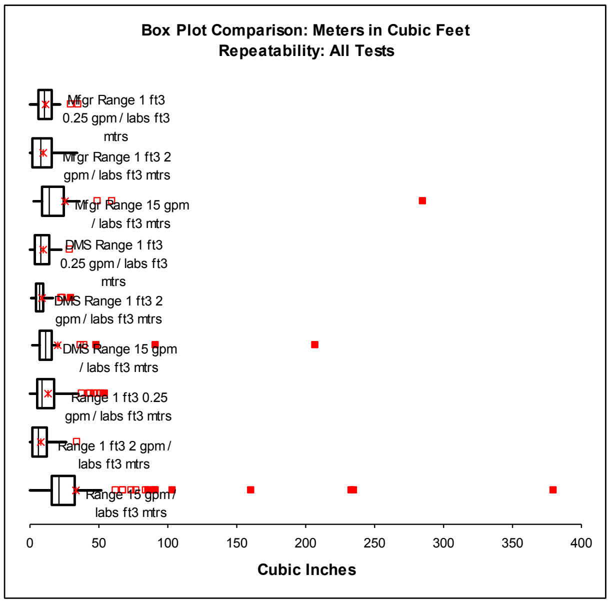


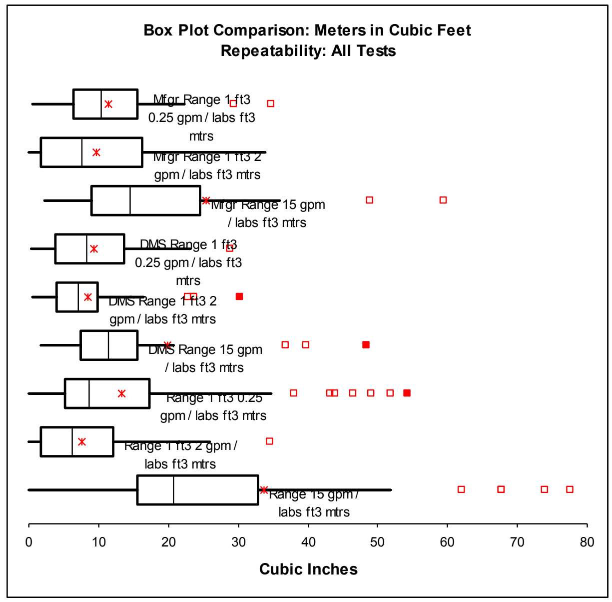
When the test results are expressed as a percent meter error for the two test draft sizes, the charts take on a significantly different appearance. To the right is a histogram for the range results when the meter errors are stated as the percent meter error. Because the percent meter error is computed by dividing the meter error by the size of the test draft, the range of test results when calculated as the percent meter error at 5 gal appears to be twice as large as the percent meter error computed for the 10-gal test draft. Because different test draft sizes are used to compute the percent meter errors and these test draft sizes are relatively small compared to the variation in meter test results for these test draft sizes, it gives the appearance that the test results for the 5-gal tests do not repeat nearly as well as for the 10-gal test drafts. This is what causes the appearance of more variability in the test results for the 5-gal test draft compared to the 10-gal test drafts in the charts of the individual test results when expressed in percent meter error.



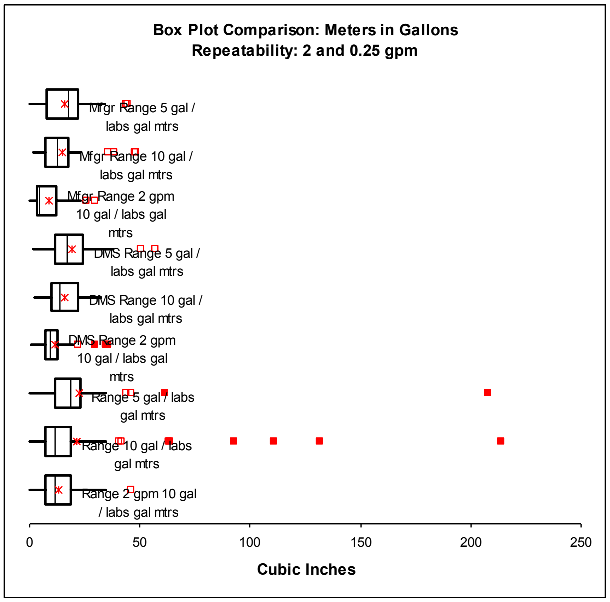
Another way to compare the variation of test results is to look at the box-and-whisker distributions of the range values for the sets of three repeat tests for different sizes of test drafts and for different groups of laboratories. The graphical explanation of the box-and-whisker graph (right) was generated by the StatTools statistical software created by Palisade Corporation, 798 Cascadilla Street, Ithaca, NY.

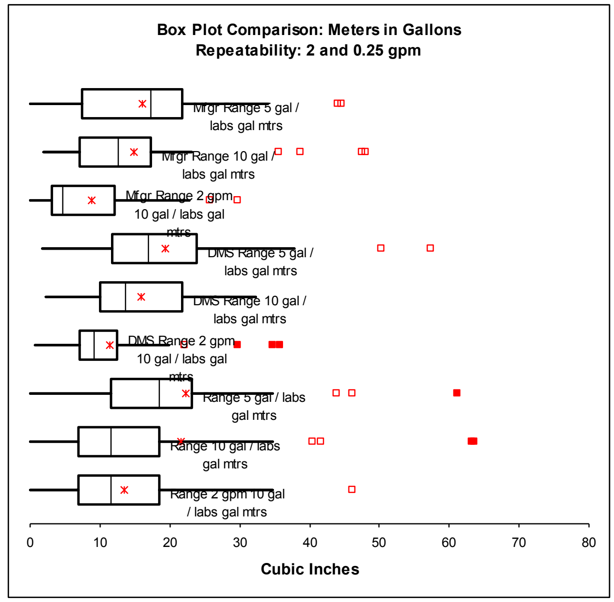
Below are two box–and-whisker charts that show the range distributions for the meters indicating in cubic feet. The charts show the range distributions for the 15-, 2- and 0.25-gpm flow rates and the test draft sizes of 5 and 1 ft^3. The top three box–and-whisker plots are the combined begin and end results for the manufacturers, which are identified on the chart as “Mfgr Range.” The next three box–and-whisker plots in the middle of the chart are the combined begin and end DMS results and identified on the chart as “DMS Range.” The bottom three box–and-whisker plots are the combined results for all of the California counties and do not have an identifier on the chart. The chart to the left shows all of the outliers. The x-axis on the chart on the right is changed to expand the box–and-whisker plots to allow a more detailed comparison of the distributions. One can see that the range distribution for the counties at 15 gpm is wider than the distributions for the manufacturers and DMS. This may be due to the water delivery not being stopped exactly on the reference mark during the tests and corrections for the delivered volume could not be made.





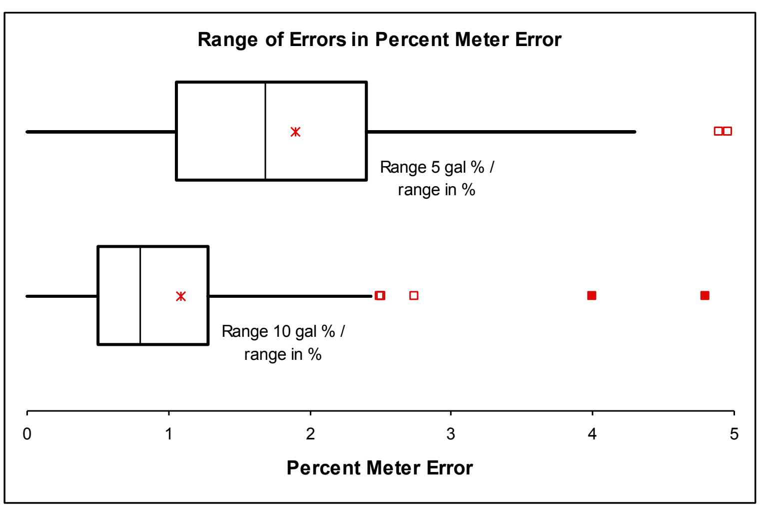
Below are two box-and-whisker charts that show distributions for the meters indicating in gallons for the flow rates of 2 and 0.25 gpm. Due to the limitation of the software to 10 distributions per chart, the 15-gpm results are not included on these two charts.





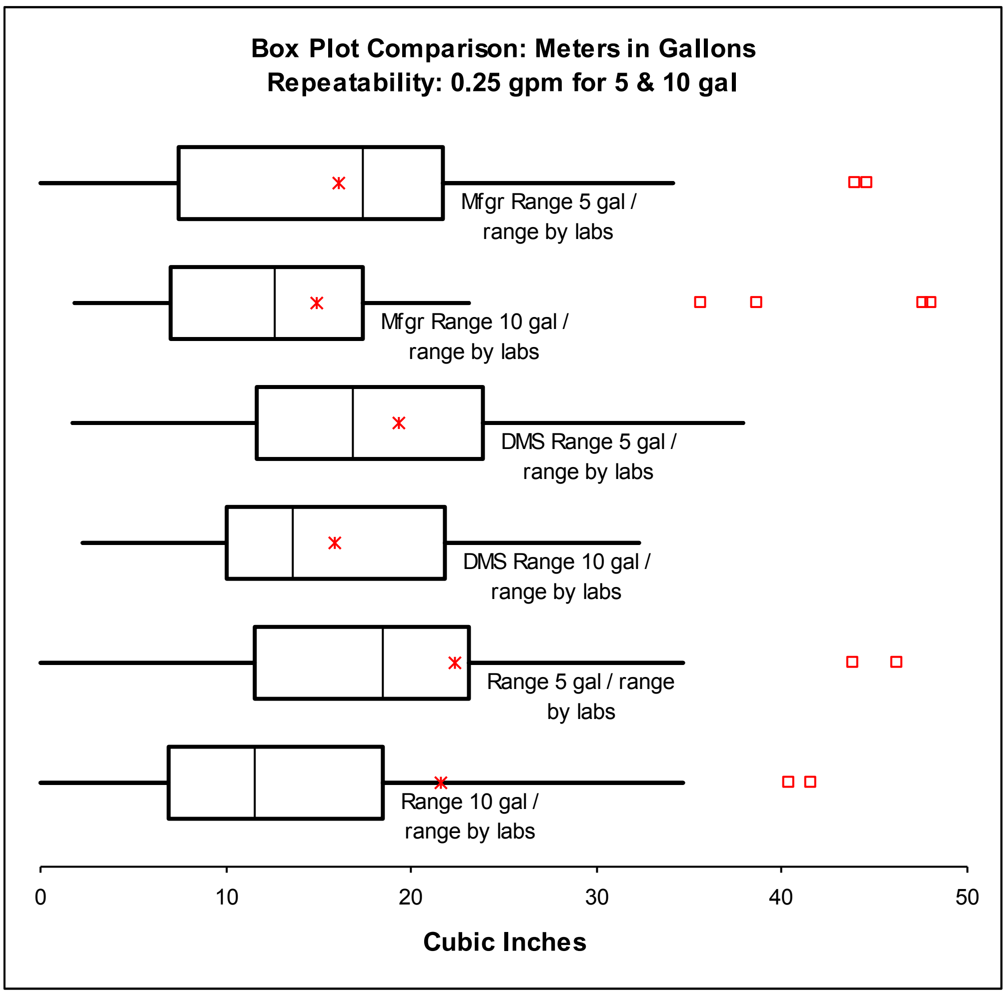
One can see in the upper-right chart that for all three groups of labs, the distributions at 0.25 gpm for the 5-gal test draft are wider than the distributions for the 10-gal test drafts. The test results for the survey do not show a significant difference in the out-of-tolerance test results for the two different sizes of the test draft for gallon meters at the minimum flow rate.

It illustrate the effect on the box-and-whisker charts for repeatability when stating the meter errors in percent meter error, below is a box-and-whisker chart that shows the difference in the appearance of the charts for the 5- and 10-gal test drafts at the minimum flow rate for all labs combined. It appears that the variation in the test results in terms of percent meter error is much greater for the 5-gal test draft (compared to the 10-gal test draft), because the smaller volume of 5 gal is used to calculate the percent meter error.



The box-and-whisker chart below shows only the results for the 5- and 10-gal test drafts at the minimum flow rate for each group of laboratories. Recall that the county lab results are the two plots at the bottom of the chart, DMS results are in the middle and the manufacturer results are at the top. The scale on the x-axis was adjusted to expand the part of the graphs near zero and excludes some of the outliers.

One can see that the range distributions are a little larger for the 5-gal test draft compared to the 10-gal test draft. The larger distributions may be due to the many variables that can affect test results (e.g., parallax, the uncertainty associated with reading the start and end meter indications, eccentricity errors associated with the dials and the indicator shaft, setting the water level in the reference tanks, round-off errors associated with the meter readings, etc.) and which have a relatively larger impact on the smaller sizes of test drafts.

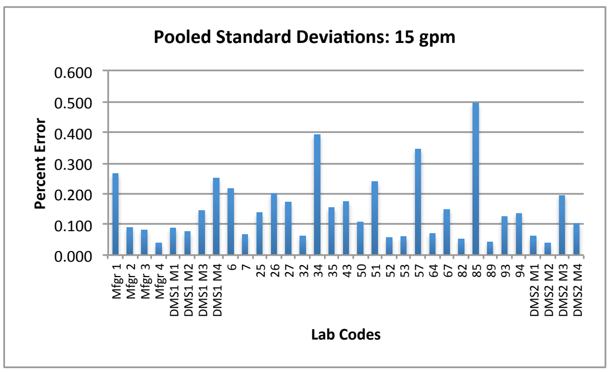


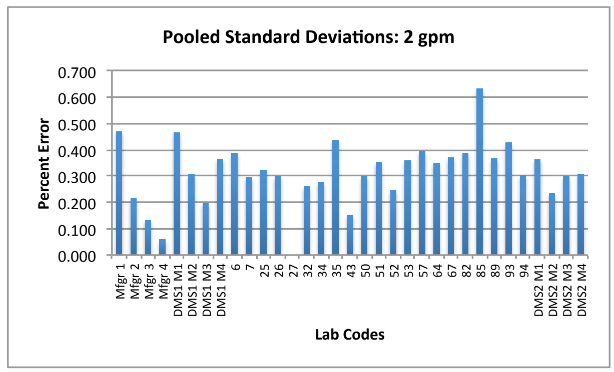
Evaluation of County Repeatability Results

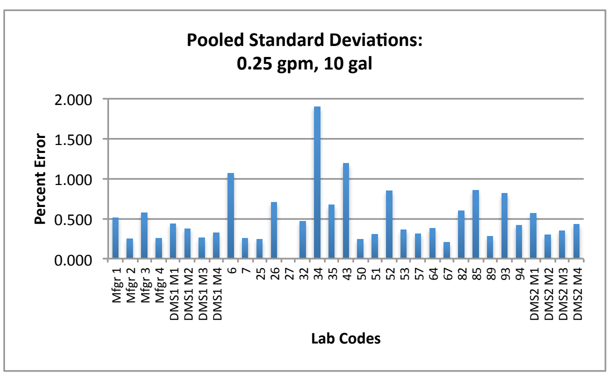
The charts of the pooled standard deviations in the section titled, "Repeatability of Test Results in County Laboratories," represent the pooled within-series standard deviations. The pooled standard deviations are stated as the percent meter error. The standard deviation of the percent meter error will differ for each flow rate and size of test draft, because the repeatability of the meter changes with the flow rate (as well as the accuracy) and the size of the test draft influences the percent calculation of the meter error.

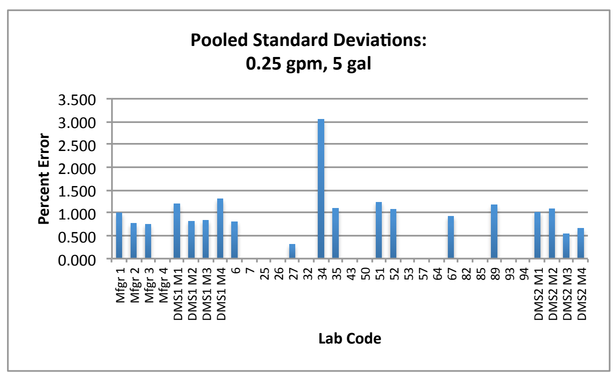
It is difficult to provide a specific numeric guideline as to when the within-series standard deviations are “too large,” because the within-series standard deviations differ for the manufacturers and the DMS results. Furthermore, the counties tested meters from each manufacturer in the groups of meters that they tested.

The best guidance that I can give is that if counties had within-series standard deviations that are significantly larger at any given flow rate and test draft size than DMS, then they should review their test facilities and test procedures to see if they are contributing to the larger standard deviations.

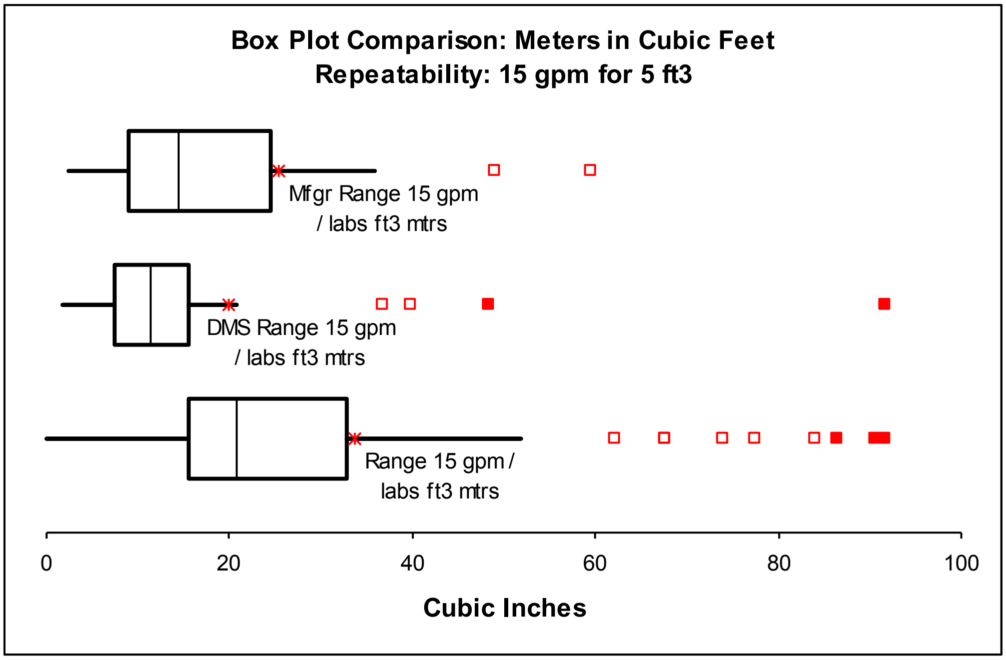


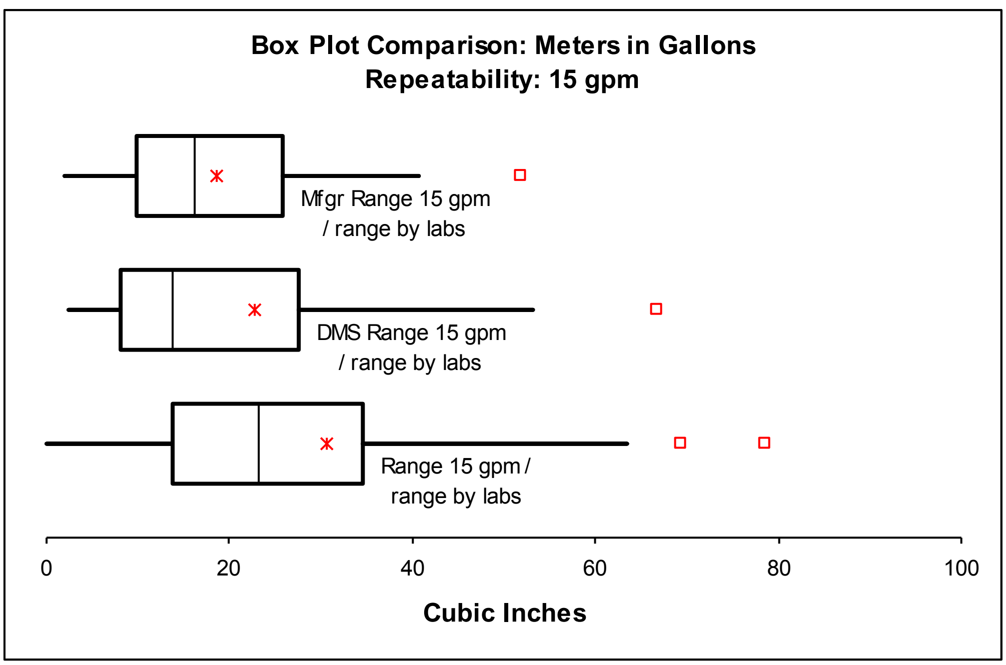


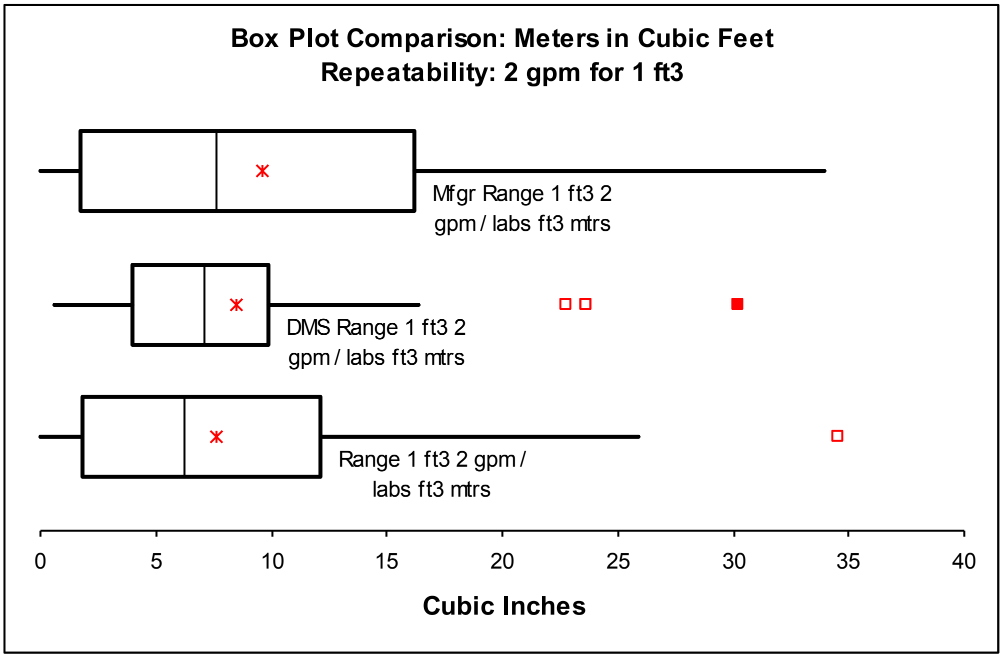


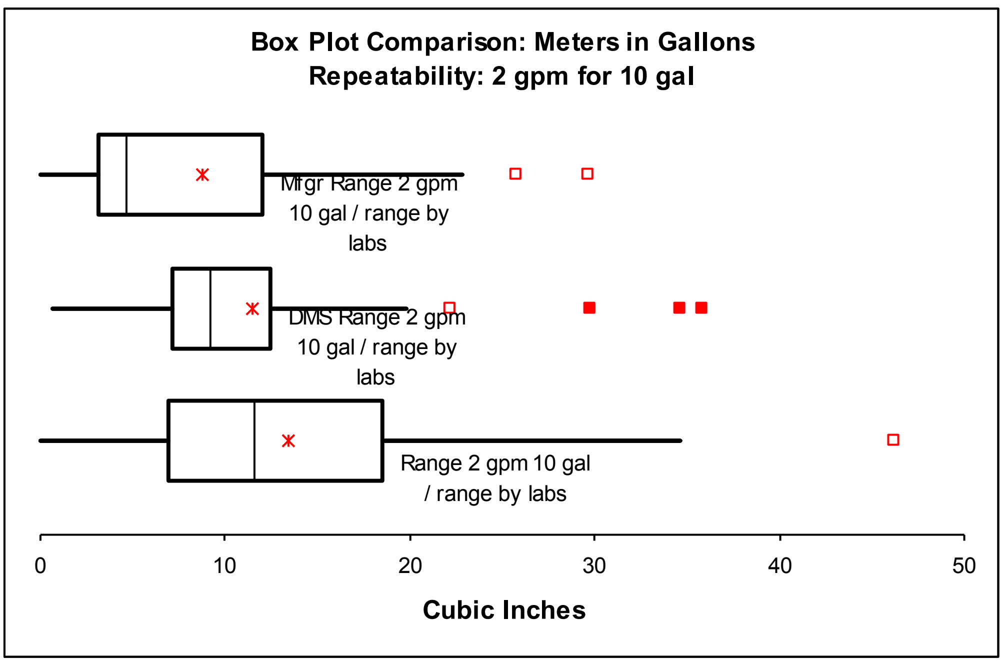


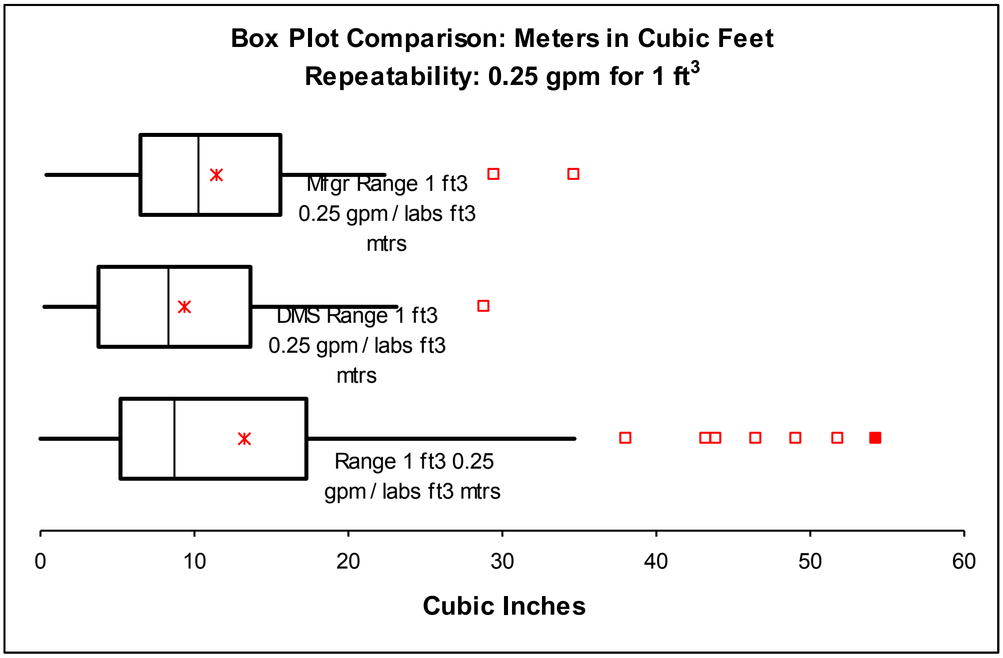
Below are box-and-whisker charts for each type of meter register (cubic feet and gallons) for each flow rate and each size of test draft. The range distributions near zero are expanded for ease of comparison so some of the outliers are not shown. Many of the counties tested with 100-gal test drafts at 15 gpm.

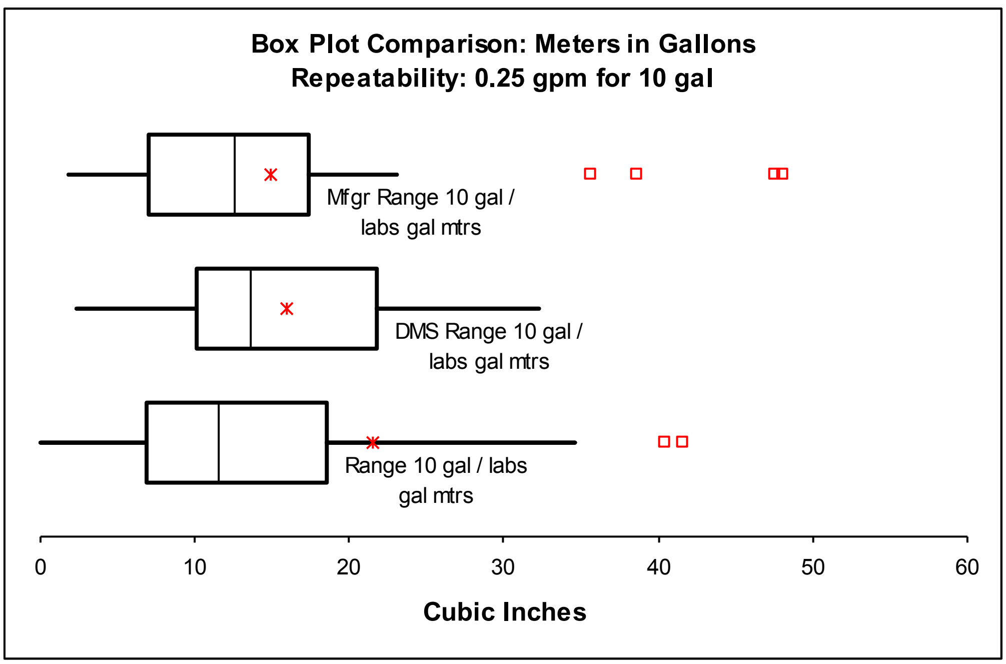


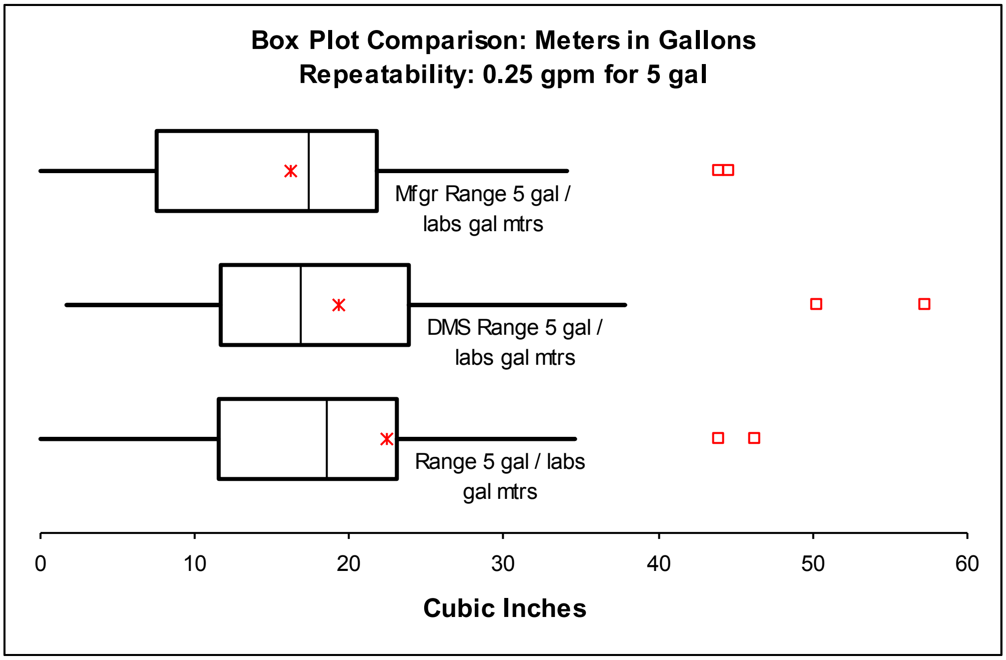



Box Plot Comparison: Meters in Cubic Feet
Repeatability: 2 gpm for 1 ft3
Mfgr Range 1 ft3 2 gpm / labs ft3 mtrs
DMS Range 1 ft3 2 gpm / labs ft3 mtrs
Range 1 ft3 2 gpm / labs ft3 mtrs
0
5
10
15
20
25
30
35
40
Cubic Inches


Box Plot Comparison: Meters in Gallons
Repeatability: 2 gpm for 10 gal
Mfgr Range 2 gpm 10 gal / range by labs
DMS Range 2 gpm 10 gal / range by labs
Range 2 gpm 10 gal / range by labs
0
10
20
30
40
50
Cubic Inches


Box Plot Comparison: Meters in Cubic Feet
Repeatability: 0.25 gpm for 1 ft3
Mfgr Range 1 ft3 0.25 gpm / labs ft3 mtrs
DMS Range 1 ft3 0.25 gpm / labs ft3 mtrs
Range 1 ft3 0.25 gpm / labs ft3 mtrs
0
10
20
30
40
50
60
Cubic Inches

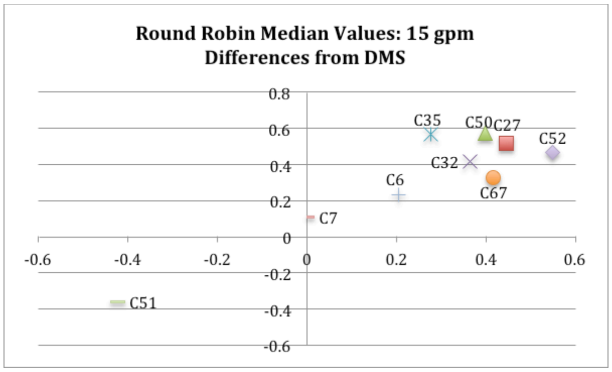

Box Plot Comparison: Meters in Gallons
Repeatability: 0.25 gpm for 10 gal
Mfgr Range 10 gal / labs gal mtrs
DMS Range 10 gal / labs gal mtrs
Range 10 gal / labs gal mtrs
0
10
20
30
40
50
60
Cubic Inches

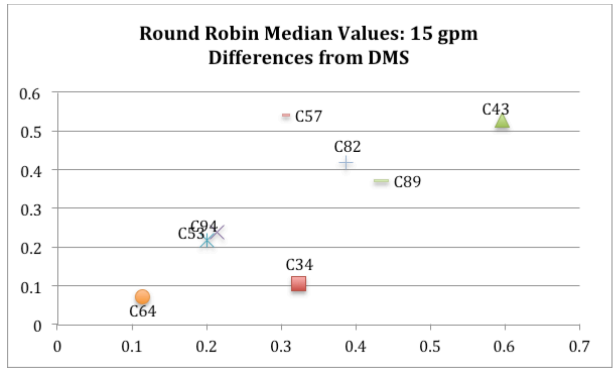


When applying the tolerance for repeatability, the test results and these analyses show that one gets similar test results for the 10-gal and 5-gal test drafts. The meter errors and repeatability results may be computed in terms of either percent meter error or cubic inches and get the same out-of-tolerance results, but one must understand that the size of the test draft affects the apparent variation in test results when the errors are computed as the percent meter error. For test drafts that are large relative to the variation in the test results for the test draft sizes (that is, for the test draft sizes used for the flow rates of 15 gpm), the distribution does not change whether one calculates the repeatability of the test results in cubic inches or in percent meter error.

Evaluating the County Test Results

The plots of the median differences from DMS for those counties that participated in the round-robin exercise are of particular interest.

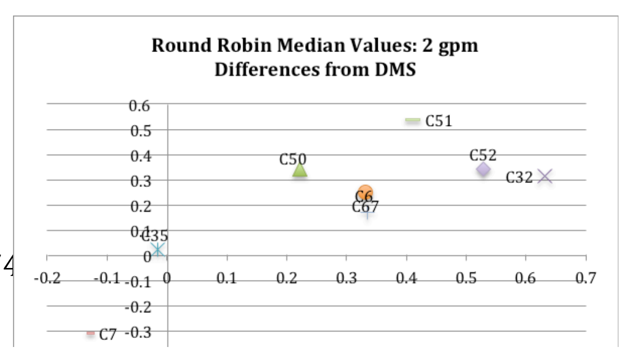




The charts for the results at 15 gpm show that most of the county results are in the upper right quadrant. While the specific reason for these results is not obvious, I will speculate on a possible explanation. Most of the counties used the cylindrical Ford tanks as the reference standards. The test procedure was to deliver water through the meters into the tanks until the tanks were filled to the mark that represented the nominal value of the test draft. It was observed that not all deliveries stopped exactly at the line. Several of the deliveries went beyond the nominal mark by 1 to 3 mm. There was no way to correct for the over delivery of the test volume. Hence, the meter error was calculated as if the volume of water in the tanks was equal to the nominal value. The practice in a few laboratories that if the water delivery was initially stopped below the reference graduation, the valve was opened to deliver more water into the tank in an effort to bring the water level up to the mark. Additionally, the flow rate of 15 gpm made it more difficult to stop the delivery exactly on the reference graduation. A similar situation existed when tests were conducted at the 2-gpm flow rate into the smaller reference tank.

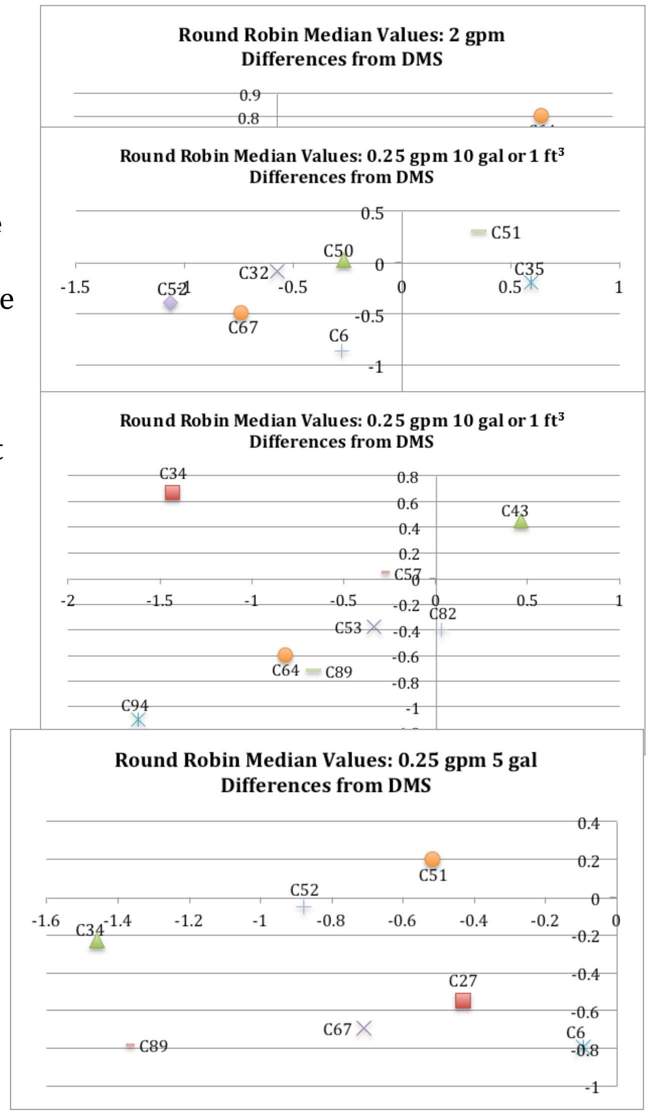
It appeared that the water deliveries, when not stopped exactly on the reference graduation, tended to be in excess of the nominal volume. Using an over-delivery of water into the tank as the nominal value would cause the meter errors to appear as overregistration errors. Also, variations in deliveries affect the range results for repeat tests on meters. Because of the consistent biases seen for the median values of the Youden plot, this is the most likely explanation.

The inability to correct for over- and under deliveries into the Ford reference tanks is a weakness in the test process. Both the manufacturers and DMS were able to correct for deliveries that were different from the nominal values. I recommend that standards with higher resolution be used or gravimetric testing be used so that corrections to the delivery volumes can be made when the deliveries are not at the exact nominal value. One must consider the costs and benefits of changing the reference standards. No meters failed the accuracy tests for overregistration at 15 gpm, even with the biases that were observed. Nevertheless, test technicians should be aware of the impact on test results if the deliveries are not stopped consistently on the reference graduation.



As mentioned previously, County 51 is the exception to the pattern at 15 gpm, because the median values for the differences from DMS are offset by about -0.4%. The negative bias at 15 gpm resulted in more meters found outside of tolerance at 15 gpm than any of the other counties. An odd aspect is that this county shows one of the largest positive offsets for test results at 2 and 0.25 gpm. County 51 and DMS should run additional comparison tests to determine why the results of County 51 differ from DMS and the other counties.

The charts of the test results at 2 gpm also show the majority of county results to be in the upper right quadrant. The probable explanations are the same as for the test results at 15 gpm. The smaller reference tank used with the Ford test is used for tests conducted at 2 gpm. The flow rate is relatively fast for the smaller volume of the standard, so stopping the delivery on the reference graduation is the same challenge as for the larger tank for tests run at 15 gpm. Five meters failed for overregistration errors at the 2-gpm flow rate. Again, test technicians should be aware of the impact on test results if the deliveries are not stopped consistently on the reference graduation.



The charts of the median difference values from the Youden plots for tests conducted at 0.25 gpm show more scatter around zero. These tests also use the smaller reference tank in the Ford test system. At the slower flow rate, it is easier for the technician to stop the delivery on the reference graduation.

The test results at the flow rate of 0.25 gpm for the 5-gal test draft show that the counties tended to have test results showing more underregistration than observed by DMS for at least one group of the two groups of meters tested. It isn't clear why these results occurred.

Summary Information for the Counties

The results for the individual counties are provided in the section titled, "County Test Results." Below is a table that provides summary information on the groups and number of meters tested by the counties and the capacity of the test bench. The specific capacities of the test benches are not stated to maintain anonymity.

	Bench Capacity	Meters Tested in ft^3 Sets				Meters in Gallon Sets			
Co. Lab	for Meters	FA	FB	FC	FD	GA	GB	GC	GD
6	< 5					5			5
7	≥ 5	5	5						
25	< 5			5					
26	≥ 5				5				
27	≥ 5			4	4				
32	≥ 5			5	5				
34	< 5					5			5
35	≥ 5	5							5
43	≥ 5			5	5				
50	≥ 5			5			5		
51	≥ 5					5			5
52	≥ 5						5	5	
53	< 5			5	5				
57	< 5			5	5				
64	≥ 5	5		5					
67	≥ 5						5	5	
82	≥ 5	5		5					
85	≥ 5	5							
89	≥ 5						5	5	
93	< 5		5						
94	< 5	5	5						

Below is a table that summarizes information on the test facilities and some test information.

County Lab	Notes and Comments
6	Ford test bench and recirculating system. Test bench capacity was less than 5 meters.
7	Ford test bench; city water supply.
25	Ford test bench. Test bench capacity was less than 5 meters.
26	Ford test bench and recirculating system. Plumbing and procedural issues. Air purge and tank starting point issues.
27	No test bench; used neck-type provers as reference standards; corrected for deliveries different from nominal. No tests run at 2 gpm.
32	Ford test bench and recirculating system.
34	Ford test bench and recirculating system Test bench capacity was less than 5 meters. Minimum flow rates were often below 0.25 gpm. Large standard deviations at 15 and 0.25 gpm.
35	Ford test bench. Tested one group of gallon meters and one group of cubic foot meters.
43	No test bench; meters were tested outdoors and the test system was constructed on hoses and pipe connectors. This laboratory has some peculiar variations in the test results compared to the other laboratories.
50	Ford test bench. Occasional repeated starts and stops of the flow rate to stop on the reference graduation.
51	Ford test bench. City water used in the tests. County had a large number of rejected meters. Unusual offset from DMS and other labs at 15 gpm.
52	Ford test bench. City water used in the tests.
53	Ford test bench and recirculating system. Test bench capacity was less than 5 meters.
57	Ford test bench and recirculating system. Incorrect technique used in the first test at 15 gpm. Significant amount of variation in the test results. Test bench capacity was less than 5 meters. Large standard deviation at 15 gpm.
64	Ford test bench and recirculating system.
67	Ford test bench. City water used in the tests. Test bench installed outdoors.
82	Ford test bench and recirculating system.
85	Ford test bench. City water used in the tests. Large standard deviations at 15 and 2 gpm.
89	Ford test bench and recirculating system.
93	Ford test bench. City water used in the tests. Test bench capacity was less than 5 meters. Two of the flow rates for the minimum flow rate tests were below 0.25 gpm.
94	Ford test bench and recirculating system. Test bench capacity was less than 5 meters.

Appendix A: Tables of Individual Test Results

Below is a table of all individual test results for each meter, for each flow rate, for each size of test draft and each laboratory.

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
Mfgr B	FA1	-0.74	0.45	0.31	0.40	-1.35	-1.20	-1.00
Mfgr B	FA1	-0.66	0.22	0.22	0.40	-0.80	-1.00	-0.80
Mfgr B	FA1	-0.80	0.27	0.30	0.43	-1.15	-1.21	-1.00
DMS B	FA1	-0.79		0.13	0.23		-0.25	-0.88
DMS B	FA1	-0.78		0.08	0.36		-0.10	-0.64
DMS B	FA1	-0.78		0.41	0.03		-0.29	-0.39
7	FA1	-0.76		0.00	-0.10		-1.00	
7	FA1	-0.88			0.10		-1.20	
7	FA1	-0.80			0.00		-1.20	
94	FA1	-0.60			0.50		-2.00	
94	FA1	-0.65			1.00		-2.50	
94	FA1	-0.60			0.50		-2.50	
35	FA1	-0.10			0.00		0.00	
35	FA1	-0.15			0.50		0.00	
35	FA1	-0.35			0.00		0.00	
85	FA1	-0.80			1.00		-1.00	
85	FA1	-1.00			-1.00		1.00	
85	FA1	-0.80			1.00		-1.00	
82	FA1	-0.38			0.25		0.50	
82	FA1	-0.27			0.00		0.50	
82	FA1	-0.35			-0.25		0.25	
64	FA1	-0.57			0.50		-0.30	
64	FA1	-0.64			0.50		-0.50	
64	FA1	-0.73			0.80		-1.00	
DMS E	FA1	-0.12		0.56	0.28		-1.01	-0.92
DMS E	FA1	-1.31		0.26	0.46		-0.34	-0.46
DMS E	FA1	-0.71		0.28	0.09		-0.23	-0.88
Mfgr E	FA1	-0.60	0.30	0.20	0.30	-0.30	-1.00	0.20
Mfgr E	FA1	-0.60	0.30	0.10	0.40	-0.90	-1.10	-1.60
Mfgr E	FA1	-0.70	0.30	0.20	0.00	-1.00	-0.50	-0.20
Mfgr B	FA2	-0.63	0.29	0.71	0.33	-1.34	-2.01	-0.09
Mfgr B	FA2	-0.64	0.42	0.08	0.74	-2.05	-0.99	-1.97
Mfgr B	FA2	-0.58	0.34	0.38	0.24	-1.51	-1.51	-2.96

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
DMS B	FA2	-0.97		-0.12	-0.17		-1.84	-2.20
DMS B	FA2	-1.07		0.13	0.16		-1.80	-1.69
DMS B	FA2	-1.00		0.21	-0.07		-2.08	-2.13
7	FA2	-1.00			-0.10		-2.10	
7	FA2	-1.04			0.10		-2.00	
7	FA2	-1.04			-0.10		-3.00	
94	FA2	-0.70			0.00		-4.00	
94	FA2	-1.10			0.00		-4.00	
94	FA2	-0.50			0.00		-3.00	
35	FA2	-0.40			0.00		-5.50	
35	FA2	-0.40			0.00		-5.50	
35	FA2	-0.70			0.00		-5.00	
85	FA2	-0.10			0.00		-5.00	
85	FA2	-2.30			0.00		-6.00	
85	FA2	-1.10			0.00		-6.00	
82	FA2	-0.70			0.00		-4.00	
82	FA2	-0.60			-0.25		-4.75	
82	FA2	-0.60			0.00		-4.50	
64	FA2	-0.90			-0.30		-8.40	
64	FA2	-0.81			-0.90		-8.10	
64	FA2	-1.07			0.00		-8.70	
DMS E	FA2	-1.02		0.06	-0.22		-3.71	-4.24
DMS E	FA2	-0.97		-0.19	-0.33		-3.34	-3.68
DMS E	FA2	-0.98		-0.17	-0.01		-3.63	-4.19
Mfgr E	FA2	-0.35	0.41	0.77	1.36	-3.55	-3.09	-1.68
Mfgr E	FA2	-0.51	0.16	-0.02	-0.60	-3.68	-3.82	-1.58
Mfgr E	FA2	-0.30	0.40	1.00	0.54	-2.97	-2.81	-3.22
Mfgr B	FA3	-0.78	0.80	0.80	0.53	0.40	-0.06	0.23
Mfgr B	FA3	-0.70	0.64	0.56	0.97	0.28	0.12	0.98
Mfgr B	FA3	-0.79	0.87	0.70	0.71	0.10	-0.25	0.00
DMS B	FA3	-0.67		0.58	0.33		0.35	0.44
DMS B	FA3	-0.66		0.67	0.46		-0.60	0.54
DMS B	FA3	-0.68		0.61	0.72		-0.09	-0.39
7	FA3	-0.56			0.20		0.10	
7	FA3	-0.64			0.80		-0.20	
7	FA3	-0.64			0.10		0.10	
94	FA3	-0.40			0.50		-0.50	

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
94	FA3	-0.45			0.50		-1.00	
94	FA3	-0.30			0.50		0.00	
35	FA3	0.00			0.50		0.50	
35	FA3	-0.10			0.50		-1.50	
35	FA3	-0.20			0.50		1.50	
85	FA3	-0.70			1.00		1.00	
85	FA3	-0.70			1.00		-1.00	
85	FA3	-0.70			0.00		0.00	
82	FA3	-0.32			0.25		0.25	
82	FA3	-0.23			0.50		-0.25	
82	FA3	-0.30			0.50		-0.25	
64	FA3	-0.52			0.80		0.10	
64	FA3	-0.59			1.20		0.30	
64	FA3	-0.64			0.80		0.00	
DMS E	FA3	-0.62		0.66	0.68		0.38	-0.15
DMS E	FA3	-0.65		0.71	0.46		0.65	0.35
DMS E	FA3	-0.65		0.74	0.19		0.17	-0.16
Mfgr E	FA3	-0.54	0.73	0.64	1.22	-0.07	-0.04	1.09
Mfgr E	FA3	-0.62	0.69	0.48	-0.01	-0.10	-0.21	-0.39
Mfgr E	FA3	-0.59	0.72	0.63	0.80	-0.23	-0.44	-0.19
Mfgr B	FA4	-0.74	0.42	0.19	0.10	-1.60	-1.40	-1.00
Mfgr B	FA4	-0.81	0.27	0.20	0.70	-1.30	-1.00	-0.80
Mfgr B	FA4	-0.82	0.35	0.45	0.41	-1.30	-1.00	-1.40
DMS B	FA4	-1.15		0.33	0.23		-0.05	1.19
DMS B	FA4	-0.62		0.43	0.26		0.30	-1.39
DMS B	FA4	-0.91		0.17	-0.17		-0.19	-0.82
7	FA4	-0.80			0.00		-0.80	
7	FA4	-0.88			0.10		-1.00	
7	FA4	-0.90			0.10		-0.90	
94	FA4	-0.65			0.50		0.00	
94	FA4	-0.75			0.50		-0.50	
94	FA4	-0.70			0.00		-0.50	
35	FA4	-0.30			0.00		0.00	
35	FA4	-0.30			0.00		-0.50	
35	FA4	-0.50			0.50		0.00	
85	FA4	-0.90			0.00		-1.00	
85	FA4	-0.90			1.00		0.00	

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
85	FA4	-0.90			1.00		-2.00	
82	FA4	-0.40			0.00		0.50	
82	FA4	-0.43			0.25		0.00	
82	FA4	-0.45			0.00		-0.25	
64	FA4	-0.68			0.30		-0.50	
64	FA4	-0.77			0.70		-0.90	
64	FA4	-0.75			0.40		-1.00	
DMS E	FA4	-0.74		0.51	0.18		-0.92	-1.17
DMS E	FA4	-0.76		0.21	0.46		-0.94	-1.13
DMS E	FA4	-0.85		0.38	0.19		-0.33	-0.73
Mfgr E	FA4	-0.70	0.20	0.20	0.30	-0.60	-0.40	-0.60
Mfgr E	FA4	-0.80	0.20	0.20	0.20	-1.60	-0.80	-1.80
Mfgr E	FA4	-0.80	0.20	0.30	0.30	-0.70	-1.10	0.00
Mfgr B	FA5	-0.16			0.76		-2.03	
Mfgr B	FA5	-0.14			0.78		-2.15	
Mfgr B	FA5	-0.16			0.91		-1.86	
DMS B	FA5	-0.16		0.72	1.12		-0.44	0.01
DMS B	FA5	-0.09		0.43	-0.63		-0.10	-1.69
DMS B	FA5	-0.20		0.86	0.72		-0.09	-0.68
7	FA5	-0.18		0.00	0.50		-2.00	
7	FA5	-0.18		0.00	0.20		-2.00	
7	FA5	-0.10		0.00	0.10		-1.80	
94	FA5	0.25		0.00	1.00		-1.50	
94	FA5	0.15		0.00	1.00		-2.00	
94	FA5	-0.25		0.00	1.00		-2.00	
35	FA5	0.60		0.00	0.50		-1.50	
35	FA5	0.50		0.00	1.00		-1.00	
35	FA5	0.40		0.00	0.50		-1.00	
85	FA5	-0.10		0.00	1.00		-2.00	
85	FA5	-0.20		0.00	1.00		-2.00	
85	FA5	-0.10		0.00	1.00		-2.00	
82	FA5	0.20		0.00	0.50		-0.50	
82	FA5	0.30		0.00	1.50		-2.00	
82	FA5	0.15		0.00	1.00		-1.75	
64	FA5	-0.06		0.00	1.00		-1.30	
64	FA5	0.05		0.00	1.70		-1.80	
64	FA5	-0.10		0.00	1.00		-1.50	

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
DMS E	FA5	-0.10		0.71	0.28		-1.91	-0.92
DMS E	FA5	-0.01		0.91	0.56		-1.74	-1.67
DMS E	FA5	-0.09		0.94	0.69		-1.43	0.42
Mfgr E	FA5	-0.21		0.00	0.69		-2.18	0.00
Mfgr B	FB1	-0.43	0.29	0.21	-0.18	-1.49	-2.01	-0.09
Mfgr B	FB1	-0.44	0.42	0.83	0.24	-1.30	-1.49	-1.97
Mfgr B	FB1	-0.38	0.34	0.38	0.74	-1.76	-0.01	-0.96
DMS B	FB1	-0.78		0.36	0.41		-1.08	-3.18
DMS B	FB1	-0.72		0.20	-0.60		-1.05	-3.39
DMS B	FB1	-0.78		-0.31	0.72		-1.09	-2.41
93	FB1	-0.60			0.00		-1.00	
93	FB1	-0.60			0.50		-3.00	
93	FB1	-0.60			-0.50		-1.50	
94	FB1	-0.60			-1.00		-7.00	
94	FB1	-0.65			0.00		-7.00	
94	FB1	-0.60			0.50		-8.00	
7	FB1	-0.60			-0.90		-5.40	
7	FB1	-0.56			0.00		-5.20	
7	FB1	-0.46			-0.50		-5.80	
DMS E	FB1	-0.79		0.23	-0.43		-1.80	-2.01
DMS E	FB1	-0.80		-0.30	0.39		-2.80	-3.00
DMS E	FB1	-0.84		0.07	-0.29		-2.80	-2.86
Mfgr E	FB1	-0.35	0.41	-0.17	1.36	-1.63	-2.12	-1.68
Mfgr E	FB1	-0.30	0.41	0.46	0.42	-2.13	-1.84	-1.58
Mfgr E	FB1	-0.50	0.63	0.51	0.54	-1.99	-0.82	-1.29
Mfgr B	FB2	-0.58	0.37	0.15	0.60	-1.40	-1.00	-0.40
Mfgr B	FB2	-0.56	0.47	0.45	0.30	-0.65	-1.10	-0.40
Mfgr B	FB2	-0.65	0.37	0.35	0.50	-0.65	-1.02	-0.80
DMS B	FB2	-0.56		0.61	0.51		-0.33	0.41
DMS B	FB2	-0.53		0.45	0.59		-0.35	-1.75
DMS B	FB2	-0.62		0.53	0.52		-0.14	-0.02
93	FB2	-0.35			0.50		0.00	
93	FB2	-0.45			0.50		0.50	
93	FB2	-0.40			0.50		0.00	
94	FB2	-0.40			0.00		-1.00	
94	FB2	-0.45			0.50		0.00	
94	FB2	-0.45			0.00		-1.00	

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
7	FB2	-0.62			0.10		-1.50	
7	FB2	-0.54			0.10		-1.80	
7	FB2	-0.64			0.30		-2.00	
DMS E	FB2	-0.61		0.37	0.16		-0.10	-0.32
DMS E	FB2	-0.61		0.35	0.39		-0.40	-0.60
DMS E	FB2	-0.57		0.37	0.11		-0.10	-0.16
Mfgr E	FB2	-0.40	0.50	0.70	0.50	-0.40	-0.60	-0.40
Mfgr E	FB2	-0.40	0.50	0.40	0.40	-0.80	-0.50	0.60
Mfgr E	FB2	-0.50	0.40	0.50	0.50	-0.60	0.00	1.00
Mfgr B	FB3	-0.43	0.42	-0.04	0.94	-0.84	-1.51	-1.09
Mfgr B	FB3	-0.54	0.42	0.83	-0.26	-0.80	-0.49	-0.97
Mfgr B	FB3	-0.48	0.34	0.13	0.94	-1.26	-1.51	-0.96
DMS B	FB3	-1.00		0.27	0.11		-0.98	-2.43
DMS B	FB3	-0.81		0.20	-0.41		-0.95	-3.39
DMS B	FB3	-0.77		-0.17	0.03		-1.09	-2.26
93	FB3	-1.10			0.50		-2.50	
93	FB3	-0.70			0.50		-3.00	
93	FB3	-0.60			0.00		-0.50	
94	FB3	-0.65			0.50		-2.00	
94	FB3	-0.65			0.00		-2.50	
94	FB3	-0.50			0.50		-2.50	
7	FB3	-0.64			-0.70		-2.80	
7	FB3	-0.60			0.30		-2.60	
7	FB3	-0.58			0.40		-2.60	
DMS E	FB3	-0.63		0.27	0.06		-1.40	-1.61
DMS E	FB3	-0.68		-0.20	-0.41		-2.30	-2.50
DMS E	FB3	-0.84		-0.13	0.21		-2.30	-2.36
Mfgr E	FB3	-0.15	0.41	-0.64	1.36	-2.11	-2.12	-1.68
Mfgr E	FB3	-0.30	0.41	0.46	1.45	-2.13	-1.84	-1.58
Mfgr E	FB3	-0.50	0.63	1.00	-0.42	-1.99	-0.82	-1.29
Mfgr B	FB4	-0.21			0.73		-2.40	
Mfgr B	FB4	-0.15			0.66		-2.75	
Mfgr B	FB4	-0.16			0.62		-2.38	
DMS B	FB4	-0.11		0.64	0.41		-2.23	-0.94
DMS B	FB4	-0.03		0.60	0.29		-2.05	-2.49
DMS B	FB4	-0.07		0.63	0.42		-1.94	-2.11
93	FB4	0.20			0.00		-3.00	

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
93	FB4	0.10			0.50		-3.00	
93	FB4	0.10			1.00		-2.00	
94	FB4	0.20			0.50		-3.00	
94	FB4	0.20			0.50		-3.00	
94	FB4	0.20			0.50		-3.50	
7	FB4	-0.04			-0.10		-3.30	
7	FB4	-0.06			0.20		-3.50	
7	FB4	0.06			0.10		-3.00	
DMS E	FB4	0.00		0.52	0.36		-3.50	-3.71
DMS E	FB4	-0.01		0.30	-0.31		-3.10	-3.30
DMS E	FB4	0.04		0.27	0.31		-2.70	-2.76
Mfgr E	FB4	-0.23		0.00	0.18		-3.52	0.00
Mfgr B	FB5	-0.66	0.62	0.65	0.82	0.90	0.33	-0.55
Mfgr B	FB5	-0.76	0.54	0.56	0.87	0.83	1.10	1.56
Mfgr B	FB5	-0.83	0.62	0.30	0.61	1.04	0.86	0.59
DMS B	FB5	-0.96		0.44	0.31		1.06	0.48
DMS B	FB5	-0.97		0.50	0.19		0.65	0.86
DMS B	FB5	-1.03		0.53	0.42		0.26	0.58
93	FB5	-0.70			1.00		0.00	
93	FB5	-0.80			0.00		0.50	
93	FB5	-0.80			1.00		0.50	
94	FB5	-0.70			0.50		0.00	
94	FB5	-0.80			0.50		0.00	
94	FB5	-0.80			0.50		-0.50	
7	FB5	-0.80			0.20		0.40	
7	FB5	-1.04			-0.20		0.60	
7	FB5	-0.78			0.20		0.80	
DMS E	FB5	-0.89		0.32	0.96		0.70	0.48
DMS E	FB5	-0.93		0.10	0.59		0.60	0.40
DMS E	FB5	-0.97		0.37	0.01		1.00	0.94
Mfgr E	FB5	-1.07	0.38	0.30	0.14	0.78	0.54	1.27
Mfgr E	FB5	-1.01	0.33	0.56	0.38	0.79	1.09	0.52
Mfgr E	FB5	-0.78	0.70	0.48	-0.19	1.02	0.53	0.34
Mfgr B	FC1	-0.72	0.35	0.65	0.43	-0.10	-0.56	-0.75
Mfgr B	FC1	-0.68	0.42	0.41	0.38	-0.07	0.32	0.21
Mfgr B	FC1	-0.71	0.42	0.35	0.41	-0.09	-0.35	0.78
DMS B	FC1	-0.80		0.51	-0.35		-0.05	0.35

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
DMS B	FC1	-0.72		0.20	-0.08		0.61	-0.34
DMS B	FC1	-0.79		0.38	0.40		-0.11	-0.31
50	FC1	-0.20			0.00		0.40	
50	FC1	-0.25			0.50		0.20	
50	FC1	-0.16			0.50		0.80	
57	FC1	-0.28			0.41		0.86	
57	FC1	-0.47			1.56		0.20	
57	FC1	-0.42			0.24		0.51	
25	FC1	0.00			0.40		-0.60	
25	FC1	-0.46			0.70		-1.00	
25	FC1	-0.53			0.20		-1.10	
32	FC1	-0.42			0.30		0.20	
32	FC1	-0.31			0.80		0.30	
32	FC1	-0.35			0.70		-0.30	
43	FC1	-0.12			0.39		1.74	
43	FC1	0.16			0.24		1.29	
43	FC1	-0.76			-0.10		-0.81	
53	FC1	-0.50			0.80		0.00	
53	FC1	-0.56			0.80		0.00	
53	FC1	-0.62			0.30		0.00	
82	FC1	-0.30			0.25		-0.25	
82	FC1	-0.40			0.50		-0.75	
82	FC1	-0.35			0.25		-0.50	
64	FC1	-0.64			0.80		-0.30	
64	FC1	-0.75			0.80		-0.60	
64	FC1	-0.77			0.70		0.00	
DMS E	FC1	-0.75		0.52	0.09		0.14	0.60
DMS E	FC1	-0.79		0.38	0.49		0.43	-0.51
DMS E	FC1	-0.82		0.28	0.07		-0.13	0.02
Mfgr E	FC1	-0.81	0.35	0.45	0.24	-0.61	-0.43	-0.20
Mfgr E	FC1	-0.81	0.24	0.36	-0.21	-0.60	-0.61	-0.57
Mfgr E	FC1	-0.80	0.40	0.38	0.80	-0.63	-1.02	-0.19
Mfgr B	FC2	-0.17			0.24		-2.48	
Mfgr B	FC2	-0.25			0.28		-2.90	
Mfgr B	FC2	-0.25			0.21		-3.13	
DMS B	FC2	-0.15		0.25	-0.35		-1.92	-2.05
DMS B	FC2	-0.21		0.16	0.22		-2.90	2.90

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
DMS B	FC2	-0.27		0.34	-0.19		-2.38	-2.99
50	FC2	0.30			0.10		-2.20	
50	FC2	0.29			0.20		-2.10	
50	FC2	0.30			0.40		-2.40	
27	FC2	-0.08					-2.61	
27	FC2	0.28					-2.76	
27	FC2	0.31					-2.76	
57	FC2	0.20			-0.33		-2.13	
57	FC2	0.20			0.03		-2.23	
57	FC2	-0.01			-0.71		-1.70	
25	FC2	0.12			-0.60		-3.30	
25	FC2	0.18			0.10		-3.10	
25	FC2	0.12			0.00		-3.80	
32	FC2	0.13			0.20		-2.30	
32	FC2	0.19			0.10		-2.30	
32	FC2	0.24			0.10		-2.40	
43	FC2	-0.13			-0.33		0.09	
43	FC2	-0.10			-0.49		-2.75	
43	FC2	0.04			-0.22		-2.01	
53	FC2	0.09			0.50		-2.50	
53	FC2	0.09			-0.20		-2.30	
53	FC2	0.04			-0.30		-2.30	
82	FC2	0.20			-0.01		-1.24	
82	FC2	0.23			-0.50		-2.00	
82	FC2	0.25			0.75		-3.25	
64	FC2	-0.08			0.80		-2.20	
64	FC2	-0.18			1.00		-2.70	
64	FC2	-0.15			0.30		-2.20	
DMS E	FC2	-0.17		0.37	0.09		-1.86	-2.00
DMS E	FC2	-0.14		0.08	0.29		-1.77	-1.09
DMS E	FC2	-0.21		-0.07	-0.03		-1.93	-2.00
Mfgr E	FC2	-0.32		0.00	0.10		-3.22	0.00
Mfgr B	FC3	-0.86	0.37	0.19	0.60	-0.60	-1.10	-1.80
Mfgr B	FC3	-0.74	0.25	0.25	0.20	-0.90	-1.20	-2.00
Mfgr B	FC3	-0.74	0.15	0.30	0.33	-0.65	-1.53	-1.10
DMS B	FC3	-0.90		0.06	-0.26	0.00	0.24	-0.94
DMS B	FC3	-0.91		0.09	0.02		-0.46	-0.79

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
DMS B	FC3	-0.96		0.12	0.20		-0.20	-0.01
50	FC3	-0.25			0.70		-0.20	
50	FC3	-0.30			0.70		0.00	
50	FC3	-0.19			0.60		-0.20	
27	FC3	-0.60					-0.07	
27	FC3	-0.51					0.38	
27	FC3	-0.17					0.23	
57	FC3	-0.36			0.55		-0.33	
57	FC3	-0.37			0.40		-0.35	
57	FC3	-0.28			0.61		-0.32	
25	FC3	-0.23			0.50		-1.60	
25	FC3	-0.34			0.90		-1.60	
25	FC3	-0.35			0.20		-1.20	
32	FC3	-0.48			0.50		-1.00	
32	FC3	-0.37			0.50		-0.50	
32	FC3	-0.35			0.50		-1.00	
43	FC3	-0.16			0.30		0.99	
43	FC3	-0.22			0.21		0.24	
43	FC3	-0.30			-0.06		-0.51	
53	FC3	-0.62			0.70		0.30	
53	FC3	-0.65			0.70		0.30	
53	FC3	-0.63			0.50		0.30	
82	FC3	-0.40			0.25		0.25	
82	FC3	-0.43			0.25		-0.25	
82	FC3	-0.45			0.50		-0.50	
64	FC3	-0.73			0.50		-0.10	
64	FC3	-0.84			0.80		-0.70	
64	FC3	-0.76			1.80		-1.40	
DMS E	FC3	-0.81		0.07	0.19		0.24	-0.08
DMS E	FC3	-0.77		0.38	0.09		-0.47	-0.51
DMS E	FC3	-0.83		0.13	0.27		-0.23	-0.13
Mfgr E	FC3	-0.60	0.20	0.30	0.60	-0.80	-0.70	-0.60
Mfgr E	FC3	-0.60	0.40	0.40	0.00	-0.80	-0.70	-0.60
Mfgr E	FC3	-0.80	0.30	0.50	0.30	-0.50	0.00	1.00
Mfgr B	FC4	-1.19	0.27	0.45	-0.06	0.65	0.63	-0.55
Mfgr B	FC4	-1.22	0.22	0.21	0.67	0.83	0.81	0.79
Mfgr B	FC4	-1.19	0.34	0.45	0.31	0.80	0.58	1.57

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
DMS B	FC4	-1.17		0.06	0.24		0.94	-0.50
DMS B	FC4	-1.14		0.13	-0.18		0.90	0.39
DMS B	FC4	-1.16		0.31	1.19		0.59	1.31
50	FC4	-0.59			0.80		0.90	
50	FC4	-0.60			0.60		0.80	
50	FC4	-0.30			0.70		0.80	
27	FC4	-0.64					-0.22	
27	FC4	-0.47					0.23	
27	FC4	-0.73					0.08	
57	FC4	-0.55			0.48		0.77	
57	FC4	-0.62			0.76		0.56	
57	FC4	-0.68			0.90		0.60	
25	FC4	-0.81			0.20		-0.20	
25	FC4	-0.80			0.30		-0.40	
25	FC4	-0.72			0.70		0.00	
32	FC4	-0.82			0.90		1.10	
32	FC4	-0.69			0.60		1.00	
32	FC4	-0.69			0.70		1.30	
43	FC4	-0.39			0.19		0.84	
43	FC4	-0.37			0.15		1.59	
43	FC4	-0.43			-0.21		0.39	
53	FC4	-0.82			0.20		0.40	
53	FC4	-0.92			0.80		0.30	
53	FC4	-1.01			0.60		0.40	
82	FC4	-0.70			-0.50		1.00	
82	FC4	-0.80			0.00		0.25	
82	FC4	-0.77			0.50		0.00	
64	FC4	-1.00			0.80		0.20	
64	FC4	-1.11			0.80		-0.10	
64	FC4	-1.09			0.50		0.40	
DMS E	FC4	-1.10		0.32	0.09		0.54	1.01
DMS E	FC4	-1.11		0.28	0.19		0.33	0.21
DMS E	FC4	-1.13		0.33	0.37		-0.13	0.02
Mfgr E	FC4	-1.09	0.38	0.25	0.24	0.43	0.92	-0.75
Mfgr E	FC4	-1.21	0.37	0.36	0.38	0.59	0.49	1.80
Mfgr E	FC4	-1.23	0.20	0.23	0.70	0.52	0.72	0.16
Mfgr B	FC5	-1.03	-0.08	-0.04	-0.18	-2.19	-2.51	-2.09

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
Mfgr B	FC5	-1.83	0.04	0.08	-0.26	-2.70	-2.49	-2.98
Mfgr B	FC5	-0.18	0.08	0.63	0.74	-1.76	-2.01	-2.96
DMS B	FC5	-1.38		-0.57	-0.75		-2.71	-3.32
DMS B	FC5	-1.66		-0.32	-0.68		-2.61	-4.86
DMS B	FC5	-1.51		-0.44	-0.59		-3.95	-4.91
50	FC5	-0.81			0.10		-4.70	
50	FC5	-1.07			0.30		-5.30	
50	FC5	-0.93			-0.10		-4.40	
27	FC5	-0.75					-4.56	
27	FC5	-1.22					-3.51	
27	FC5	-0.73					-4.41	
57	FC5	-0.84			0.77		-2.51	
57	FC5	-0.85			0.03		-3.55	
57	FC5	-0.88			-0.12		-3.06	
25	FC5	-0.89			-0.40		-7.40	
25	FC5	-1.02			0.30		-7.40	
25	FC5	-0.91			-0.10		-7.30	
32	FC5	-1.15			-1.00		-5.10	
32	FC5	-1.03			0.00		-4.90	
32	FC5	-1.05			-0.20		-7.10	
43	FC5	-0.93			-0.40		-1.11	
43	FC5	-1.02			-0.72		-2.90	
43	FC5	-1.08			-0.81		-4.25	
53	FC5	-1.30			-1.30		-7.20	
53	FC5	-1.30			-0.20		-7.60	
53	FC5	-1.41			0.00		-7.50	
82	FC5	-1.15			-1.25		-6.25	
82	FC5	-1.20			0.00		-8.00	
82	FC5	-1.05			-1.00		-8.00	
64	FC5	-1.47			0.00		-11.10	
64	FC5	-1.51			0.50		-11.80	
64	FC5	-1.49			-0.10		-10.50	
DMS E	FC5	-1.44		-1.09	-0.60		-5.45	-9.26
DMS E	FC5	-1.39		-0.81	-1.00		-5.57	-5.13
DMS E	FC5	-1.38		-0.87	0.37		-7.12	-5.45
Mfgr E	FC5	-0.95	-0.09	0.77	0.33	-3.07	-2.12	-3.61
Mfgr E	FC5	-0.91	-0.10	-0.02	-0.60	-3.68	-3.82	-3.51

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
Mfgr E	FC5	-0.90	-0.06	-0.47	0.54	-2.48	-3.80	-3.22
Mfgr B	FD1	-0.19			0.30		-2.30	
Mfgr B	FD1	-0.25			0.29		-1.78	
Mfgr B	FD1	-0.22			0.28		-2.01	
DMS B	FD1	-0.10		0.51	-0.06		-0.41	-0.90
DMS B	FD1	-0.16		-0.13	0.43		-1.07	-0.14
DMS B	FD1	-0.16		0.14	0.04		-1.30	-2.24
57	FD1	0.96			0.22		-1.11	
57	FD1	0.16			0.01		-1.45	
57	FD1	-0.40			-0.03		-1.11	
26	FD1	-0.06			0.30		-1.72	
26	FD1	-0.06			0.82		-3.07	
26	FD1	0.06			0.07		-1.87	
32	FD1	0.16			0.40		-1.20	
32	FD1	0.26			0.30		-1.20	
32	FD1	0.25			0.50		-2.10	
43	FD1	-0.04			-0.07		-0.66	
43	FD1	0.22			-0.15		-1.11	
43	FD1	-0.06			-0.04		1.59	
53	FD1	0.01			-0.20		-1.20	
53	FD1	0.13			0.10		-1.40	
53	FD1	0.08			0.00		-1.20	
DMS E	FD1	-0.06		1.05	-0.15		-0.89	-2.76
DMS E	FD1	-0.10		0.23	0.02		-2.20	-1.09
DMS E	FD1	-0.14		-0.08	-0.09		-1.88	-1.86
Mfgr E	FD1	-0.26		0.00	-0.42		-2.10	0.00
Mfgr B	FD2	-0.84	0.55	0.80	0.33	0.75	0.73	0.03
Mfgr B	FD2	-0.82	0.64	0.51	0.97	0.48	0.51	1.37
Mfgr B	FD2	-0.87	0.67	0.75	0.71	0.45	0.31	-0.20
DMS B	FD2	-0.77		0.76	0.34		0.46	0.88
DMS B	FD2	-0.82		0.49	0.53		0.68	1.02
DMS B	FD2	-0.80		0.49	0.53		-0.02	-0.04
27	FD2	0.24					0.83	
27	FD2	-0.21					1.14	
27	FD2	-0.28					1.14	
57	FD2	-0.47			1.40		1.09	
57	FD2	-0.40			0.59		0.84	

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
57	FD2	-1.13			1.36		0.53	
26	FD2	-0.82			0.60		0.52	
26	FD2	-0.67			0.30		-1.12	
26	FD2	-0.61			0.52		-0.07	
32	FD2	-0.48			0.70		0.40	
32	FD2	-0.41			1.30		0.40	
32	FD2	-0.39			1.30		0.40	
43	FD2	0.12			0.18		0.69	
43	FD2	-0.01			0.24		0.09	
43	FD2	0.09			0.22		1.74	
53	FD2	-0.59			1.10		-0.30	
53	FD2	-0.46			1.00		0.10	
53	FD2	-0.64			0.60		0.80	
DMS E	FD2	-0.69		1.33	0.45		0.01	-0.67
DMS E	FD2	-0.72		0.62	0.41		-0.01	0.94
DMS E	FD2	-0.73		0.56	0.60		-0.19	0.54
Mfgr E	FD2	-0.81	0.65	0.74	0.83	0.13	0.15	-0.20
Mfgr E	FD2	-0.76	0.58	0.76	0.48	0.24	0.29	-0.03
Mfgr E	FD2	-0.73	0.50	0.58	1.00	0.37	-0.15	1.75
Mfgr B	FD3	-0.10			0.55		-2.33	
Mfgr B	FD3	-0.07			0.47		-2.23	
Mfgr B	FD3	-0.10			0.45		-2.45	
DMS B	FD3	0.03		0.71	0.14		-1.47	-2.41
DMS B	FD3	0.00		0.15	0.23		-2.13	-2.47
DMS B	FD3	-0.03		0.20	0.14		-2.20	-2.24
27	FD3	0.54					-4.56	
27	FD3	0.39					-4.52	
27	FD3	0.35					-4.37	
57	FD3	0.96			0.15		-3.03	
57	FD3	-0.40			0.23		-2.54	
57	FD3	0.28			-0.25		-2.65	
26	FD3	-0.03			0.67		-2.92	
26	FD3	-0.06			-0.07		-3.22	
26	FD3	0.10			0.15		-4.56	
32	FD3	0.23			0.50		-2.60	
32	FD3	0.34			0.30		-2.80	
32	FD3	0.33			0.40		-2.80	

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
43	FD3	0.09			0.16		-1.11	
43	FD3	0.16			0.01		-2.75	
43	FD3	0.30			0.16		-0.81	
53	FD3	0.23			0.00		-2.60	
53	FD3	0.22			0.30		-2.90	
53	FD3	0.22			0.30		-3.80	
DMS E	FD3	0.11		1.15	0.55		-3.18	-4.10
DMS E	FD3	0.10		0.18	0.02		-2.90	-3.43
DMS E	FD3	0.00		0.02	0.01		-3.68	-3.63
Mfgr E	FD3	-0.17		0.00	0.01		-3.45	0.00
Mfgr B	FD4	-1.03	-0.08	0.96	0.77	-2.09	-2.01	-0.09
Mfgr B	FD4	-0.94	0.54	0.83	0.74	-1.80	-1.99	-0.97
Mfgr B	FD4	-0.98	0.59	0.13	0.24	-2.01	-2.01	-1.96
DMS B	FD4	-1.45		0.42	0.14		-1.77	-1.02
DMS B	FD4	-1.37		0.06	-0.27		-1.75	-1.44
DMS B	FD4	-1.45		0.10	0.04		-1.69	-2.24
27	FD4	-0.96					-2.91	
27	FD4	-0.92					-3.33	
27	FD4	-1.00					-2.29	
57	FD4	-1.06			-0.14		-2.57	
57	FD4	-0.67			0.89		-1.90	
57	FD4	-1.17			0.34		-2.75	
26	FD4	-1.02			0.45		-3.66	
26	FD4	-1.38			0.22		-3.96	
26	FD4	-0.97			-0.22		-4.26	
32	FD4	-1.01			0.70		-2.10	
32	FD4	-1.18			0.90		-2.70	
32	FD4	-1.04			0.40		-2.90	
43	FD4	-0.79			-0.49		-0.36	
43	FD4	-0.97			-0.57		-3.05	
43	FD4	-0.72			-0.69		-2.60	
53	FD4	-1.38			0.30		-5.40	
53	FD4	-1.28			0.10		-5.80	
53	FD4	-1.27			-0.60		-4.70	
DMS E	FD4	-1.46		0.55	-0.64		-4.38	-4.40
DMS E	FD4	-1.40		-0.36	-1.08		-4.60	-2.34
DMS E	FD4	-1.43		-0.37	-0.29		-5.57	-4.26

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
Mfgr E	FD4	-0.95	0.16	-1.11	-0.71	-2.59	-3.09	-1.68
Mfgr E	FD4	-0.91	0.16	-0.50	0.42	-2.65	-1.84	-1.58
Mfgr E	FD4	-0.90	0.17	0.51	0.54	-2.48	-3.80	-1.99
Mfgr B	FD5	-0.74	0.42	0.11	0.50	-0.45	-1.60	-0.40
Mfgr B	FD5	-0.81	0.35	0.40	0.50	-0.45	-0.70	-0.80
Mfgr B	FD5	-0.72	0.25	0.15	0.43	-0.75	-0.52	-0.50
DMS B	FD5	-0.82		0.51	0.24		-0.70	-1.02
DMS B	FD5	-0.89		0.10	0.33		-0.58	-1.02
DMS B	FD5	-0.92		0.14	0.14		-1.10	-1.51
27	FD5	-0.36					-0.22	
27	FD5	-0.55					-1.09	
27	FD5	-0.58					-0.35	
57	FD5	-0.68			0.83		0.61	
57	FD5	-0.50			0.69		-0.04	
57	FD5	-0.54			0.39		0.31	
26	FD5	-1.39			1.35		-1.42	
26	FD5	-0.87			1.35		-0.22	
26	FD5	-0.70			1.12		-0.97	
32	FD5	-0.52			0.50		-0.80	
32	FD5	-0.50			1.00		-0.80	
32	FD5	-0.50			1.10		-0.80	
43	FD5	-0.07			0.16		0.99	
43	FD5	-0.04			0.25		0.54	
43	FD5	0.01			0.15		2.18	
53	FD5	-0.73			0.50		0.50	
53	FD5	-0.63			1.00		-0.40	
53	FD5	-0.70			1.00		-0.10	
DMS E	FD5	-0.81		1.24	0.35		-0.49	-0.08
DMS E	FD5	-0.73		0.37	1.01		-0.61	0.32
DMS E	FD5	-0.76		0.32	-0.09		-0.69	-1.23
Mfgr E	FD5	-0.70	0.40	0.30	0.40	-0.50	-0.30	-0.10
Mfgr E	FD5	-0.90	0.40	0.50	0.30	-0.90	-1.10	0.40
Mfgr E	FD5	-0.70	0.40	0.50	0.30	-1.10	-0.60	-1.00
Mfgr B	GA1	-0.40	0.62	0.57	1.05	-0.07	0.17	1.13
Mfgr B	GA1	-0.25	0.93	1.13	0.80	-0.57	-0.34	0.18
Mfgr B	GA1	-0.27	0.67	0.72	0.08	-0.07	-0.22	-0.88
DMS B	GA1	-0.76		0.35	0.53		-1.03	-0.59

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
DMS B	GA1	-0.56		0.33	0.88		-0.63	-1.54
DMS B	GA1	-0.81		0.35	0.48		-1.82	-3.32
51	GA1	-1.10			1.00		-2.00	-1.00
51	GA1	-1.00			1.00		-2.50	-3.00
51	GA1	-1.30			0.50		-3.00	-3.00
6	GA1	-0.61			1.30		-2.00	-0.40
6	GA1	0.41			0.90		-2.50	-1.60
6	GA1	-0.35			0.50		-3.80	-1.40
34	GA1	-0.70			-0.50		-12.75	-26.50
34	GA1	-0.70			-0.80		-20.75	-8.50
34	GA1	-0.60			-0.70		-22.00	-15.50
DMS E	GA1	-0.82		0.04	-0.25		-2.93	-4.38
DMS E	GA1	-0.78		-0.45	-0.50		-2.75	-3.33
DMS E	GA1	-0.76		-0.09	0.06		-3.01	-5.01
Mfgr E	GA1	-0.26	0.33	0.46	0.70	-1.28	-1.09	0.28
Mfgr E	GA1	-0.12	0.37	0.65	-0.15	-1.29	-1.51	-1.60
Mfgr E	GA1	-0.17	0.21	0.18	0.68	-1.88	-1.50	-0.90
Mfgr B	GA2	-0.96	-0.05	0.08	-0.24	0.26	-0.30	1.16
Mfgr B	GA2	-0.63	-0.13	-0.05	-0.04	0.00	-0.15	1.01
Mfgr B	GA2	-1.08	0.13	-0.31	0.06	-0.05	-0.22	0.46
DMS B	GA2	-1.59		0.05	-0.05	0.00	-0.83	-0.37
DMS B	GA2	-1.25		-0.26	-0.08	0.00	-0.73	-0.63
DMS B	GA2	-1.49		-0.25	-0.10		-1.14	-1.12
51	GA2	-1.80			0.50		0.00	-1.00
51	GA2	-1.80			0.00		-0.50	0.00
51	GA2	-2.10			0.50		-0.50	0.00
6	GA2	-1.40			0.10		-1.00	-2.00
6	GA2	-1.20			-1.00		-1.00	-0.40
6	GA2	-1.20			0.00		-1.60	0.00
34	GA2	-1.00			0.20		-2.25	-3.00
34	GA2	-0.96			0.50		-2.25	-1.00
34	GA2	-1.14			0.80		-2.50	-2.50
DMS E	GA2	-1.61		-0.06	-0.25		-0.36	-2.83
DMS E	GA2	-1.60		-0.21	-0.50		-0.10	-1.38
DMS E	GA2	-1.56		-0.14	-0.04		-0.93	-1.29
Mfgr E	GA2	-1.48	-0.32	-0.50	-0.12	-1.10	-1.08	-0.02
Mfgr E	GA2	-1.55	-0.35	-0.33	0.06	-0.67	-0.65	-1.69

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
Mfgr E	GA2	-1.52	-0.22	-0.21	-0.46	-0.67	-1.61	-0.55
Mfgr B	GA3	-0.63	0.41	0.36	0.67	-1.49	-1.11	-0.28
Mfgr B	GA3	-0.60	0.64	0.77	0.82	-1.08	-1.03	-2.02
Mfgr B	GA3	-0.59	0.42	0.34	0.85	-0.63	-1.07	-0.26
DMS B	GA3	-0.61		0.60	0.43		-0.45	0.26
DMS B	GA3	-0.41		0.18	0.69		-0.35	0.05
DMS B	GA3	-0.61		0.40	0.38		-0.94	0.63
51	GA3	-0.90			1.00		-0.50	-1.00
51	GA3	-0.80			1.00		0.00	1.00
51	GA3	-1.20			1.00		0.00	-2.00
6	GA3	-0.60			0.90		0.00	0.00
6	GA3	-0.34			0.80		-0.50	0.00
6	GA3	-0.30			0.80		-0.50	-0.20
34	GA3	-0.20			0.95		0.50	-1.00
34	GA3	-0.20			1.30		-0.25	0.50
34	GA3	-0.26			0.75		0.00	0.00
DMS E	GA3	-0.65		0.53	0.54		0.04	-0.50
DMS E	GA3	-0.61		0.49	0.39		0.10	-0.40
DMS E	GA3	-0.65		0.51	0.66		-0.34	-0.11
Mfgr E	GA3	-0.70	0.40	0.40	0.30	-0.50	-0.70	-0.30
Mfgr E	GA3	-0.70	0.40	0.30	0.40	-1.00	-0.50	-0.10
Mfgr E	GA3	-0.60	0.40	0.30	0.50	-0.80	-0.70	-0.30
Mfgr B	GA4	-0.22			0.39		-2.30	
Mfgr B	GA4	-0.30			0.35		-2.90	
Mfgr B	GA4	-0.34			0.35		-3.05	
DMS B	GA4	-0.19		0.05	0.14		-2.18	-1.44
DMS B	GA4	0.05		0.18	0.11		-1.59	-1.77
DMS B	GA4	-0.17		0.30	0.19		-1.82	-3.10
51	GA4	-0.40			0.50		-2.50	-2.00
51	GA4	-0.30			0.50		-2.00	-2.00
51	GA4	-0.70			0.50		-2.50	-4.00
6	GA4	0.00			0.30		-2.20	0.00
6	GA4	0.11			0.20		2.50	-2.00
6	GA4	0.19			1.00		-3.20	-1.60
34	GA4	0.14			-0.50		-3.75	-4.50
34	GA4	0.30			-0.50		-4.25	-4.50
34	GA4	0.26			-0.75		-4.00	-4.50

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
DMS E	GA4	-0.10		0.58	0.34		-2.54	-2.83
DMS E	GA4	-0.06		0.09	0.30		-2.26	-3.33
DMS E	GA4	-0.08		-0.09	0.66		-3.11	-3.84
Mfgr E	GA4	-0.27			0.29		-4.00	
Mfgr B	GA5	-0.19			0.78		-1.69	
Mfgr B	GA5	-0.22			0.77		-1.50	
Mfgr B	GA5	-0.10			0.72		-2.05	
DMS B	GA5	-0.13		0.55	0.82		-1.41	-0.37
DMS B	GA5	0.19		0.48	0.88		-1.21	-1.54
DMS B	GA5	-0.06		0.75	0.57		-0.94	-0.46
51	GA5	-1.30			1.00		-1.00	-1.00
51	GA5	-0.30			1.50		-1.00	-1.00
51	GA5	-0.60			1.50		-0.50	0.00
6	GA5	0.10			1.00		-1.00	-2.00
6	GA5	0.60			0.90		-1.30	-2.00
6	GA5	0.30			2.00		-2.10	-1.80
34	GA5	0.20			0.50		0.99	-2.00
34	GA5	0.35			0.75		-1.75	-0.50
34	GA5	0.25			0.26		-1.50	-1.50
DMS E	GA5	-0.03		0.93	0.74		-1.05	-0.89
DMS E	GA5	0.02		0.79	0.69		-0.98	-0.40
DMS E	GA5	0.06		0.51	1.15		-1.33	-1.87
Mfgr E	GA5	-0.17		0.00	0.73		-2.30	0.00
Mfgr B	GB1	-1.08	-0.08	-0.02	0.16	0.16	-0.20	-0.44
Mfgr B	GB1	-0.95	0.19	-0.05	0.16	-0.15	-0.15	-0.59
Mfgr B	GB1	-1.02	0.17	0.19	0.16	-0.35	-0.41	-1.94
DMS B	GB1	-1.21		-0.12	0.24		-0.03	-0.55
DMS B	GB1	-1.26		-0.08	0.26		-0.60	1.07
DMS B	GB1	-1.10		-0.06	-0.16		-0.26	-1.51
50	GB1	-0.76			1.00		-0.40	-0.80
50	GB1	-0.72			-0.40		-0.50	0.00
50	GB1	-0.94			0.40		-0.80	-1.00
89	GB1	-0.92			0.50		-1.20	-2.60
89	GB1	-0.89			0.50		-0.80	0.00
89	GB1	-0.90			0.70		-0.90	-3.00
67	GB1	-0.90			0.20		-0.20	-1.00
67	GB1	-1.06			0.60		-0.30	0.60

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
67	GB1	-0.84			0.10		-0.30	-0.20
52	GB1	-0.86			0.00		0.00	-1.20
52	GB1	-0.81			0.30		0.10	1.80
52	GB1	-0.91			0.40		0.40	-2.00
DMS E	GB1	-1.33		-0.23	-0.37		-0.64	1.37
DMS E	GB1	-1.28		0.05	0.09		-0.47	-2.85
DMS E	GB1	-1.38		-0.10	0.06		-0.90	1.50
Mfgr E	GB1	-1.32	-0.10	-0.05	-0.12	-0.80	-1.08	-3.40
Mfgr E	GB1	-1.37	-0.22	0.01	0.06	-0.72	-1.24	0.46
Mfgr E	GB1	-1.28	-0.22	-0.36	-0.27	-0.72	-0.66	-2.67
Mfgr B	GB2	-0.40	1.12	0.57	0.55	-1.57	-1.34	0.13
Mfgr B	GB2	-0.35	0.56	0.88	0.30	-0.82	-1.34	-1.82
Mfgr B	GB2	-0.46	0.42	-0.04	0.08	-2.32	-1.22	-0.88
DMS B	GB2	-0.73		0.38	-0.55		-0.03	-0.94
DMS B	GB2	-0.87		0.07	-0.23		-0.91	-0.52
DMS B	GB2	-0.89		-0.01	1.00		-1.04	-2.10
50	GB2	-0.36			0.20		-0.60	-1.40
50	GB2	-0.50			0.30		-0.70	-0.60
50	GB2	-0.54			0.60		-0.70	-1.80
89	GB2	-0.34			0.90		-2.70	-2.00
89	GB2	-0.26			0.00		-2.20	-1.20
89	GB2	-0.35			0.80		-2.10	-3.20
67	GB2	-0.82			1.20		-1.20	-0.40
67	GB2	-0.14			0.00		-1.60	-1.20
67	GB2	-0.28			0.50		-1.40	-0.80
52	GB2	-0.23			1.10		-1.20	-1.20
52	GB2	-0.13			0.60		-1.80	-2.80
52	GB2	-0.31			0.20		-2.00	-2.20
DMS E	GB2	-0.93		0.02	0.52		-1.74	-1.38
DMS E	GB2	-0.91		0.19	0.09		-2.14	-2.66
DMS E	GB2	-0.93		-0.10	-0.34		-2.74	-1.83
Mfgr E	GB2	-0.46	0.11	0.46	0.70	-2.81	-1.97	-1.65
Mfgr E	GB2	-0.32	2.10	0.65	0.83	-2.29	-2.51	-1.60
Mfgr E	GB2	-0.17	0.46	0.18	0.68	-2.38	-2.50	-2.84
Mfgr B	GB3	-0.15			0.60		-2.30	
Mfgr B	GB3	-0.18			0.50		-2.50	
Mfgr B	GB3	-0.15			0.45		-2.95	

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
DMS B	GB3	-0.16		0.28	-0.25		-1.59	-0.36
DMS B	GB3	-0.18		0.02	-0.42		-2.03	-2.51
DMS B	GB3	-0.06		-0.06	0.42		-1.72	-2.49
50	GB3	0.44			0.10		-3.10	-4.20
50	GB3	0.22			0.00		-3.20	-2.60
50	GB3	0.14			0.00		-3.00	-3.40
89	GB3	0.30			0.50		-2.20	-1.80
89	GB3	0.30			0.00		-2.80	-3.60
89	GB3	0.30			0.00		-2.00	-2.00
67	GB3	0.06			0.40		-3.00	-4.00
67	GB3	0.20			0.10		-3.00	-2.00
67	GB3	0.28			0.00		-3.00	-3.60
52	GB3	0.18			0.20		-3.20	-2.80
52	GB3	0.34			0.10		-3.30	-3.80
52	GB3	0.26			0.30		-3.30	-2.20
DMS E	GB3	-0.16		0.52	-0.17		-2.93	-1.38
DMS E	GB3	-0.03		-0.15	-0.21		-1.75	-2.46
DMS E	GB3	-0.22		-0.05	0.25		-1.87	-1.48
Mfgr E	GB3	-0.20		0.00	0.24		-3.60	0.00
Mfgr B	GB4	-0.45	0.41	0.36	0.73	-1.05	-1.03	-0.22
Mfgr B	GB4	-0.59	0.64	0.31	0.79	-0.88	-0.07	-2.02
Mfgr B	GB4	-0.58	0.43	0.80	0.82	1.04	-0.99	-0.16
DMS B	GB4	-0.79		0.63	0.24		-0.12	1.20
DMS B	GB4	-0.39		0.32	0.55		0.11	-1.52
DMS B	GB4	-0.57		0.14	0.62		0.33	1.45
50	GB4	0.02			0.20		-0.10	-0.80
50	GB4	-0.16			1.00		-0.40	-0.40
50	GB4	-0.16			0.70		0.40	0.00
89	GB4	-0.15			1.00		-0.50	-2.00
89	GB4	-0.15			0.50		-0.50	1.00
89	GB4	-0.15			1.00		-0.30	-2.00
67	GB4	-0.20			0.40		0.00	0.00
67	GB4	-0.20			1.30		0.00	0.00
67	GB4	-0.04			0.70		-0.50	-1.00
52	GB4	-0.01			0.80		-0.10	-0.20
52	GB4	-0.03			0.90		0.20	0.80
52	GB4	-0.07			1.30		-0.10	-0.60

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
DMS E	GB4	-0.48		0.52	0.72		-0.15	0.58
DMS E	GB4	-0.59		0.44	0.58		0.12	-1.30
DMS E	GB4	-0.49		0.40	0.25		-0.42	0.45
Mfgr E	GB4	-0.70	0.40	0.50	0.30	-0.50	-1.20	-0.30
Mfgr E	GB4	-0.60	0.40	0.40	0.50	-0.90	-0.20	-1.90
Mfgr E	GB4	-0.40	0.30	0.30	0.40	-0.60	-0.40	-0.20
Mfgr B	GB5	-0.80	1.00	0.82	1.05	-2.07	-1.34	0.13
Mfgr B	GB5	-0.65	0.68	1.38	-0.21	-2.07	-1.84	-2.83
Mfgr B	GB5	-0.66	0.95	0.72	1.08	-1.82	-1.22	-0.88
DMS B	GB5	-1.15		0.08	0.53		-0.21	-0.36
DMS B	GB5	-1.34		0.52	0.16		-1.11	-1.52
DMS B	GB5	-1.20		-0.01	0.23		-0.55	-0.52
50	GB5	-0.40			1.10		-1.20	-1.40
50	GB5	-0.54			1.00		-1.40	-2.40
50	GB5	-0.58			0.70		-1.40	-0.80
89	GB5	-0.62			0.40		-3.80	-4.80
89	GB5	-0.65			0.30		-3.20	-2.00
89	GB5	-0.75			1.50		-3.50	-4.00
67	GB5	-0.80			1.50		-3.50	-1.40
67	GB5	-0.60			0.90		-3.30	-4.20
67	GB5	-0.54			0.30		-3.20	-2.20
52	GB5	-0.53			0.80		-2.80	-4.00
52	GB5	-0.45			1.00		-3.30	-4.00
52	GB5	-0.58			0.70		-3.30	-2.40
DMS E	GB5	-1.44		-0.33	-0.37		-3.92	-4.32
DMS E	GB5	-1.35		-0.20	-0.11		-4.21	-5.19
DMS E	GB5	-1.43		-0.40	-0.04		-4.86	-3.93
Mfgr E	GB5	-0.66	0.11	1.67	1.67	-2.81	-2.84	-3.58
Mfgr E	GB5	-0.52	0.37	0.83	0.83	-3.30	-3.52	-3.53
Mfgr E	GB5	-0.56	0.46	0.68	0.68	-3.38	-4.51	-4.78
Mfgr B	GC1	-0.44	0.41	0.35	0.70	-0.76	1.05	-0.32
Mfgr B	GC1	-0.59	0.43	0.31	0.80	-0.86	-0.36	-1.96
Mfgr B	GC1	-0.58	0.65	0.35	0.82	0.59	-1.03	-0.20
DMS B	GC1	-0.53		0.25	-0.12		0.10	-0.39
DMS B	GC1	-0.61		0.22	0.63		-0.16	0.31
DMS B	GC1	-0.53		0.68	0.12		-0.38	-0.94
89	GC1	-0.18			0.30		-0.80	-0.60

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
89	GC1	-0.22			1.00		-0.70	-1.00
89	GC1	-0.11			0.60		-0.30	0.00
67	GC1	-0.20			0.80		-0.50	0.00
67	GC1	-0.18			0.60		-0.50	-2.00
67	GC1	-0.30			0.60		-0.50	1.00
52	GC1	-0.10			0.80		-0.90	-0.80
52	GC1	-0.06			0.40		-0.10	0.00
52	GC1	-0.10			1.30		-0.60	1.20
DMS E	GC1	-0.53		0.42	0.34		-0.19	-0.16
DMS E	GC1	-0.61		0.36	0.73		-0.19	-0.30
DMS E	GC1	-0.56		0.35	0.34		-0.64	-0.31
Mfgr E	GC1	-0.60	0.30	0.50	0.50	-0.40	-0.70	-0.50
Mfgr E	GC1	-0.70	0.30	0.30	0.10	-1.00	-0.40	-0.30
Mfgr E	GC1	-0.40	0.30	0.30	0.40	-0.60	-0.30	-1.50
Mfgr B	GC2	-0.10			0.17		-3.50	
Mfgr B	GC2	-0.18			0.08		-3.80	
Mfgr B	GC2	-0.10			0.01		-3.75	
DMS B	GC2	0.03		0.30	0.37		-2.12	-0.58
DMS B	GC2	-0.77		-0.13	0.06		-2.83	-3.12
DMS B	GC2	0.68		-0.12	0.12		-2.74	-2.38
89	GC2	0.28			0.20		-3.20	-4.00
89	GC2	0.22			-0.50		-3.20	-2.00
89	GC2	0.26			-0.50		-3.60	-3.60
67	GC2	0.22			-0.70		-4.10	-4.00
67	GC2	0.24			-0.20		-4.40	-4.00
67	GC2	0.12			-1.00		-4.40	-3.60
52	GC2	0.15			-0.80		-3.90	-1.80
52	GC2	0.26			-1.00		-3.00	-4.20
52	GC2	0.27			-1.00		0.90	-2.00
DMS E	GC2	-0.66		-0.18	-0.24		-2.18	-2.93
DMS E	GC2	-0.31		0.06	-0.95		-2.96	-1.87
DMS E	GC2	-0.08		-0.50	0.34		-1.91	-3.11
Mfgr E	GC2	-0.20		0.00	-0.88		-3.80	0.00
Mfgr B	GC3	-0.40	0.25	0.31	0.05	-0.82	-1.30	-0.87
Mfgr B	GC3	-0.45	0.68	0.63	0.80	-1.07	-2.84	0.18
Mfgr B	GC3	-0.46	0.55	0.97	0.08	-0.82	-2.23	-0.88
DMS B	GC3	-0.85		1.09	0.28		0.21	2.48

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
DMS B	GC3	-0.85		-0.47	0.44		-0.98	-2.48
DMS B	GC3	-0.92		0.18	0.02		-0.64	-0.73
89	GC3	-0.51			0.30		-2.50	-3.00
89	GC3	-0.56			0.50		-2.00	-1.60
89	GC3	-0.43			0.50		-2.00	-1.40
67	GC3	-0.38			0.40		-1.00	-2.00
67	GC3	-0.42			0.40		-1.50	0.40
67	GC3	-0.58			0.70		-0.60	-1.20
52	GC3	-0.44			0.30		-2.60	-1.60
52	GC3	-0.35			0.50		-2.10	-2.20
52	GC3	-0.37			0.50		-2.00	-0.40
DMS E	GC3	-0.87		-0.13	-0.34		-1.38	-2.01
DMS E	GC3	-0.82		-0.14	-0.16		-2.66	-1.67
DMS E	GC3	-0.92		0.15	0.05		-1.62	-3.63
Mfgr E	GC3	-0.86	-0.10	-0.05	-0.26	-1.79	-1.97	0.28
Mfgr E	GC3	-1.12	-1.35	-0.40	-0.15	-1.79	-1.51	-3.53
Mfgr E	GC3	-0.76	-0.04	0.18	-0.29	-1.88	-1.50	-0.90
Mfgr B	GC4	-0.50	0.62	0.78	0.46	0.16	0.18	0.56
Mfgr B	GC4	-0.51	0.64	0.65	0.95	0.30	0.25	0.01
Mfgr B	GC4	-0.52	0.74	0.59	0.95	0.20	-0.31	-0.74
DMS B	GC4	-0.58		0.74	0.37		0.65	-0.58
DMS B	GC4	-0.50		0.52	1.00		0.25	1.17
DMS B	GC4	-0.51		0.53	0.42		-0.29	-0.32
89	GC4	-0.10			1.00		-0.50	1.00
89	GC4	-0.18			0.80		-0.50	-1.00
89	GC4	-0.10			0.50		0.00	1.00
67	GC4	-0.16			1.00		0.20	-0.20
67	GC4	-0.14			0.70		0.00	0.60
67	GC4	-0.24			1.00		0.30	-0.40
52	GC4	-0.07			1.00		-0.10	0.80
52	GC4	0.00			1.10		-0.20	0.00
52	GC4	-0.03			0.80		-0.20	1.80
DMS E	GC4	-0.42		0.67	0.44		0.51	-0.53
DMS E	GC4	-0.55		0.65	0.64		0.40	0.88
DMS E	GC4	-0.43		0.59	0.34		-0.34	-1.18
Mfgr E	GC4	-0.53	0.55	0.60	0.78	-0.01	-0.08	1.49
Mfgr E	GC4	-0.39	0.57	0.71	0.95	-0.12	0.35	-0.71

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
Mfgr E	GC4	-0.54	0.50	0.64	0.57	0.06	-0.40	1.05
Mfgr B	GC5	-1.00	0.30	0.13	0.16	0.01	-0.20	0.96
Mfgr B	GC5	-0.99	0.14	0.40	0.06	-0.15	-0.35	1.60
Mfgr B	GC5	-1.02	0.15	-0.11	-0.04	-0.25	-0.51	1.25
DMS B	GC5	-1.19		0.05	0.08		0.43	0.76
DMS B	GC5	-1.20		0.12	-0.03		-0.06	-0.76
DMS B	GC5	-1.15		-0.02	0.42		-0.73	1.94
89	GC5	-0.85			0.80		-1.00	0.60
89	GC5	-0.85			0.20		-1.00	-1.00
89	GC5	-0.80			0.20		-0.50	0.00
67	GC5	-0.90			0.30		-0.50	0.00
67	GC5	-0.72			0.70		-0.60	0.00
67	GC5	-1.00			0.10		-0.70	-0.20
52	GC5	-0.74			0.60		-0.90	1.20
52	GC5	-0.69			0.50		-0.40	-0.20
52	GC5	-0.78			0.40		-0.40	0.80
DMS E	GC5	-1.11		0.22	-0.05		0.21	-1.82
DMS E	GC5	-1.15		-0.09	0.04		0.01	0.88
DMS E	GC5	-1.22		0.15	0.34		-0.44	-1.53
Mfgr E	GC5	-1.08	-0.03	0.05	-0.21	-0.85	-0.68	-0.77
Mfgr E	GC5	-1.31	0.05	0.11	0.36	-0.87	-1.14	-0.91
Mfgr E	GC5	-1.22	0.00	0.24	0.01	-0.62	-0.48	-0.55
Mfgr B	GD1	-0.25			0.43		-1.50	
Mfgr B	GD1	-0.32			0.30		-1.30	
Mfgr B	GD1	-0.24			0.24		-1.25	
DMS B	GD1	-0.19		0.60	-0.04		-0.72	-0.95
DMS B	GD1	-0.26		0.22	0.50		-0.87	-1.06
DMS B	GD1	-0.57		-0.27	0.14		-0.71	-0.60
35	GD1	-0.20			1.00		0.50	-2.00
35	GD1	0.00			0.00		0.00	-1.00
35	GD1	0.00			0.00		-1.00	-1.00
6	GD1	-0.10			0.50		-1.80	-2.00
6	GD1	0.10			0.00		-2.20	-3.60
6	GD1	0.02			0.10		-2.00	-2.00
51	GD1	-0.80			0.00		-0.50	0.00
51	GD1	-0.50			1.00		-0.50	-1.00
51	GD1	-0.50			0.50		-0.50	-1.00

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
34	GD1	-0.50			-0.50		-1.50	-0.50
34	GD1	-0.25			0.25		0.75	-2.00
34	GD1	0.05			0.00		-2.00	-0.50
DMS E	GD1	-0.13		0.19	-0.01		-1.63	-0.81
DMS E	GD1	-0.14		0.10	-0.17		-1.23	-1.52
DMS E	GD1	-0.09		0.05	0.31		-1.40	-1.85
Mfgr E	GD1	-0.30		0.00	-0.50		-2.20	0.00
Mfgr B	GD2	-0.45	0.40	0.81	0.73	-1.30	-1.14	-1.98
Mfgr B	GD2	-0.59	0.66	0.32	0.85	-1.13	-1.05	-2.12
Mfgr B	GD2	-0.77	0.42	0.33	0.85	1.06	-1.01	-0.14
DMS B	GD2	-0.68		0.31	0.72		-1.01	-0.95
DMS B	GD2	-0.58		0.17	0.41		-0.77	-0.27
DMS B	GD2	-0.46		0.27	0.42		-1.00	-0.60
35	GD2	-1.20			-0.50		0.00	-2.00
35	GD2	-1.00			0.00		-1.00	0.00
35	GD2	-1.30			0.00		0.00	-2.00
6	GD2	0.10			1.00		0.00	0.60
6	GD2	-0.20			0.50		1.00	-1.00
6	GD2	-0.20			0.50		-0.50	0.00
51	GD2	-1.00			1.00		-0.50	-1.00
51	GD2	-1.00			1.00		0.00	1.00
51	GD2	-0.90			1.00		0.00	-1.00
34	GD2	-0.60			1.25		-0.50	-1.50
34	GD2	-0.50			0.50		1.00	0.50
34	GD2	-0.40			0.75		-0.50	-1.50
DMS E	GD2	-0.40		0.54	0.18		-0.14	-0.42
DMS E	GD2	-0.53		0.64	0.91		-0.55	-0.34
DMS E	GD2	-0.41		0.54	0.40		-0.21	-1.26
Mfgr E	GD2	-0.50	0.40	0.50	0.40	-0.60	-0.30	-1.10
Mfgr E	GD2	-0.60	0.40	0.50	0.40	-1.00	-0.60	-0.10
Mfgr E	GD2	-0.40	0.40	0.70	0.50	-0.70	-0.70	-0.60
Mfgr B	GD3	-0.96	0.39	0.43	0.46	0.71	0.57	-0.24
Mfgr B	GD3	-0.91	0.56	0.45	0.76	0.60	0.35	1.40
Mfgr B	GD3	-0.76	-0.27	0.39	0.36	0.55	0.47	0.26
DMS B	GD3	-1.04		0.36	0.34		0.07	-0.55
DMS B	GD3	-0.93		0.17	0.31		0.02	0.91
DMS B	GD3	-1.17		0.27	0.23		-0.03	0.01

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
35	GD3	0.00			0.00		0.50	-2.00
35	GD3	0.10			0.00		0.50	1.00
35	GD3	-0.40			0.00		0.50	-1.00
6	GD3	-0.88			0.30		-0.50	-1.00
6	GD3	-0.75			0.80		-1.00	0.00
6	GD3	-0.80			0.30		-1.00	-1.00
51	GD3	-1.70			1.00		0.50	1.00
51	GD3	-1.10			0.50		0.00	0.00
51	GD3	-1.40			1.00		0.50	-4.30
34	GD3	-0.95			1.00		0.00	-2.00
34	GD3	-1.10			0.50		3.25	1.50
34	GD3	-0.70			0.75		-0.75	-2.50
DMS E	GD3	-1.05		0.49	0.28		0.36	0.37
DMS E	GD3	-1.05		0.25	0.42		0.24	0.25
DMS E	GD3	-1.03		-0.05	0.40		0.38	-0.47
Mfgr E	GD3	-0.98	0.20	0.15	0.68	0.19	0.02	0.55
Mfgr E	GD3	-1.09	0.22	0.31	0.16	0.38	0.45	0.27
Mfgr E	GD3	-1.06	0.30	0.19	-0.09	0.25	0.64	-0.72
Mfgr B	GD4	-0.80	-0.01	0.06	0.05	-1.57	-1.34	0.13
Mfgr B	GD4	-0.85	0.18	0.63	-0.21	-1.32	-0.84	-1.82
Mfgr B	GD4	-0.76	0.04	0.21	0.08	-1.32	-1.22	0.12
DMS B	GD4	-1.32		-0.54	-0.99		-1.80	0.85
DMS B	GD4	-1.25		-0.43	0.50		-2.36	-1.85
DMS B	GD4	-1.30		-0.27	-1.00		-2.07	-2.43
35	GD4	-1.10			0.50		-1.50	-1.00
35	GD4	-0.80			1.50		-1.50	-3.00
35	GD4	-1.10			-0.50		-3.00	-2.00
6	GD4	-1.25			0.10		-4.00	-4.00
6	GD4	-1.00			-0.50		-4.00	-2.00
6	GD4	-1.10			-0.20		-4.00	-4.00
51	GD4	-1.80			0.00		-1.50	-2.00
51	GD4	-1.40			0.50		-2.00	-2.00
51	GD4	-1.60			0.00		-2.00	-2.00
34	GD4	0.85			-0.50		-3.50	-4.00
34	GD4	-1.25			0.00		-2.25	-3.00
34	GD4	-1.05			-0.75		-4.00	-5.00
DMS E	GD4	-1.37		-0.60	-0.41		-3.92	-2.00

County code	Code	50 gal/5 ft3 15 gpm	40 gal/4 ft3 2 gpm	20 gal/2 ft3 2 gpm	10 gal/1 ft3 2 gpm	20 gal/2 ft3 0.25 gpm	10 gal/1 ft3 0.25 gpm	5 gal/0.5 ft3 0.25 gpm
DMS E	GD4	-1.17		-0.29	-0.67		-3.10	-3.10
DMS E	GD4	-1.14		-0.84	-0.36		-4.27	-3.23
Mfgr E	GD4	-0.46	0.33	0.46	-0.26	-2.30	-1.97	-1.65
Mfgr E	GD4	-0.32	1.11	0.65	0.83	-2.29	-2.51	-3.53
Mfgr E	GD4	-0.56	0.21	0.18	-0.29	-2.38	-2.50	-2.84
Mfgr B	GD5	-0.62	0.41	0.78	0.73	-1.05	-1.07	-2.08
Mfgr B	GD5	-0.41	0.42	0.35	0.80	-1.05	0.99	-1.20
Mfgr B	GD5	-0.47	0.65	0.79	0.83	-0.61	-0.99	-0.28
DMS B	GD5	-0.10		0.45	0.53		-0.42	-0.75
DMS B	GD5	-0.54		0.41	0.50		-0.67	0.12
DMS B	GD5	-0.56		0.47	0.52		-1.19	-0.60
35	GD5	-0.40			0.50		0.50	-2.00
35	GD5	-0.30			1.00		-0.50	0.00
35	GD5	-0.60			0.00		0.00	-1.00
6	GD5	-0.35			1.00		-0.20	-0.40
6	GD5	-0.10			0.50		-0.50	1.00
6	GD5	-0.20			1.00		0.00	-0.40
51	GD5	-1.00			1.00		0.00	0.00
51	GD5	-0.80			0.50		-0.50	0.00
51	GD5	-0.90			2.00		0.00	0.00
34	GD5	-0.20			0.75		0.00	1.00
34	GD5	-0.15			0.75		-0.25	0.00
34	GD5	-0.55			0.75		0.00	0.50
DMS E	GD5	-0.51		0.74	1.27		0.06	-1.01
DMS E	GD5	-0.41		0.54	0.81		-1.33	0.25
DMS E	GD5	-0.37		0.59	0.31		-0.51	0.52
Mfgr E	GD5	-0.50	0.40	0.50	0.30	-1.10	-0.50	-0.70
Mfgr E	GD5	-0.60	0.50	0.50	0.40	-1.30	-1.30	-0.50
Mfgr E	GD5	-0.30	0.40	0.50	0.50	-1.30	-0.80	-0.20

Appendix B: Tables of Range Values

Table of Range Values for Meters Indicating in Cubic Feet

Lab Code	Meter Code	15 gpm 5 ft^3	2 gpm 4 ft^3	2 gpm 2 ft^3	2 gpm 1 ft^3	0.25 gpm 2 ft^3	0.25 gpm 1 ft^3	0.25 gpm 0.5 ft^3
Mfgr B	FA1	0.14	0.23	0.09	0.03	0.55	0.21	0.20
DMS B	FA1	0.01		0.33	0.33		0.19	0.49
7	FA1	0.12			0.20		0.20	
94	FA1	0.05			0.50		0.50	
35	FA1	0.25			0.50		0.00	
85	FA1	0.20			2.00		2.00	
82	FA1	0.10			0.50		0.25	
64	FA1	0.16			0.30		0.70	
DMS E	FA1	1.20		0.30	0.37		0.79	0.46
Mfgr E	FA1	0.10		0.10	0.40	0.70	0.60	1.80
Mfgr B	FA2	0.06	0.12	0.63	0.50	0.71	1.03	2.87
DMS B	FA2	0.10		0.33	0.33		0.28	0.51
7	FA2	0.04			0.20		1.00	
94	FA2	0.60			0.00		1.00	
35	FA2	0.30			0.00		0.50	
85	FA2	2.20			0.00		1.00	
82	FA2	0.10			0.25		0.75	
64	FA2	0.26			0.90		0.60	
DMS E	FA2	0.04		0.25	0.33		0.37	0.55
Mfgr E	FA2	0.21	0.26	1.02	1.96	0.71	1.01	1.64
Mfgr B	FA3	0.09	0.22	0.24	0.44	0.30	0.38	0.98
DMS B	FA3	0.02		0.09	0.39		0.95	0.93
7	FA3	0.08			0.70		0.30	
94	FA3	0.15			0.00		1.00	
35	FA3	0.20			0.00		3.00	
85	FA3	0.00			1.00		2.00	
82	FA3	0.10			0.25		0.50	
64	FA3	0.12			0.40		0.30	
DMS E	FA3	0.04		0.08	0.48		0.48	0.50
Mfgr E	FA3	0.08	0.04	0.16	1.23	0.16	0.40	1.48
Mfgr B	FA4	0.08	0.15	0.26	0.60	0.30	0.40	0.60
DMS B	FA4	0.53		0.26	0.43		0.49	2.58
7	FA4	0.10			0.10		0.20	
94	FA4	0.10			0.50		0.50	

Lab Code	Meter Code	15 gpm 5 ft^3	2 gpm 4 ft^3	2 gpm 2 ft^3	2 gpm 1 ft^3	0.25 gpm 2 ft^3	0.25 gpm 1 ft^3	0.25 gpm 0.5 ft^3
35	FA4	0.20			0.50		0.50	
85	FA4	0.00			1.00		2.00	
82	FA4	0.05			0.25		0.75	
64	FA4	0.09			0.40		0.50	
DMS E	FA4	0.11		0.30	0.28		0.62	0.44
Mfgr E	FA4	0.10		0.10	0.10	1.00	0.70	1.80
Mfgr B	FA5	0.02			0.15		0.30	
DMS B	FA5	0.11		0.43	1.75		0.35	1.70
7	FA5	0.08			0.40		0.20	
94	FA5	0.50			0.00		0.50	
35	FA5	0.20			0.50		0.50	
85	FA5	0.10			0.00		0.00	
82	FA5	0.15			1.00		1.50	
64	FA5	0.15			0.70		0.50	
DMS E	FA5	0.09		0.23	0.41		0.48	2.09
Mfgr E	FA5							
Mfgr B	FB1	0.06	0.12	0.61	0.92	0.46	2.01	1.89
DMS B	FB1	0.06		0.67	1.32		0.04	0.98
93	FB1	0.00			1.00		2.00	
94	FB1	0.05			1.50		1.00	
7	FB1	0.14			0.90		0.60	
DMS E	FB1	0.05		0.52	0.82		1.00	0.98
Mfgr E	FB1	0.20	0.22	0.68	0.94	0.50	1.29	0.39
Mfgr B	FB2	0.09	0.10	0.30	0.30	0.75	0.10	0.40
DMS B	FB2	0.09		0.16	0.08		0.21	2.16
93	FB2	0.10			0.00		0.50	
94	FB2	0.05			0.50		1.00	
7	FB2	0.10			0.20		0.50	
DMS E	FB2	0.04		0.02	0.28		0.30	0.44
Mfgr E	FB2	0.10	0.10	0.30	0.10	0.40	0.60	1.40
Mfgr B	FB3	0.11	0.08	0.86	1.20	0.46	1.03	0.13
DMS B	FB3	0.23		0.44	0.52		0.14	1.13
93	FB3	0.50			0.50		2.50	
94	FB3	0.15			0.50		0.50	
7	FB3	0.06			1.10		0.20	
DMS E	FB3	0.21		0.47	0.61		0.90	0.88
Mfgr E	FB3	0.34	0.22	1.64	1.87	0.15	1.29	0.39
Mfgr B	FB4	0.06			0.11		0.37	

Lab Code	Meter Code	15 gpm 5 ft^3	2 gpm 4 ft^3	2 gpm 2 ft^3	2 gpm 1 ft^3	0.25 gpm 2 ft^3	0.25 gpm 1 ft^3	0.25 gpm 0.5 ft^3
DMS B	FB4	0.08		0.04	0.13		0.29	1.55
93	FB4	0.10			1.00		1.00	
94	FB4	0.00			0.00		0.50	
7	FB4	0.12			0.30		0.50	
DMS E	FB4	0.05		0.25	0.67		0.80	0.95
Mfgr E	FB4							
Mfgr B	FB5	0.17	0.08	0.35	0.26	0.22	0.76	2.12
DMS B	FB5	0.07		0.09	0.23		0.80	0.38
93	FB5	0.10			1.00		0.50	
94	FB5	0.10			0.00		0.50	
7	FB5	0.26			0.40		0.40	
DMS E	FB5	0.08		0.27	0.95		0.40	0.54
Mfgr E	FB5	0.28	0.37	0.27	0.57	0.24	0.56	0.93
Mfgr B	FC1	0.04	0.07	0.30	0.05	0.03	0.88	1.53
DMS B	FC1	0.08		0.31	0.75		0.72	0.69
50	FC1	0.09			0.50		0.60	
57	FC1	0.19			1.32		0.66	
25	FC1	0.53			0.50		0.50	
32	FC1	0.11			0.50		0.60	
43	FC1	0.93			0.49		2.54	
53	FC1	0.12			0.50		0.00	
82	FC1	0.10			0.25		0.50	
64	FC1	0.13			0.10		0.60	
DMS E	FC1	0.07		0.24	0.43		0.56	1.11
Mfgr E	FC1	0.01	0.16	0.09	1.01	0.03	0.60	0.38
Mfgr B	FC2	0.07			0.06		0.65	
DMS B	FC2	0.12		0.18	0.57		0.98	5.89
50	FC2	0.01			0.30		0.30	
27	FC2	0.39					0.15	
57	FC2	0.21			0.74		0.54	
25	FC2	0.06			0.70		0.70	
32	FC2	0.11			0.10		0.10	
43	FC2	0.18			0.27		2.84	
53	FC2	0.05			0.80		0.20	
82	FC2	0.05			1.25		2.01	
64	FC2	0.10			0.70		0.50	
DMS E	FC2	0.07		0.44	0.33		0.16	0.91
Mfgr E	FC2							

Lab Code	Meter Code	15 gpm 5 ft^3	2 gpm 4 ft^3	2 gpm 2 ft^3	2 gpm 1 ft^3	0.25 gpm 2 ft^3	0.25 gpm 1 ft^3	0.25 gpm 0.5 ft^3
Mfgr B	FC3	0.12	0.22	0.11	0.40	0.30	0.43	0.90
DMS B	FC3	0.06		0.06	0.46		0.70	0.93
50	FC3	0.11			0.10		0.20	
27	FC3	0.43			0.00		0.45	
57	FC3	0.09			0.21		0.04	
25	FC3	0.12			0.70		0.40	
32	FC3	0.13			0.00		0.50	
43	FC3	0.13			0.36		1.50	
53	FC3	0.03			0.20		0.00	
82	FC3	0.05			0.25		0.75	
64	FC3	0.11			1.30		1.30	
DMS E	FC3	0.06		0.31	0.17		0.71	0.43
Mfgr E	FC3	0.20	0.20	0.20	0.60	0.30	0.70	1.60
Mfgr B	FC4	0.03	0.12	0.24	0.74	0.17	0.22	2.12
DMS B	FC4	0.03		0.25	1.37		0.35	1.81
50	FC4	0.30			0.20		0.10	
27	FC4	0.26					0.45	
57	FC4	0.13			0.42		0.21	
25	FC4	0.09			0.50		0.40	
32	FC4	0.13			0.30		0.30	
43	FC4	0.06			0.40		1.20	
53	FC4	0.19			0.60		0.10	
82	FC4	0.10			1.00		1.00	
64	FC4	0.11			0.30		0.50	
DMS E	FC4	0.02		0.06	0.27		0.67	1.00
Mfgr E	FC4	0.15	0.18	0.13	0.46	0.16	0.43	2.55
Mfgr B	FC5	1.65	0.17	0.67	1.00	0.94	0.51	0.89
DMS B	FC5	0.28		0.25	0.16		1.34	1.59
50	FC5	0.26			0.40		0.90	
27	FC5	0.49					1.05	
57	FC5	0.04			0.90		1.04	
25	FC5	0.13			0.70		0.10	
32	FC5	0.12			1.00		2.20	
43	FC5	0.15			0.40		3.14	
53	FC5	0.11			1.30		0.40	
82	FC5	0.15			1.25		1.75	
64	FC5	0.04			0.60		1.30	
DMS E	FC5	0.07		0.28	1.37		1.67	4.13

Lab Code	Meter Code	15 gpm 5 ft^3	2 gpm 4 ft^3	2 gpm 2 ft^3	2 gpm 1 ft^3	0.25 gpm 2 ft^3	0.25 gpm 1 ft^3	0.25 gpm 0.5 ft^3
Mfgr E	FC5	0.05	0.04	1.23	1.15	1.20	1.70	0.38
Mfgr B	FD1	0.05			0.02		0.52	
DMS B	FD1	0.06		0.64	0.49		0.89	2.10
57	FD1	1.36			0.25		0.34	
26	FD1	0.12			0.75		1.35	
32	FD1	0.10			0.20		0.90	
43	FD1	0.28			0.10		2.69	
53	FD1	0.12			0.30		0.20	
DMS E	FD1	0.08		1.13	0.16		1.31	1.67
Mfgr E	FD1							
Mfgr B	FD2	0.05	0.12	0.29	0.64	0.30	0.42	1.57
DMS B	FD2	0.05		0.27	0.19		0.70	1.06
27	FD2	0.52					0.31	
57	FD2	0.74			0.80		0.56	
26	FD2	0.21			0.30		1.65	
32	FD2	0.09			0.60		0.00	
43	FD2	0.13			0.06		1.65	
53	FD2	0.18			0.50		1.10	
DMS E	FD2	0.04		0.77	0.19		0.20	1.62
Mfgr E	FD2	0.09	0.15	0.19	0.52	0.24	0.44	1.95
Mfgr B	FD3	0.03			0.09		0.22	
DMS B	FD3	0.06		0.56	0.09		0.73	0.23
27	FD3	0.19			0.00		0.18	
57	FD3	1.35			0.48		0.49	
26	FD3	0.16			0.75		1.65	
32	FD3	0.11			0.20		0.20	
43	FD3	0.21			0.15		1.94	
53	FD3	0.01			0.30		1.20	
DMS E	FD3	0.11		1.12	0.54		0.77	0.67
Mfgr E	FD3							
Mfgr B	FD4	0.09	0.67	0.83	0.53	0.29	0.03	1.87
DMS B	FD4	0.08		0.36	0.41		0.08	1.22
27	FD4	0.07			0.00		1.04	
57	FD4	0.51			1.03		0.84	
26	FD4	0.40			0.67		0.60	
32	FD4	0.17			0.50		0.80	
43	FD4	0.25			0.19		2.69	
53	FD4	0.11			0.90		1.10	

Lab Code	Meter Code	15 gpm 5 ft^3	2 gpm 4 ft^3	2 gpm 2 ft^3	2 gpm 1 ft^3	0.25 gpm 2 ft^3	0.25 gpm 1 ft^3	0.25 gpm 0.5 ft^3
DMS E	FD4	0.05		0.92	0.78		1.19	2.06
Mfgr E	FD4	0.05	0.01	1.62	1.25	0.17	1.96	0.41
Mfgr B	FD5	0.09	0.17	0.29	0.07	0.30	1.08	0.40
DMS B	FD5	0.10		0.41	0.19		0.52	0.49
27	FD5	0.22			0.00		0.88	
57	FD5	0.18			0.44		0.65	
26	FD5	0.69			0.22		1.20	
32	FD5	0.02			0.60		0.00	
43	FD5	0.09			0.10		1.65	
53	FD5	0.10			0.50		0.90	
DMS E	FD5	0.07		0.92	1.10		0.20	1.55
Mfgr E	FD5	0.20		0.20	0.10	0.60	0.80	1.40

Table of Range Values for Meters Indicating in Gallons

Lab Code	Meter Code	15 gpm 50 gal	2 gpm 40 gal	2 gpm 20 gal	2 gpm 10 gal	0.25 gpm 20 gal	0.25 gpm 10 gal	0.25 gpm 5 gal
Mfgr B	GA1	0.14	0.31	0.56	0.97	0.50	0.51	2.01
DMS B	GA1	0.25		0.02	0.40		1.19	2.73
51	GA1	0.30			0.50		1.00	2.00
6	GA1	1.02			0.80		1.80	1.20
34	GA1	0.10			0.30		9.25	18.00
DMS E	GA1	0.06		0.49	0.55		0.26	1.68
Mfgr E	GA1	0.14	0.16	0.46	0.85	0.60	0.42	1.88
Mfgr B	GA2	0.45	0.26	0.39	0.30	0.30	0.15	0.70
DMS B	GA2	0.34		0.31	0.05		0.41	0.75
51	GA2	0.30			0.50		0.50	1.00
6	GA2	0.20			1.10		0.60	2.00
34	GA2	0.18			0.60		0.25	2.00
DMS E	GA2	0.05		0.14	0.45		0.83	1.54
Mfgr E	GA2	0.06	0.13	0.29	0.52	0.43	0.97	1.67
Mfgr B	GA3	0.04	0.23	0.43	0.18	0.86	0.08	1.76
DMS B	GA3	0.20		0.42	0.31		0.59	0.58
51	GA3	0.40			0.00		0.50	3.00
6	GA3	0.30			0.10		0.50	0.20
34	GA3	0.06			0.55		0.75	1.50
DMS E	GA3	0.04		0.04	0.26		0.44	0.39
Mfgr E	GA3	0.10		0.10	0.20	0.50	0.20	0.20
Mfgr B	GA4	0.12			0.04		0.75	
DMS B	GA4	0.24		0.25	0.08		0.59	1.66
51	GA4	0.40			0.00		0.50	2.00
6	GA4	0.19			0.80		5.70	2.00
34	GA4	0.16			0.25		0.50	0.00
DMS E	GA4	0.04		0.67	0.36		0.85	1.01
Mfgr E	GA4							
Mfgr B	GA5	0.12			0.06		0.55	
DMS B	GA5	0.32		0.27	0.31		0.47	1.17
51	GA5	1.00			0.50		0.50	1.00
6	GA5	0.50			1.10		1.10	0.20
34	GA5	0.15			0.49		2.74	1.50
DMS E	GA5	0.09		0.42	0.46		0.35	1.47
Mfgr E	GA5							
Mfgr B	GB1	0.13	0.27	0.24	0.00	0.50	0.27	1.50
DMS B	GB1	0.16		0.06	0.42		0.57	2.58

50	GB1	0.22			1.40		0.40	1.00
89	GB1	0.03			0.20		0.40	3.00
67	GB1	0.22			0.50		0.10	1.60
52	GB1	0.10			0.40		0.40	3.80
DMS E	GB1	0.10		0.27	0.46		0.44	4.35
Mfgr E	GB1	0.09	0.12	0.38	0.33	0.08	0.59	3.86
Mfgr B	GB2	0.11	0.70	0.91	0.47	1.50	0.12	1.95
DMS B	GB2	0.16		0.39	1.55		1.01	1.58
50	GB2	0.18			0.40		0.10	1.20
89	GB2	0.09			0.90		0.60	2.00
67	GB2	0.68			1.20		0.40	0.80
52	GB2	0.18			0.90		0.80	1.60
DMS E	GB2	0.02		0.29	0.86		1.00	1.28
Mfgr E	GB2	0.29	1.98	0.46	0.15	0.51	0.55	1.24
Mfgr B	GB3	0.03			0.15		0.65	
DMS B	GB3	0.12		0.34	0.84		0.44	2.15
50	GB3	0.30			0.10		0.20	1.60
89	GB3	0.00			0.50		0.80	1.80
67	GB3	0.22			0.40		0.00	2.00
52	GB3	0.16			0.20		0.10	1.60
DMS E	GB3	0.19		0.67	0.46		1.18	1.09
Mfgr E	GB3							
Mfgr B	GB4	0.14	0.23	0.49	0.09	2.09	0.96	1.86
DMS B	GB4	0.40		0.49	0.38		0.45	2.97
50	GB4	0.18			0.80		0.80	0.80
89	GB4	0.00			0.50		0.20	3.00
67	GB4	0.16			0.90		0.50	1.00
52	GB4	0.06			0.50		0.30	1.40
DMS E	GB4	0.11		0.12	0.46		0.54	1.88
Mfgr E	GB4	0.30	0.10	0.20	0.20	0.40	1.00	1.70
Mfgr B	GB5	0.14	0.32	0.66	1.29	0.25	0.62	2.95
DMS B	GB5	0.19		0.53	0.37		0.90	1.16
50	GB5	0.18			0.40		0.20	1.60
89	GB5	0.13			1.20		0.60	2.80
67	GB5	0.26			1.20		0.30	2.80
52	GB5	0.13			0.30		0.50	1.60
DMS E	GB5	0.09		0.20	0.33		0.94	1.26
Mfgr E	GB5	0.14	0.34	0.99	0.99	0.57	1.67	1.25
Mfgr B	GC1	0.15	0.24	0.04	0.12	1.45	2.08	1.76
DMS B	GC1	0.08		0.46	0.75		0.48	1.25

89	GC1	0.11			0.70		0.50	1.00
67	GC1	0.12			0.20		0.00	3.00
52	GC1	0.04			0.90		0.80	2.00
DMS E	GC1	0.08		0.07	0.40		0.45	0.15
Mfgr E	GC1	0.30		0.20	0.40	0.60	0.40	1.20
Mfgr B	GC2	0.08			0.16		0.30	
DMS B	GC2	1.45		0.43	0.31		0.71	2.54
89	GC2	0.06			0.70		0.40	2.00
67	GC2	0.12			0.80		0.30	0.40
52	GC2	0.12			0.20		4.80	2.40
DMS E	GC2	0.58		0.56	1.29		1.05	1.24
Mfgr E	GC2							
Mfgr B	GC3	0.07	0.44	0.65	0.75	0.25	1.54	1.06
DMS B	GC3	0.07		1.56	0.42		1.19	4.96
89	GC3	0.13			0.20		0.50	1.60
67	GC3	0.20			0.30		0.90	2.40
52	GC3	0.09			0.20		0.60	1.80
DMS E	GC3	0.10		0.29	0.39		1.28	1.96
Mfgr E	GC3	0.35	1.32	0.58	0.13	0.09	0.47	3.81
Mfgr B	GC4	0.02	0.12	0.19	0.50	0.14	0.57	1.30
DMS B	GC4	0.08		0.22	0.63		0.94	1.75
89	GC4	0.08			0.50		0.50	2.00
67	GC4	0.10			0.30		0.30	1.00
52	GC4	0.07			0.30		0.10	1.80
DMS E	GC4	0.13		0.07	0.30		0.85	2.07
Mfgr E	GC4	0.15	0.07	0.12	0.39	0.18	0.75	2.20
Mfgr B	GC5	0.03	0.15	0.51	0.20	0.26	0.31	0.65
DMS B	GC5	0.05		0.14	0.45		1.16	2.70
89	GC5	0.05			0.60		0.50	1.60
67	GC5	0.28			0.60		0.20	0.20
52	GC5	0.09			0.20		0.50	1.40
DMS E	GC5	0.10		0.31	0.39		0.65	2.71
Mfgr E	GC5	0.22	0.07	0.19	0.57	0.25	0.66	0.36
Mfgr B	GD1	0.08			0.19		0.25	
DMS B	GD1	0.38		0.87	0.54		0.16	0.46
35	GD1	0.20			1.00		1.50	1.00
6	GD1	0.20			0.50		0.40	1.60
51	GD1	0.30			1.00		0.00	1.00
34	GD1	0.55			0.75		2.75	1.50
DMS E	GD1	0.05		0.14	0.48		0.39	1.03

Mfgr E	GD1							
Mfgr B	GD2	0.32	0.26	0.49	0.12	2.36	0.13	1.98
DMS B	GD2	0.22		0.14	0.31		0.24	0.68
35	GD2	0.30			0.50		1.00	2.00
6	GD2	0.30			0.50		1.50	1.60
51	GD2	0.10			0.00		0.50	2.00
34	GD2	0.20			0.75		1.50	2.00
DMS E	GD2	0.13		0.10	0.73		0.41	0.92
Mfgr E	GD2	0.20		0.20	0.10	0.40	0.40	1.00
Mfgr B	GD3	0.20	0.83	0.06	0.40	0.15	0.22	1.64
DMS B	GD3	0.24		0.19	0.11		0.10	1.46
35	GD3	0.50			0.00		0.00	3.00
6	GD3	0.13			0.50		0.50	1.00
51	GD3	0.60			0.50		0.50	5.30
34	GD3	0.40			0.50		4.00	4.00
DMS E	GD3	0.02		0.54	0.14		0.15	0.84
Mfgr E	GD3	0.10	0.10	0.17	0.76	0.19	0.62	1.27
Mfgr B	GD4	0.09	0.19	0.56	0.29	0.25	0.50	1.95
DMS B	GD4	0.07		0.27	1.50		0.56	3.28
35	GD4	0.30			2.00		1.50	2.00
6	GD4	0.25			0.60		0.00	2.00
51	GD4	0.40			0.50		0.50	0.00
34	GD4	2.10			0.75		1.75	2.00
DMS E	GD4	0.24		0.55	0.31		1.17	1.23
Mfgr E	GD4	0.24	0.90	0.46	1.11	0.09	0.55	1.88
Mfgr B	GD5	0.21	0.24	0.44	0.10	0.44	2.06	1.80
DMS B	GD5	0.46		0.06	0.03		0.77	0.87
35	GD5	0.30			1.00		1.00	2.00
6	GD5	0.25			0.50		0.50	1.40
51	GD5	0.20			1.50		0.50	0.00
34	GD5	0.40			0.00		0.25	1.00
DMS E	GD5	0.13		0.20	0.96		1.40	1.53
Mfgr E	GD5	0.30	0.10		0.20	0.20	0.80	0.50