The Impact of Display Resolution on Flow Computer Calculation Verification

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At SOLV® we are often challenged by users regarding perceived calculation errors when comparing software results against flow computers. Through rigorous QA testing, we are confident in FLOWSOLV® results and have taken this opportunity to outline the frequent reasons we witness calculations exceeding the verification tolerance. When verifying flow computer calculations, the customary tolerance used is |0.001%|of the Reference Value. Vertical bars || indicate the unsigned (absolute) percentage value of the verification tolerance. It is derived as follows:

$$|Flow\ Computer\ Verification\ (FCV)|\% = \frac{|Reference\ Value - Test\ Value|}{Reference\ Value}\%$$

Attaining a tolerance of |0.001%| relies on having good quality inputs into the verification calculation. Here we show the importance of input precision to achieve the verification tolerance. There is no one size fits all rule, however, if we pay attention to sensitivity of outputs to inputs and potential input discrepancies, we can get close to the reference value.

In our experience, discrepancies between FLOWSOLV® results and those of the flow computer arise in the following categories:

- **Data Entry** – Simple mistakes in number entry, either in the flow computer or FLOWSOLV® verification software.
- **Mixed Engineering Units** – Confusion in the use of Absolute or Gauge pressures, Upstream, Downstream or Measured Temperature to name a few.
- **Insufficient Significant Digits/Figures** – Numbers are often rounded for ease of display or to avoid reporting insignificant figures. For example, if a pressure measurement of 52.34525 bar is displayed, it is to seven significant figures. That's not to say that the number being used in the calculation isn't to a greater number of **SF** (Significant Figures), you just can't see them. **As a guideline we recommend a minimum of 6 SF to ensure the |0.001%| tolerance is always achieved.**

Data Entry errors or mixed Engineering units can be solved with a little detective work. We are going to concentrate of the effects of **SF** from here onwards.

Golden Rules

i. It's very difficult to verify a flow computer using live inputs. **Always use keypad entered values in the flow computer**. (Off-line or in Maintenance Mode first)
ii. Even if a number is only displayed to say 2 decimal places, a flow computer should use significantly more decimal places. Increase the display resolution of the flow computer if possible and enter a keypad value of at least 6 SF.
iii. It's important to ensure that the input numbers to a verification are not cascaded from another calculation. Knowledge of the overall calculation sequence can be a great help to trace discrepancies in a flow computer.
iv. Most flow computer manufacturers provide a Snapshot or Live Values Report. This is convenient for collecting all data needed to verify a calculation. However, data must

come from the same calculation cycle (Typically 500 milli-seconds) and be of sufficient resolution (Significant Digits/Figures) to permit meaningful number comparison.

So why is using full precision values on the calculation input side important? If you have found there is greater than |0.001%| difference between the FLOWSOLV® reference value and the flow computer test value; and you are certain of all your input numbers, then it may be because inputs you are using to calculate the test value are rounded in the flow computer.

Case Study using API MPMS Chapter 11.1:2004 calculation

We have put together three simple case studies to illustrate the impact of significant figures and display rounding on API MPMS 11.1:2004. The example uses Observed Temperature, Observed Pressure and Base Density to calculate density at observed conditions.

The reference value for Observed Density we have used is calculated using inputs with 8 SF, it's shown in yellow in the tables below, test values are compared to this value. Test values which deviate more than 0.001% from the reference value are shown in red.

Case 1: Significant Figures of input Temperature, Pressure and Density all varied.

The calculation inputs are all varied from 1 to 7 SF. If the input values were rounded, they would be rounded down to give the same value but with fewer SF.

Inputs	Units	Significant Figures							
		1	2	3	4	5	6	7	8
Observed Temp.	°F	100	110	111.0	111.10	111.110	111.1110	111.11110	111.111110
Observed Pressure	psig	50	51	51.1	51.11	51.111	51.1111	51.11111	51.111111
Base Density	API°	10	11	11.1	11.11	11.111	11.1111	11.11111	11.111111
Output	**Unit**								
Observed Density	API°	11.9420	13.4970	13.6540	13.6697	13.6713	13.6715	13.6715	13.6715
Flow Computer Verification									
FCV		12.6503%	1.2761%	0.1277%	0.0128%	0.0013%	0.0001%	0.0000%	

In this example the tolerance of 0.001% has been achieved with 6 SF inputs.

Case 2: Significant Figures of Density varied, Temperature and Pressure constant.

Input Base Density is varied from 1 to 7 SF. Pressure and temperature input SF remain constant. To achieve 0.001% tolerance between reference value and test value, only 5 SF are needed for density input. Fewer than when all values are varied because we are dealing only with the sensitivity of a single (density) input.

Inputs	Units	Significant Figures							
		1	2	3	4	5	6	7	8
Observed Temp.	°F	100	100	100.0	100.00	100.000	100.0000	100.00000	100.000000
Observed Pressure	psig	50	50	50.0	50.00	50.000	50.0000	50.00000	50.000000
Base Density	API°	10	11	11.1	11.11	11.111	11.1111	11.11111	11.111111
Output	**Unit**								
Observed Density	API°	11.9420	12.9839	13.0882	13.0986	13.0996	13.0997	13.0998	13.0998
Flow Computer Verification									
FCV		8.8381%	0.8841%	0.0884%	0.0088%	0.0009%	0.0001%	0.0000%	

Here we do not look at what happens when only temperature is varied from 1 to 7 SF, but in order to achieve the 0.001% tolerance 5 SF are needed for inputs, very similar results to Case 2. Due to dealing with liquids, temperature and density both have a large effect on the resultant base density.

Case 3: Significant Figures of Pressure varied, Temperature and Density constant.

Input Pressure is varied from 1 to 7 SF. Temperature and density inputs are constant. In order to be within tolerance only 2 SF are needed for inputs. Due to the density calculated not being sensitive to the effect of pressure, if we were working with a gas calculation the resultant density would be far more sensitive to pressure and we would need a higher number of SF to achieve the tolerance. Therefore, we cannot use a one size fits all rule in recommending the number of input SF used to achieve tolerance.

Inputs	Units	Significant Figures							
		1	2	3	4	5	6	7	8
Observed Temp.	°F	100	100	100.0	100.00	100.000	100.0000	100.00000	100.000000
Observed Pressure	psig	50	51	51.1	51.11	51.111	51.1111	51.11111	51.111111
Base Density	API°	10	10	10.0	10.00	10.000	10.0000	10.00000	10.000000
Output	**Unit**								
Observed Density	API°	11.9420	11.9414	11.9414	11.9414	11.9414	11.9414	11.9414	11.9414
Flow Computer Verification									
FCV		0.0051%	0.0005%	0.0001%	0.0000%	0.0000%	0.0000%	0.0000%	

Conclusions

We have shown that the number of significant figures on inputs has a large impact on the ability to achieve the |0.001%| flow computer verification tolerance. The precise number of significant figures required is dependent on the calculation and sensitivity of the output to the input. Certain inputs have more significant impact, for example, gas calculations are not particularly sensitive to temperature, however, they are far more sensitive to composition and pressure. Liquid calculations are more sensitive to temperature.

Click here for a great sensitivity example http://www2.flowsolv.com/measurement-sensitivity

However, a general rule of 6 significant figures for inputs is good measurement practice to eliminate the effects of number rounding as a source of error in flow computer verifications. If you are writing a flow computer specification, this would be a great item to include to help with Factory Acceptance Testing and in its operational life phase.

So, to avoid a red face with your flow computer vendor, make sure you have checked for Data Entry errors, Mismatched Engineering Units and eliminated significant figures as a source for discrepancy before sending that "*we have a problem*" email.

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SOLV® is a UK based engineering consultancy and software company providing flow measurement engineering and consultancy services for fiscal, allocation and process flow measurement of hydrocarbons. We pioneered the use of Monte Carlo Simulation for uncertainty determination in measurement systems.