HKA TECHNOLOGIES INC.

TEMPERATURE COMPENSATION

Different Methods of Air Leak Testing

- Conventional vs Bell Jar
- Pressure Decay and Differential Pressure Decay
- Mass Flow and Differential Mass Flow
- HKA mainly focus on Mass Flow Technology, most effective method of quantifying leak rate

Different Methods of Air Leak Testing

Leak Test Comparison — Source: InterTech Development

	Pressure Decay	Differential Pressure	Mass Flow	Differential Mass Flow	Mass Flow Bell Jar	Helium Sniffer	Helium Vacuum
Initial Cost	Low	Moderate	Moderate	Moderate	Moderate	Moderate	High
Fixture Cost	Low	Low	Low	Low	High	Moderate	High
Test Time	Longest	Shorter	Shortest	Shorest	Shortest	Shorter	Shortest
Accuracy	Poorest	Better	Best	Best	Best	Better	Best
Small Leaks	Unsatis.	Satis.	Best	Best	Best	Better	Best
Ideal Pressure	Low-Medium	Medium	Up to 150 psi	Up to 150 psi	High	Medium	High
Temp. Compensation	Difficult	Difficult	Available	Available	Available	N/A	Available

Mass Flow vs. Differential Mass Flow

- Mass flow technology uses a mass flow transducer to measure any flow between the two parts.
- No need to measure pressure, volume, and time

Mass Flow

- Uses only one test part
- For measuring large leak rate such as litres / minute
- Take a longer time to stabilize
- Unable to use temperature compensation

Differential Mass Flow

- Uses one reference part and one test part
- Measuring leak rate in sccm
- Reference part tracks the flow of test part, thus faster stabilization time
- Has the option to add on temperature compensation

Temperature Effects

- PV = nRT, V, n, and R stay constant during a test, change in temperature is proportional to change in pressure, and the change in pressure results a change in leak rate

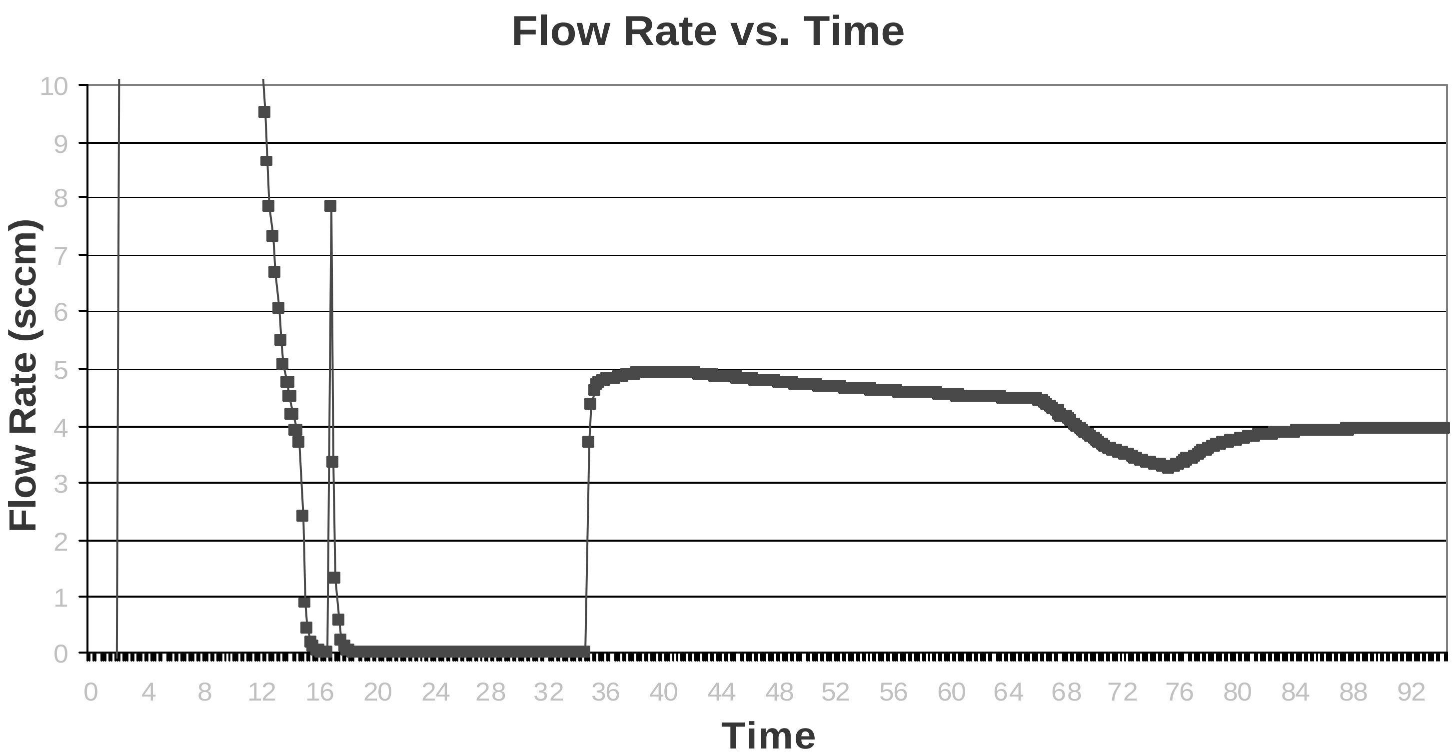
PRESSURE	30	
Cal Leak	3.2	
TEST #	TEMP	LEAK
1	84.8	3.71
2	91	3.87
3	98.5	4.2
4	104.9	4.44
5	109.7	4.84

PRESSURE	45	
Cal Leak	4.7	
TEST #	TEMP	LEAK
1	84.6	4.71
2	91	4.95
3	98.5	5.53
4	104.9	6
5	109.8	5.91

Temperature Effects

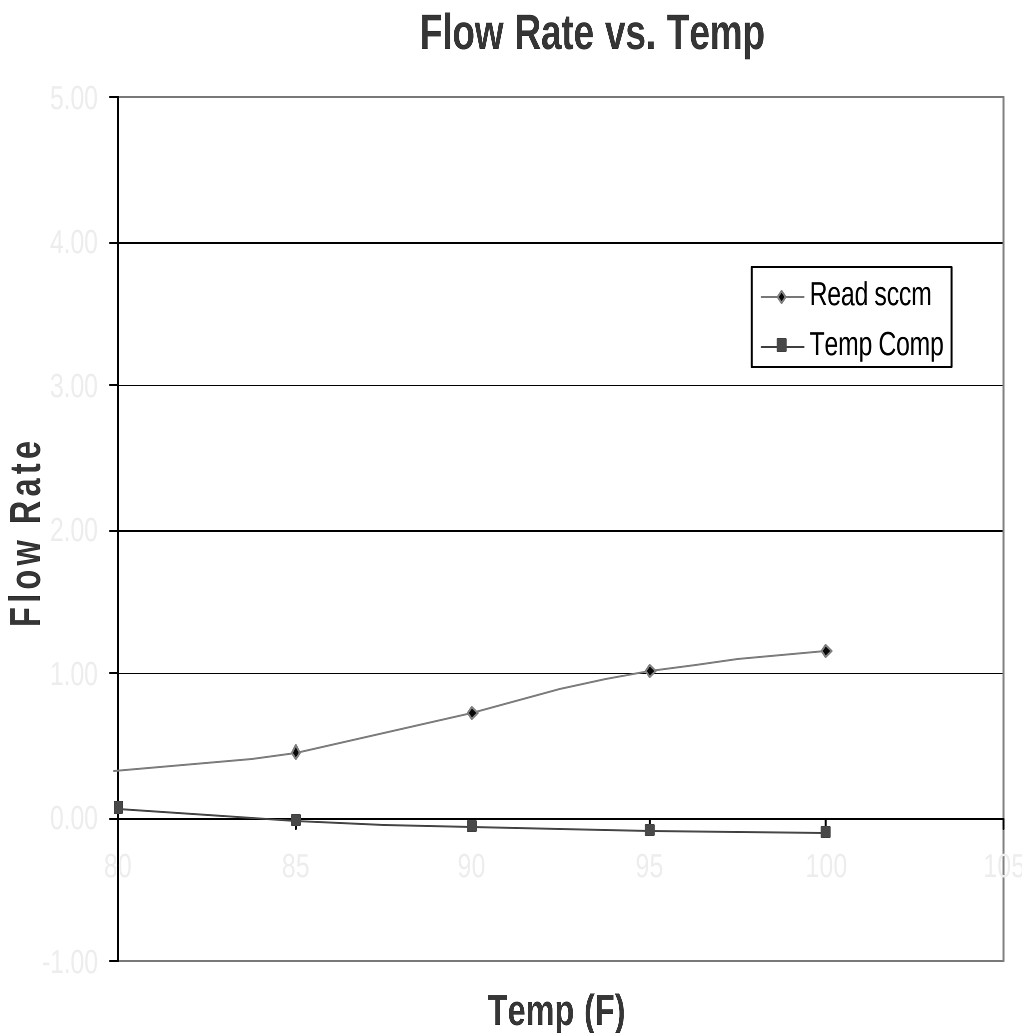
- The more change in temperature, the more shift in leak rate
- More difficult to cool down a part than heat it up because some kind of cooling device is required
- Heating up the reference part simulates the effect of cooling down the test part
- Negative change in temperature on the test part causes higher leak rate
- Negative change in temperature on the reference part causes lower leak rate
- Put hands on the test part (heat up) causes the graphs to go down
- Different height level can cause a shift in leak rate
- A higher altitude is slightly warmer than a lower altitude

Temperature Effects



- Put a hand on the test part heats it up, causing the graph to drop
- Warmer hand creates a positive change in temperature on the test part, which has the same effect as creating a negative change in temperature on the reference part, thus resulting in a lower leak rate

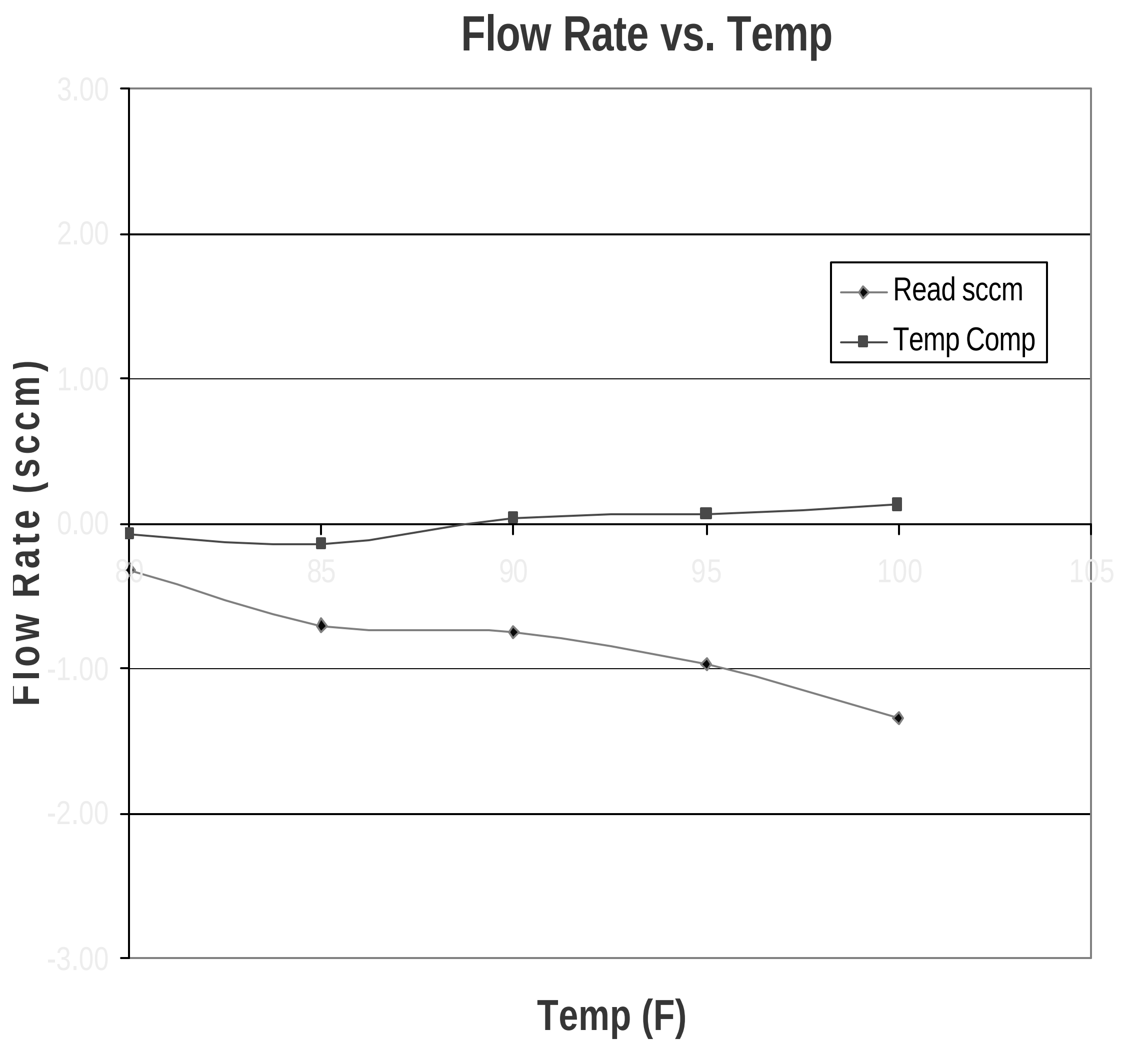
Temperature Effects



- Graph showing five tests at different temperature with no leak added
- Heat up test part prior to pressuring the parts
- Top curve is the uncompensated leak, very inaccurate results, gets worse as temperature increases
- Lower curve is the compensated leak, very close to zero

Temperature Effects

- Graph showing five tests at different temperature with no leak added
- Heat up reference part prior pressuring the parts
- Bottom curve is the uncompensated leak, the results gets worse as temperature increase
- Upper curve is the compensated leak, very close to zero



Temperature Compensation

➢Temp Comp can provide an accurate leak regardless of the temperature effect

How does it work?

➢Measure the initial flow between test part and reference part prior to pressurizing the parts using a mass flow transducer

➢Any pressure change during this COMP period is due to temperature change

➢The rate of change in temperature determines the slope of the initial flow; the fast the rate of change, the steeper the slope

➢The measured initial flow is multiplied by a temperature compensation factor, then either subtracts or adds this value from the uncompensated leak to obtain compensated leak

Temperature Compensation

TC Factor

- The TC factor (temperature compensation factor) is pressure dependent
- TC factor is inversely proportional to initial flow
- Theoretical TC factor can be calculated based on the fact that temperature effect is proportional to absolute pressure
- Theoretical TC factor can be determined by scaling the ratio of the absolute test pressure divided by the absolute pressure during the ambient test condition
- For example, if the test pressure is at 30 psi, and ambient pressure is 1 atm or 14.7 psi, then

$$\text{Theoretical TC factor} = (30 + 14.7) / 14.7$$

$$= 3$$

Temperature Compensation

Actual TC Factor

- The actual TC factor should always be less than the theoretical TC factor under normal conditions
- At higher temperatures, the parts are cooling down much faster in the FILL state because of the incoming gas is at room temperature
- Actual TC factor equals to the theoretical TC factor only if the rate of temperature change is constant
- Higher the temperature, the more the TC factors vary
- Near room temperature, TC factor is pretty constant
- Therefore TC factors are nonlinear and there is a certain range of TC factors at different temperatures
- Higher the temperature, lower the TC factor and vice versa, but only within the TC factor range

Temperature Compensation

Calculating the Actual TC Factor

- To facilitate the calculation, do not add leak during a test
- First take the raw flow reading at the end of COMP state and convert it into flow rate
- Then take the raw flow reading at the end of READ state and convert it into leak rate
- The formula for calculating TC factor is:

Compensated Leak = Uncompensated Leak – (TC Factor * Initial Flow)

- Since leak is not added, compensate leak = 0
- Rearranging the equation:

TC Factor = Uncompensated Leak / Initial Flow

- Both uncompensated leak and initial are known, therefore the TC factor can be obtained

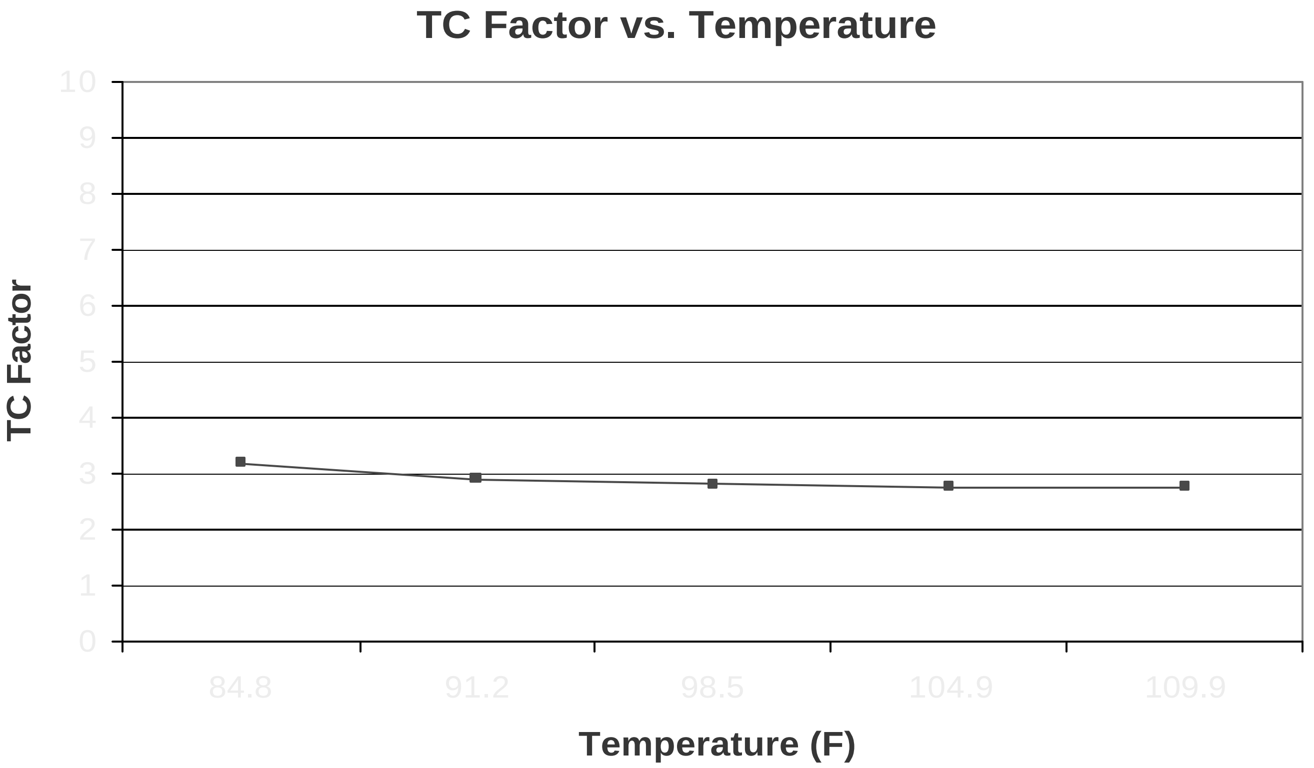
Temperature Compensation

Obtaining Accurate TC Factor

- When a part is being heated, try to distribute the heat evenly
- The larger the parts are, the more difficult it is to evenly distribute the heat manually
- Good ways to distribute the heat such as having parts coming out of a furnace or a well-insulated area
- Unevenly distribution of heated can cause inaccurate and inconsistent initial flow, resulting in obtaining the wrong TC factor
- Leads to an inaccurate compensated leak
- The optimized TC factor in the area of interest should be used for all tests
- The optimized TC factor depends on the temperature range of the tests

Temperature Compensation

➢Slightly lower TC factors as temperature increases, therefore it is usually more accurate to take the average



Temperature Compensation

Inaccurate TC Factors

- Flow restriction is essential to protect the mass flow transducer
- Due to the flow restriction to the transducer, less flow is measured between the parts, thus causing a lower initial flow
- Lower initial flow requires a higher TC factor to maintain the same compensated leak
- TC factors will be higher than the theoretical TC factor
- The cure is to add a valve to provide the right amount of initial flow

Theoretical TC factor at 200 psi is 14.61, the average of all the TC factors below is 16.96

TEST #	TEMP	TC FACTOR
1	80	18.89
2	85	18.9
3	90	15.87
4	95	15.75
5	100	15.4

Application of Temperature Compensation

- Imagine without temperature compensation, hot parts coming out of a furnace is rapidly cooling down, thus causing a higher leak rate. Resulting in failing good test parts
- Colder parts trying to reach room temperature causes a lower leak rate, resulting in passing defects
- Parts such as heat exchangers have low mass, large volume, and high surface area, making them even more difficult to test
- Large heat exchangers can take a long time to test, but without temperature compensation, test technicians may need to run a second or a third test to evaluate the quality of the heat exchangers
- With temperature compensation, a good test part will always be below the leak limit, there will no uncertainties on the test part

Application of Temperature Compensation

Combining Temperature Compensation with Fast Cycle

- The main objective for any kind of leak testing is to obtain an accurate result in the shortest amount of time
- Most of the test time is spent on the READ state
- Fast cycle is enabled only if the curve is under the leak limit, and after a certain amount of time into READ state, so that the slope of the curve can only go in one direction, then the software checks for two conditions that must be true :
  - The slope of the curve is either zero or negative
- Fast cycle cannot guarantee that the curve is below the leak limit on every test
- With temperature compensation, fast cycle can always be enabled
- Significantly reduce the amount of test time

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