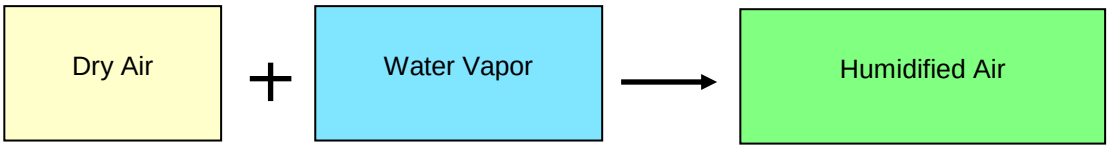
CORRECTING FOR HUMIDITY EFFECTS ON TSI® GENERAL PURPOSE FLOWMETERS

APPLICATION NOTE FLOW-001

This application note applies to all TSI flowmeters equipped with a mini-DIN connector

Like all thermal mass flow meters, humidity affects the output of the TSI general-purpose flowmeters. The mass flow rate, thermal conductivity and viscosity all affect the amount of heat transferred from the sensor element. If water vapor is added to the gas, the total mass is increased and both the overall thermal conductivity and overall viscosity change.



On the following pages are a series of graphs that can be used to correct for the effects of water vapor. To correct the readings you need to know what percentage of the overall gas is water vapor. The percent water vapor can be determined from the relative humidity or dew point, barometric pressure, and temperature of the gas.

Below are the equations for converting from relative humidity to percent water vapor by volume. If the dew point is known, then the following equations can be used by substituting the dew point temperature for the gas temperature and using 100% for the relative humidity.

Percent water vapor by volume is given by

% Water vapor by volume = RH/100 * p_{ws}/p

where

RH = percent relative humidity
p_{ws} = saturated vapor pressure, which is a function of temperature
p = absolute pressure

The saturation vapor pressure over liquid water for the temperature range of 32°F to 392°F is given by[1]:

$$\ln(pws) = C_8 / T + C_9 + C_{10}T + C_{11}T^2 + C_{12}T^3 + C_{13} \ln(T)$$

where

C_8 = -1.0440397E +04
C_9 = -1.1294650E +01
C_{10} = -2.7022355E -02
C_{11} = 1.2890360E -05
C_{12} = -2.4780681E -09
C_{13} = 6.5459673
T = absolute temperature, °R = °F + 459.67, °R = °K*9/5, °R = (°C+273.15)*9/5
pws = saturated vapor pressure (psia)

1 psia = mmHg/51.715 = Kpa/6.8947 = mBar/68.947 =
cm H2O/70.308 = inches H2O/27.680

1. For the purposes of effect on flow readings the above equation can be used below 32°F within the pressure range of these meters.

Reference: 1997 ASHRAE Handbook, Fundamentals, American Society of Heating, Refrigeration and Air Conditioning Engineers.

List of Graphs

Example 1:

A 4040 reads 50.0 Std L/min of air with 20% R.H. at one atmosphere and 21˚C. If you want the mass flow rate of air without the water vapor, then use the second graph from page eight. The correction from the graph is -1.0%.

The mass flow rate of just the air then is 50 std L/min *(1-0.010) = 49.5 std L/min of air.

Example 2:

A 4140 reads 5.00 std L/min of air with 30% R.H. at 0.9 atmospheres and 26˚C. If you want the mass flow rate including the water vapor, then you use the equations on page two and the first graph on page five.

The percent water vapor
= Relative Humidity * saturated vapor pressure/absolute pressure
$=RH * \exp(C_{8/}T + C_9 + C_{10}T + C_{11}T^2 + C_{12}T^3 + C_{13} \ln(T))$ psia/$P_{abs(psia)}$
where RH = 30% and T = (26 +273.15)*9/5 =538.47

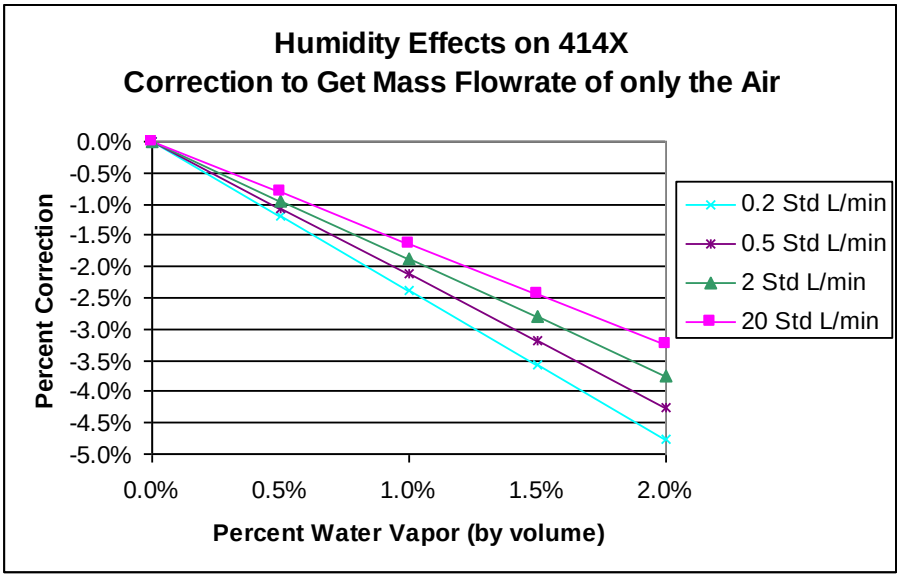
percent water vapor
$= 30\% * \exp(C_{8/}T + C_9 + C_{10}T + C_{11}T^2 + C_{12}T^3 + C_{13} \ln(T))$psia/(0.9atm*14.7 psia/atm)
= 30% * 0.4878 psia/ 13.23 psia = 1.1% water vapor

Using 1.1% water vapor, 5 L/min, and the first graph on page six the correction is approximately -1.2%.

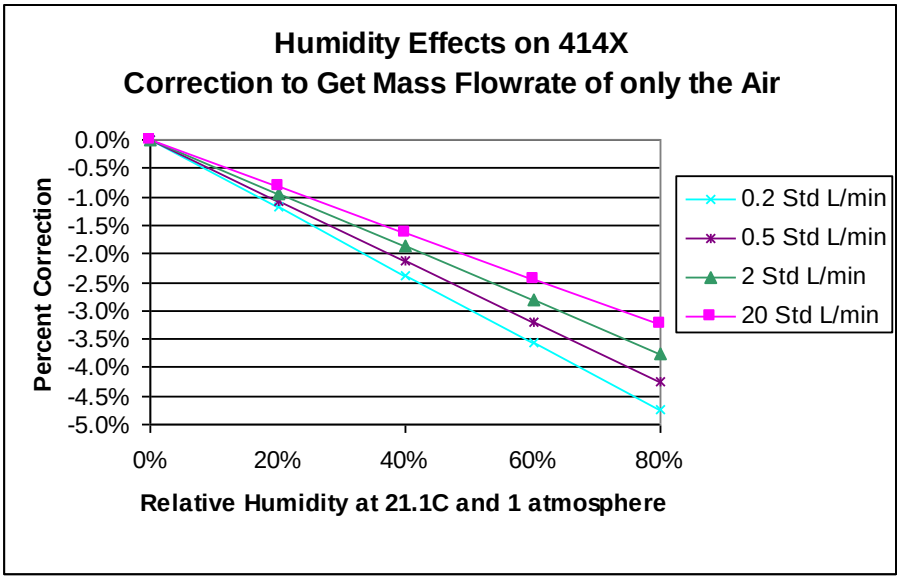
Therefore the total mass flow rate is 5.00 std L/min * (1-.012) = 4.94 std L/min

Model 414x Flowmeters–Humidity Correction to get Air Flow Rate

Use the following graphs if you are interested in measuring the mass flow of just the air, not including the water vapor. Most of the correction is due to the added mass of the water vapor.

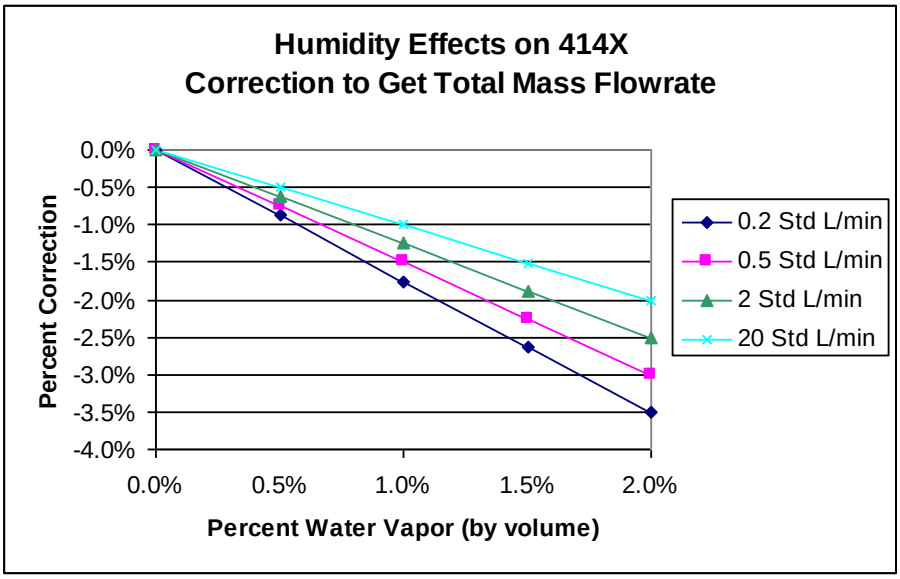


Example Conditions

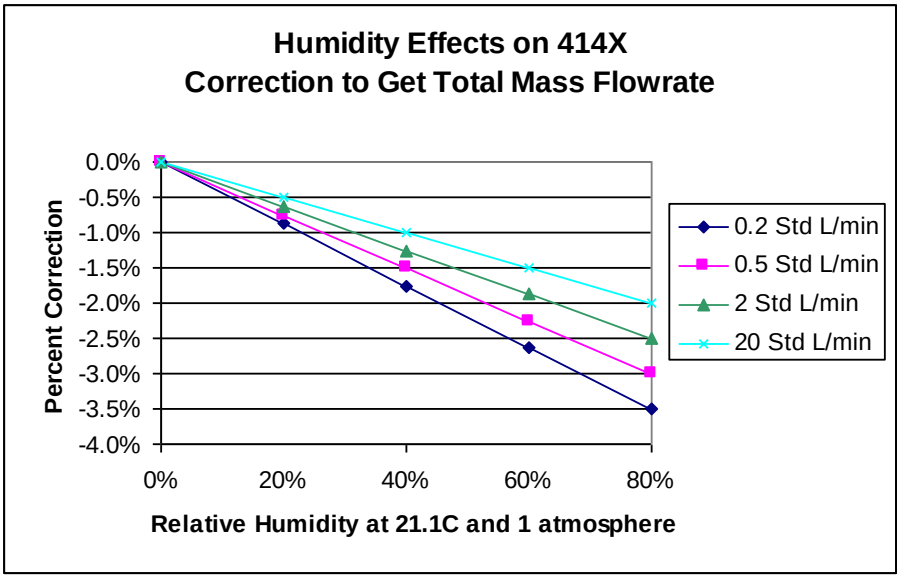


Model 414x Flowmeters–Humidity Correction to Total Mass Flow Rate

Use the following graph if you are interested in measuring the total mass flow including the water vapor mass.

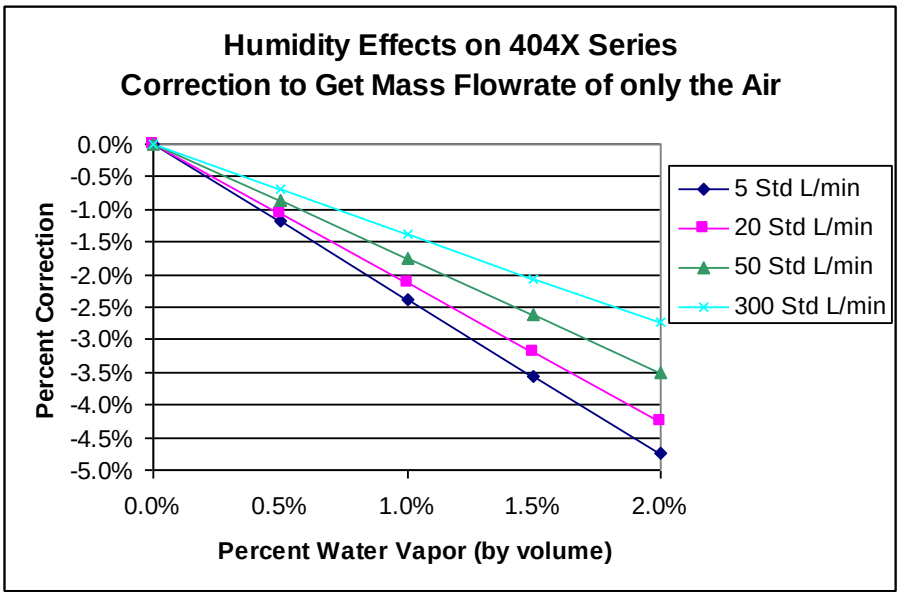


Example Conditions

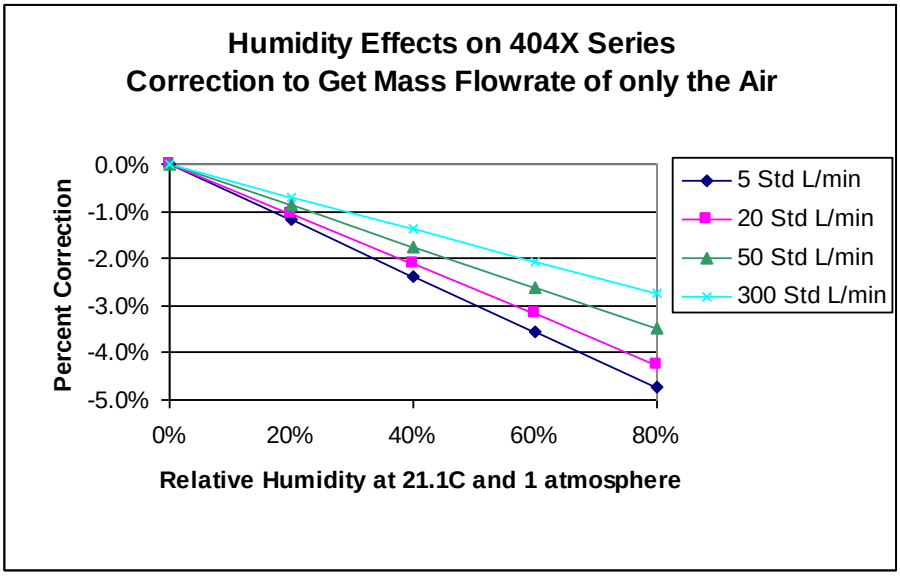


Model 404x Flowmeters–Humidity Correction to get Air Flow Rate

Use the following graphs if you are interested in measuring the *mass flow of just the air*, not including the water vapor. Most of the correction is due to the added mass of the water vapor.

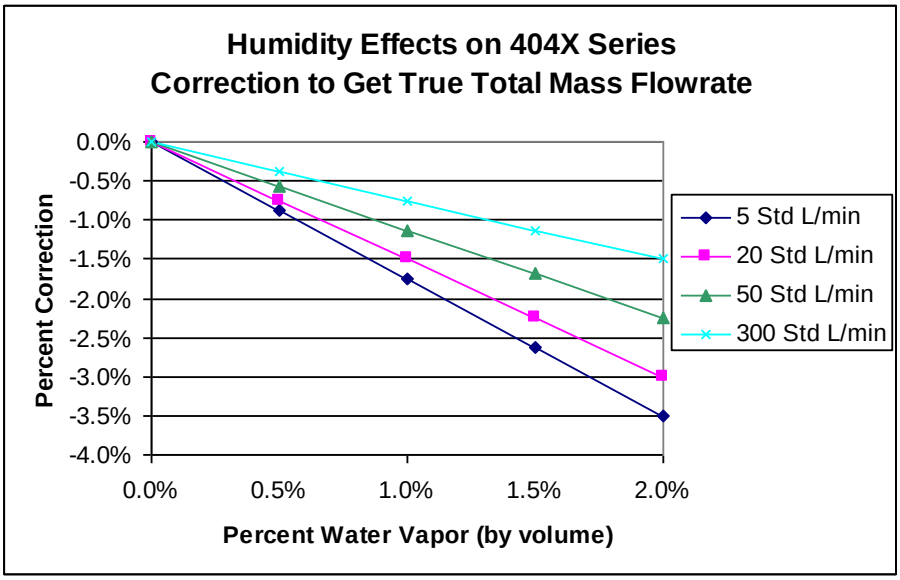


Example Conditions

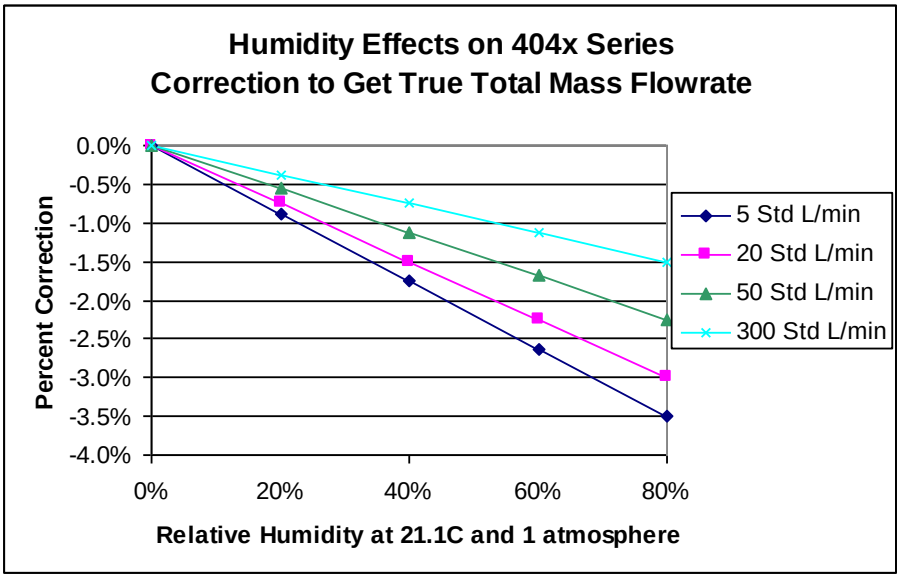


Model 404x Flowmeters–Humidity Correction to Total Mass Flow Rate

Use the following graph if you are interested in measuring the total mass flow including the water vapor mass.



Example Conditions



UNDERSTANDING, ACCELERATED

TSI Incorporated – Visit our website www.tsi.com for more information.

USA	**Tel:** +1 800 874 2811	**India**	**Tel:** +91 80 67877200
UK	**Tel:** +44 149 4 459200	**China**	**Tel:** +86 10 8251 6588
France	**Tel:** +33 4 91 11 87 64	**Singapore**	**Tel:** +65 6595 6388
Germany	**Tel:** +49 241 523030		

FLOW-001 Rev. D

©2013 TSI Incorporated

Printed in U.S.A.