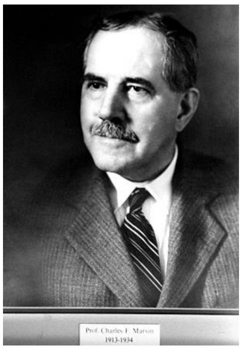
How to measure moisture of a gas by wet bulb temperature

Pyroprocessing
Grinding

Introduction

- In order to accurately calculate an industrial gas flow, the following parameters must be determined:
  - Cross Sectional Area
  - Temperature
  - ***Gas Density***
  - Gas Velocity
- In order to accurately calculate the density of a gas one must be able to determine, among other parameters, the chemical composition of the gas which includes its moisture content.
- The "Wet Bulb" measurement along with a standard gas temperature measurement ("Dry Bulb") is used to determine moisture content.
- The Wet Bulb temperature is defined as the temperature of adiabatic saturation.
- This temperature is measured using a standard mercury-in-glass thermometer or a fast acting thermocouple.
- The thermometers mercury bulb, or the thermocouples junction is wrapped tightly in muslin (cloth), fastened securely, and then soaked in distilled water and maintained wet. The adiabatic evaporation of water from the cloth when exposed to the measured gas stream has a cooling effect, so the temperature is typically less than the temperature indicated by a dry-bulb measurement. The exception to this is when the relative humidity of the gas is 100%, in which case the temperatures will be identical. I.e. the air is at saturation.
- The rate of evaporation from the wet-bulb thermometer therefore depends on the humidity of the gas in the measured stream. Evaporation is slower when the gas is already full of water vapour and higher when the content of water vapour is low. It is this principle that allows us to determine the moisture of a gas based on the difference of these two measured temperatures.



- 1858 to 1943 a US meteorologist by the name of ***Dr. Charles Frederick Marvin*** established the relationship of wet bulb and dry bulb measurements for relative humidity determination. His original humidity tables are still a standard today and are better known as the psychometric charts.
- Psychometric charts, Microsoft Excel add-ins, and other developed tools are used to determine gas moisture from the wet and dry bulb temperatures.
- The measurement is not suitable for extremely dusty or low velocity gas streams
- This measurement is normally conducted by Process Technicians and Engineers

Safety aspects

- Be aware that casing temperatures and internal gases may be ***extremely hot*** and during periods of process instability may become positive. Verify circuit stability with operations prior to measurements.
- Consider the use of fast acting thermocouples over mercury in glass thermometers to reduce the real risk of breakage and exposure to mercury.
- Process measurements often require working on temporary platforms or ladders. Always wear proper fall arrest equipment when working at height and ensure all platforms and ladders are suitable for the task properly assembled and in good condition.

- Measuring equipment removed from the process after the measurement has been taken, can pose a burn hazard if hands are not protected in high temp applications.
- Be certain that all hand tools are properly secured when working at height to ensure they do not create a hazard for those below if accidentally dropped.

Prerequisites

- Familiarization with the circuit in order to ensure air and material flow direction / measuring locations.
- All portable measuring equipment used for process evaluations must be properly calibrated to ensure the accuracy of results. A regular schedule of verification / calibration of all process equipment should be implemented based on the manufacturers recommendations.
- A formal hazard assessment should be initiated and documented for all areas that poses or could pose a danger to the employee during the execution of the measuring activity due to the nature of the location.

Time frame

- The time required to complete this measurement is relatively short. Factors affecting this could be the size of duct work that may cause potential stratification of temperatures requiring a temperature traverse to ensure accurate results.
- Generally the procedure should be completed in a matter of minutes once the initial set up is complete.

Tools

- Digital thermometer and fast acting thermocouple
- Mercury in glass thermometer
- Muslin or other cloth wrap
- Distilled water
- Additional tools required to complete this procedure may include Psychometric charts
- Lafarge developed spreadsheets for airflow calculations
- Standalone excel add-ins configured and installed for moisture determination based on Wet and Dry bulb results.

Action Steps

1. Preparation: determine a suitable location for the gas temperature measurements

- Always attempt to measure on the clean side of the process whenever possible (after dust collectors ESP's Cyclones)
- Verify the airflow velocity to ensure that it is a minimum of 2.5 m/s.
- Once the general location has been identified, select a specific section of ductwork that will give as laminar a flow as possible following the standard process guidelines for optimum measuring locations. Realize this is very often a significant compromise.
- Determine the size and number of sample points required and if the location has potential for other measurements.
- For locations previously installed, check to ensure that they can be opened and that the measuring hole is clear of build up or other obstruction.

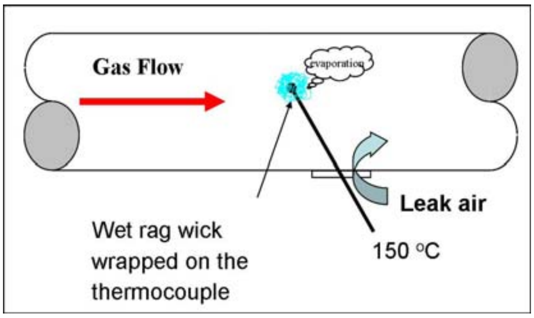
2 Determine standard gas temperature (dry bulb) for measuring location

- In order to determine the moisture of a gas we must have both wet and dry bulb temperatures. Follow steps outlined in the procedure below in order to accurately determine the dry bulb temperature for the specific location:

  How to measure gas temperature by thermocouple

3 Determine wet bulb temperature

- Assemble all of the equipment required to safely access and execute the measurement at the specific location.
  - Hand tools / Safety Equipment / Radio/ Light
  - Process Equipment – Digital thermometer – thermocouple, mercury in glass thermometer, muslin wrap or cloth, distilled water, audit sheets.
  - Contact the control room if taking the measurement has the potential to cause a process disturbance.
- Install the muslin wrap over the end of the thermocouple junction or the glass bulb of the Mercury thermometer.
- Soak the wrap in the distilled water until saturated.
- Determine the direction of gas flow and insert the thermocouple probe into gas upstream and seal the hole as much as possible to prevent in leakage.



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Action Steps

- The wet bulb temperature is recorded when the temperature reaches equilibrium.
- Insert temperature results of both dry and wet bulb measurements into airflow spreadsheet, add-ins or use appropriate Psychrometric charts to determine the moisture content of the gases.
- In the case of a Psychrometric chart:
  - Find wet bulb temperature on saturated line on left hand side of chart
  - Follow adiabatic saturation line at wet bulb temperature until it intersects with vertical line corresponding to dry bulb temperature
  - From this point follow horizontally to right hand scale and read relative humidity of gas in g water / kg dry air.

Appendix

1. Example

- The example below shows air with a wet bulb temperature of 30°C and dry bulb temperature of 50°C – result 18.6 g water / kg dry air.

Psychrometric Chart