Steam
Quality, Sampling and Analysis

A Review of
Requirements, Methods
and Special Considerations

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Steam Quality and Purity

Many individuals use the terms Steam Quality and Steam Purity interchangeably. This is not strictly correct. Steam Quality refers to the amount of steam that is actually water vapor, while Steam Purity refers to the amount of *all non-water* components contained in the steam.

Steam Purity is usually, expressed as the number of parts (generally parts per billion, sometimes in gross impurity situations parts per million) of impurities. Steam Quality is expressed as a percentage by the following equation:

$$\text{Quality} = 100 - (\text{solids in steam} \times 100)/\text{solids in boiler water}$$

For example, if the steam contains 25 percent moisture, it is said to be of 75 Percent quality. Obviously from the equation for Steam Quality it can be seen that to accurately determine the Quality, the Purity must be known. For approximations of quality, calorimetry is applicable and measures steam quality directly, but the limitations of calorimetry as well as developments of other technologies have made other methods more popular, particularly where absolute quality monitoring is critical.

The first step in obtaining Steam Purity or Quality is the acquisition of a steam sample. This is not a trivial matter, and requires detailed research, calculation and mechanical work. Specifications exist which ennumerate all the requirements for performing this function. The ASTM Designation D-1066-82 is probably the most widely utilized of these industrially (other specifications include ASME PTC19.11). The specification requires a "sample nozzle" for representative sampling of the steam flow via sample ports drilled in the side of the nozzle facing the steam flow. The nozzle must be properly placed in the steam piping so as not to be interfered with by bends or fittings. The flow of sample must be carefully monitored and related to steam flow so as to provide "isokinetic" sampling. This ensures the proper amount of steam is flowing through the sample ports to correspond with the steam flow in the line and the area of steam line sampled by a given port. The sample must also be carefully cooled so as not to allow the deposition of any impunities within the sample line which would cause substantial errors in the determination.

The procedure is even more involved for superheated and pre-superheated steam samples, making adherence to the ASTM or other designated sampling method specification extremely critical.

Methods of Steam Analysis

Methods of analyzing the sampled steam include, but are not necessarily limited to:

Sodium Analysis - Ion Specific Electrode
Sodium Analysis - Flame Photometry
Sodium Analysis - Ion Chromatography
Specific Conductivity
Calorimetry -Throttling Type
Calorimetry - Separating Type
Gravimetric Analysis

Some of the advantages and disadvantages of each are reviewed below:

Sodium Analysis - ISE Technology - Provides Immediate Results
Can be Continuously Monitored and Recorded
Good Accuracy

Sodium Analysis - Flame Photometry - Lab Verifiable
Can be Recorded Continuously
Can be Very Accurate

Sodium Analysis - Ion Chromatography - Lab Verifiable
Properly Run can be Very Accurate Can be used to Verify Other Methods

Specific Conductivity - Most Flexible Method
Influenced by Dissolved Gases and Volatiles Less Accurate than Sodium Methods Can be Reliable if Related to More Accurate Methods Usually Limited to TDS In Excess of 0.5ppm

Calorimetric - Gives Instantaneous Results
Least Accurate Method Available
Not Applicable Above 600 psi
Not Applicable At Extremely Low Moisture Contents (Less Than 1 %)

Gravimetric- Requires Large Sample Sizes
Requires Accurate Steam Flow Measurement
Will Not Detect Spikes in Impurity (Moisture) Content
Does Not Provide Real-Time Results

In cases where documented, verified results are extremely critical, Sodium Analysis (usually by ISE or Ion Chromatographic technology) has been the method of choice. Coupled with a recorder (or online computer tracking) and verified by independent laboratory sampling and analysis to confirm field calibration of ISE probe and/or ion monitoring equipment.

Field analysis for non-critical use (i.e. when it is for in-plant information as opposed to a conflict between parties who differ in opinion) usually consists of verified conductivity analysis, which can be done continuously or on-line, and can be verified at the outset using any of the more precise methods mentioned.

The Methods of Steam Analysis in Summary

Sodium Analysis

In determinations using sodium content, the assumption is that by using the ratio of sodium in the produced steam to that in the boiler water, the moisture content of the steam can be determined. (See formula on page 1.) Variables that must be taken into account in verifying this assumption include but are not necessarily limited to:

Interferences of the analysis technique introduced by water treatment chemicals (potassium interferes with sodium ion analysis for example)

Calibration and maintenance of monitoring equipment

Temperature of sample and its effect on analysis

Ion Specific Electrode

A representative condensed steam sample is contacted with an ion-specific electrode either in-line or after grab sampling (preferably in-line). The electrode (or probe) sends a signal to a meter which measures the signal and relates it to a calibration curve for that ion.

This technology is very similar to pH measurement in that there is a probe used that appears to be similar to a pH probe that sends a signal to a meter device (like a pH meter). The difference is that rather than a pH sensitive membrane in the probe, one which is selective to the ion which is being measured (Sodium in our case) is in the probe. The membrane monitors the number of sodium ions which it contacts and thereby measures the sodium ion content of the sample. The probe can be installed in-line and thereby can monitor, display and record real-time results. Maintaining calibration is important, and following the manufacturers recommendation with respect to cleaning and calibration procedures and frequency is the minimum required to accomplish this.

Flame Photometry

A representative condensed steam sample is injected into an Oxygen/Hydrogen flame, which vaporizes the liquid phase and excites the Sodium atoms, causing an emission of yellow light of specific wavelength. The intensity of the yellow emission is proportional to the amount of Sodium in the sample stream and is measured spectrophotometrically. By comparing the emission to that of a sample of know Sodium content, the amount of Sodium can be accurately determined.

Ion Chromatography

A representative condensed steam sample is passed through High Temperature, Highly Pressure Tolerant Ion Exchange Resin where the Sodium Ions are contained until later analyzed for. This method is often used to verify the readings found using other perhaps less precise methods which are much easier to run in the field (like conductivity).

Specific Conductivity

A representative condensed steam sample is measured, usually using continuous monitoring methods (but sometimes grab samples - provided the sample is handled properly), for electrical conductivity. It is usually best to conduct the analysis on a de-gassed sample since dissolved gasses can be a major contributor to the conductivity reading. This method is usually verified using one of the more precise methods available.

Calorimeters

Throttling Type

A representative condensed steam sample flows through an oriface of size determined by Napier's Formula:

$$S = P \times A \times 360/7$$ **where**

S is steam flow, lbs/hr
P is Absolute Steam Pressure, psia
A is orifice cross sectional area, in^2

This gives a fixed sampling flow rate. The pressure drop from steam line pressure to atmospheric through the orifice causes a release of energy which will cause any moisture in the sampled steam to be vaporized. The energy remaining after vaporization can be measured by monitoring an increase in steam temperature. With the measured temperature above boiling at atmospheric (212°F), the excess heat of the sampled steam can be calculated:

Moisture Content = ((B - b - K(T - t))/LH) where

B is heat of steam at steam line pressure (saturated), BTU
b is heat of steam at calorimeter pressure (saturated), BTU
K is specific heat of steam at calorimeter pressure, BTU
T is superheat temperature of steam in calorimeter t is saturation temperature of steam at calorimeter pressure
LH is Latent Heat of Vaporization at steam line pressure

Separating Type

A representative condensed steam sample is forced to undergo directional changes which induce the heavier non-vaporous particles to drop out of the vapor phase. The liquid phase is collected for measurement, and the vapor phase is passed to a Throttling Type Calorimeter. The measured non-vapor phase is matched to the vapor phase analysis via the Throttling unit and the steam flow during collection. A resulting moisture content can be determined using the mass ratio from the Separating unit and the Moisture content from the Throttling unit. (See Gravimetric)

Gravimetric Analysis

A representative condensed steam sample is evaporated to dryness and the residual is weighed. This method can be run continuously or batchwise, but has the disadvantage of requiring a large sample volume, particularly if the amount of impurities is very low.

Where to Go For More Information

Steam Sampling

ASME Performance Test Code 19.11, *Water and Steam in the Power Cycle* American Society of Mechanical Engineers
345 East 47th Street
New York, NY 10017

ASTM Standard D1066, *Standard Practice for Sampling Steam* ASTM Committee on Standards
1916 Race Street
Philadelphia, PA 19103

Analytical Methods

Ion-Specific Electrode Analysis
Waltron, Ltd.
50 Tannery Road Whitehouse, NJ 08888
1-908-534-5100

Ion Chromatography
Dionex Corporation
P.O. Box 3603
Sunnyvale, CA 94088
1-408-737-0700

Calorimetry
Cal Research, Inc.
4271 Dickersonville Road Ransomville,
NY 14131
1-716-791-4206