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A technical memorandum concerning your Streamline FTS - principles, calibration, accuracy and traceability.

Chinook Engineering wants those who use the Streamline™ Flow Transfer Standard to be familiar with their flow measurement device. To that end we have prepared this technical memorandum concerning the Streamline's principle of operation, and how Streamlines themselves are calibrated. Detailed instructions for using the Streamline are included elsewhere in your documentation packet.

Bernoulli's Theorem & the Streamline FTS:

The Streamline FTS is an orifice type flowmeter. The mathematical relationship which relates the volumetric flow rate through the device to the pressure drop which develops across the device is modeled after Bernoulli's Theorem. Orifice type flowmeters provide accurate, robust flow measurements at reasonable cost. They have been in wide use for over a century, and their usefulness and application is well understood.

In Bernoulli's model, the volumetric flow rate through an orifice is proportional to the square root of the pressure drop across the orifice, and the fluid density. For ambient air, a measurement of ambient temperature, pressure and the pressure drop across a Streamline can thus produce a measurement of volumetric flow rate.

Bernoulli's model makes assumptions regarding fluid compressibility, viscosity and frictional effects. In most gaseous situations the ideal gas law is assumed.

In reality, friction introduces non-ideal behaviors in Bernoulli's model. These non-idealities can be accounted for with parameters known as inlet and outlet "discharge coefficients", "friction factors" and "expansion factors" which are empirically determined.

The exact geometries and hence flow pathways of every orifice type flow meter are unique. Rather than relying on empirically derived performance characteristics, it is a better practice to "calibrate" orifice flow meters against another flow apparatus, a "primary standard" of well characterized repeatability and accuracy. Each flow meter is thus calibrated against a primary standard through a range of expected flow conditions. Each Streamline is calibrated against an NIST traceable "primary" flow apparatus.

Using Bernoulli's model, such calibrations can produce unique linearized calibration constants for each flowmeter ("m" and "b") which relate flow through the device to the square root of the pressure drop.

As the calibration and QA data included with your Streamline show, its performance very closely approximates Bernoulli's model through its calibrated range of flow, but not perfectly. The QA criteria Chinook Engineering uses is that no calibration point(s) will exceed ±2% of a least squares fit of flow rate versus the square root of the pressure drop.

Sonic Nozzles as Primary Flow Standards:

Every Streamline Flow Transfer Standard is calibrated against primary flow rate standards known as a critical flow venturis (CFVs), or "sonic nozzles".

- ***What are "sonic nozzles". Why use them…?***

Sonic nozzles are converging-diverging nozzles. A smoothly convergent nozzle has the ability to deliver a compressible fluid (like air) up to the velocity of sound in its minimum cross section or "throat". Super-sonic velocity is then be produced in the diverging section downstream of the throat. When sonic velocity is achieved in the throat, the mass flow rate through the nozzle is a function only of upstream pressure and temperature. By varying the pressure upstream of a convergent-divergent nozzle, one can predictably vary the mass flow rate through the nozzle. Knowing the temperature and pressure upstream of the nozzle allows conversion to volumetric flow rates.

Due to supersonic conditions, CFVs produce very stable flow, a highly desirable characteristic in a flow rate standard. The reader is referred to References (2) and (6) for a thorough treatment of sonic nozzles.

Due to their applications in aeronautics and rocketry, supersonic flow, and converging-diverging nozzles have been extensively researched and characterized, especially for air, over a wide variety of conditions.

Due to their highly stable nature and comprehensive characterization, CFVs are well accepted as repeatable, highly accurate flow meters. CFVs are expensive, so are often used as flow rate "primary" or "reference" standards against which other flow rate meters are calibrated. Devices calibrated against such primary standards are referred to as "transfer standards", hence Streamline Flow Transfer Standard.

Following consultation with the National Institute of Standards and Technology's Fluid Flow Group in Gaithersburg, Maryland USA, Chinook Engineering selected CFVs as the primary flow standards against which all Streamlines are calibrated.

Unique nozzles were manufactured for Chinook, and NIST traceable calibrations were performed on them (using sonic nozzle transfer standards, which are calibrated against NIST traceable primary mass and time standards). Chinook's sonic nozzles were then incorporated into a stable, accurate flow calibration apparatus, all components being NIST traceable.

All Streamline FTS calibrations are therefore directly traceable to NIST flow rate standards, rather than volumetric or dimensional standards, as are many other flow rate measurement devices. The sonic nozzles used by Chinook Engineering are NIST traceable mass flow rate standards, with an estimated accuracy of ±0.5% (95% confidence).

Your Streamline FTS is a Superior Flow Rate Measurement Device for the Measurement of Ambient Air:

The inherent and patented advantage of the Streamline FTS lies in the materials of which the device is fabricated.

When your Streamline was calibrated against a sonic nozzle standard, at laboratory conditions, the orifice element in the Streamline provided a calibration relationship based on the specific geometry it had at those laboratory conditions.

If the Streamline's geometry were to change, say with temperature, so would the device's calibration. However, because of the materials of which it is constructed, the physical dimensions of the Streamline change infinitesimally with temperature. As such, its performance and calibration do not change with changes in air temperature (or barometric pressure for that matter).

Other flow rate measurement devices can expand, contract or distort when used at conditions other than those at which they were calibrated, providing unreliable flow rate measurements away from the lab. This situation is at its worst when the flow rate measurement device relies on polymeric, metallic, or combined materials, which have high and/or variable thermal expansion properties.

Further, many commercial flow rate measurement device's calibrations are based solely on NIST traceable standards for volume (that is, traceable to physical dimensions), not NIST traceable standards for flow rate.

EPA Tested:

The US EPA tested the Streamline FTS over a range of ambient conditions (1.) Their testing showed that the Streamline provides accurate flow rate measurements through a range of ambient conditions with an estimated maximum error of ±0.8%.

⇒ The result of the above discussions is that a properly calibrated Streamline FTS will provide accurate, dependable, NIST traceable flow rate measurements, over all ranges of ambient conditions. With an integral wind screen, robust, easily cleaned design, and a protective case, the Streamline FTS is the definitive instrument for flow rate measurements for ambient air samplers, in the field or in the lab.

⇒ ***Streamline™ FTS –accuracy and performance based on first principles, and NIST traceable for flow rate.***

Questions? Other Applications?

Streamline technology lends itself to a variety of gas flow applications, especially those in which the fluid temperature changes. If you have other flow rate measurement applications that need a better solution, or have additional questions about the Streamline FTS, contact Chinook Engineering at *chinook@warmwind.com*, (307) 672-7790.

A Note on Auxiliary Instruments Used with Streamlines

Reliable instruments should be used for collecting the associated measurements for determining flow rate with a Streamline- ambient pressure and temperature, and pressure drop across the Streamline FTS. Many end-users take measurements with electronic manometers, thermometers and barometers. While convenient, electronic instruments can drift with changes in temperature.

Chinook Engineering recommends that electronic instruments be used near room temperature. A shirt pocket is a good place to keep your electronic instruments when in the field, and if applicable, always zero the instruments immediately prior to use. Do not leave these electronic instruments on a dash board, or in a trunk for extended periods.

As discussed earlier, the Streamline itself is unaffected by temperature.

A Note on Calibration Constants:

Why is my Streamline's intercept "b") not zero"? Bernoulli's Equation, and our intuition, suggests that zero flow through an orifice should produce zero pressure drop across such a device.

Your Streamline FTS calibration which relates volumetric flow rate versus pressure drop is very linear through its calibrated range. However, when the calibration is fit to a linear form for ease of use, the line will generally not extend, or extrapolate to zero flow. Frictional factors change at very high and low flow rates (Reynolds Numbers). Your Streamline is sized and calibrated to operate in a regime of constant frictional parameters, which your calibration confirms. DO NOT USE YOUR STREAMLINE OUTSIDE ITS CALIBRATED RANGE. If you need calibrations in other ranges, contact Chinook.

References:

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