Modern Technology Closes the Gap caused by the Deficiencies in Traditional Analog Air Sampling Instrument Technology

Smart air sampling instruments can reduce, minimize and often eliminate the deficiencies of traditional analog air sampling instruments at a time when the industry needs maximum credibility on health and safety issues in preparation for the resurgence of commercial nuclear power plant construction on a worldwide basis.

The rapid evolution of microprocessor technology since the mid 1980s has revolutionized the world of computers to plateaus unimaginable at that time.

This same evolution of technology is making its impact upon the world of air sampling and air monitoring applications. For most of the 20th century, the air sampling technology revolved around devices for the measurement of differential pressure (DP), such as orifices, venturis, laminar-flow elements, etc. In many cases, these devices were coupled to analog DP gauges that were calibrated in units of flow to the desired measuring range. Typically, DP measurement gauges, such as magnehelic or pressure gauges, were utilized for this purpose. They reported flow rates at the actual temperature (T) and pressure (P) conditions existing in the flow measuring device.

During the second half of the 20th century, the nuclear industry accepted flow rate accuracies for field air sampling instruments as liberal as 20% of conventionally true values (CTV). Usually, the analog laboratory quality calibration instruments utilizing these principles had accuracies, at their best, of ±5% Full Scale (F.S.).

Generally, the size of these analog devices made them suitable for fixed-station air sampling systems that usually had an adequately sized enclosure. Variable area rotameters, which were available in small dimensional footprints, were the devices of choice for portable air sampling instruments.

The industry has recognized deficiencies in the analog flow measurement systems, including the following:

(a) Field instruments utilized in air sampling were very inaccurate as com pared with laboratory instruments.

(b) Flow measurement accuracy was impacted by the variations in tempe ature, which depended on the location of the sampling stations. Temperature varies between day and night, from day to day, season to season and more importantly, is not universally comparable on a worldwide basis.

Inaccuracies from a reference temperature condition could be as high as ±5% when comparing a summer sample event with a winter sample event

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(c) Flow measurement was impacted by the variable absolute pressure existing in the location of the analog sample system flow measurement device. Absolute pressure at the analog flow measurement device depends on (1) the local barometric pressure at the sample location (elevation related), (2) the filter collection media pressure drop, (3) the pressure drop due to the air circuitry design, (4) the pressure drop due to daily barometric pressure variations and (5) dust loading, if applicable.

The resulting effect is that flow measurements made with analog flow meter at two different sample locations or two samples taken at the same sampling location at different times are not truly an apples-to-apples comparison. Normalization of flow, measured at different absolute pressures to an industry-agreed reference point, must be applied in order to have a valid comparison of the flow rate and the accumulated sample volume calculated from the flow rate value.

Inaccuracies from a reference pressure condition, such as 1 atmosphere, could be as much as 20 – 30% depending on the magnitude of the absolute pressure value obtained from the analog flow measurement device. As far as accuracies are concerned, the absolute pressure impact is more important that that resulting from temperature variation.

(d) In air sampling, the main objective is to determine the total volume, which passed through the collection medium during the sampling event. To do this, one would simply multiply the average flow during the sampling event by the duration of the sampling period. The duration of the sampling can be measured with relatively good accuracy. However, how does one accurately determine the average flow rate of the sampling event when it fluctuates with daily temperature changes and with changes in pressure drop due to daily changing barometric pressure and dust loading, if any?

For technician-attended short-duration sampling at a specific site, this is a minor issue. For long-term remote unattended sampling, this can be a source of large error in the volume determination of the sampling event, where data comparison among industry members is one of the objectives.

What is the impact upon volumetric activity determinations? The objective of determining the total volume passing through the collection filter media is generally for purposes of determining volumetric activity of radioactive pollutants, such as Bq/m^3 of gross β- γ or Bq/m^3 of specific isotopes.

Radioactivity measurements performed in the laboratory on the filter media are predominantly reported to accuracies stated to the 95% confidence level.

Combinations of radioactivity measurements, which are collected on the filter media and have a known industry standard accuracy, and a volume determination of unknown accuracy for a weeklong sampling event, may have an error as high as 30 – 35%. The probable error at best can only be estimated. This dilutes the accuracy of the radiochemical analyses performed on the filter media, as well as any downstream calculations derived from volumetric activity. Dose rates calculated from these volumetric activities may also involve a significant error.

What is at stake?

Credibility is at stake when air sampling/air monitoring events among industry members are compared regardless of their location or the air sampling equipment employed.

In order to accurately compare air sampling/monitoring measurements of all industry members properly, a reference point for pressure and temperature conditions must be established, at which all industry members normalize their volume determinations derived from variable absolute pressure and temperature conditions at their flow measuring devices. This is supported scientifically by the Ideal Gas Laws (Charles' Law, Boyle's Law, Avogadro's Law, etc). The volume of two different gases can only be compared properly at the same temperature and pressure conditions.

Four such reference T and P conditions are prime contenders for an industry standard:

Classical Standard T and P	(STP)	0ºC, 760 mmHg
Normal T and P	(NTP)	20ºC, 760 mmHg
Modified Normal T and P*	(MNTP)	21.1ºC (70ºF), 1 ATM
Standard Ambient T and P	(SATP)	25ºC, 760 mmHg

* Primarily USA reference standard

The selected reference conditions are irrelevant. The commitment of industry members to correct measured volumes to an industry accepted reference is highly relevant. Comparing air monitoring data and dose calculations derived from air sampling/monitoring data among all industry members that represent many different elevations, climatic conditions and equipment designs requires the normalization of flow rates to reference T and P conditions.

In other words, the credibility and technical value of inter-comparisons among industry members of the reported air monitoring data and dose estimates derived from their air sampling data are lower than what they should be.

Can modern technological advances provide a solution to compensate or overcome the recognized inaccuracies and deficiencies inherent in traditional analog air sampling/monitoring instruments?

Definitely! Air sampling instrumentation is currently available with microprocessor-controlled electronics having the capability of measuring, correcting, displaying and storing or transmitting real-time flow data to any reference T and P conditions acceptable to all industry members or to subsets of members within the industry.

What are the benefits brought along by this category of advanced-technology instruments?

Firstly, a higher accuracy can be achieved. The current technology enables the manufacture of reasonably priced air flow calibrators having an accuracy of ±1%. Air sampling systems accuracies of 2 to 4% are easily achievable for in-field instruments, including instruments with automatic flow control features. The nuclear industry should be utilizing the Best Available Technology for air sampling applications involving radiation protection.

Secondly, these smart instruments save money because they are more reliable and require less maintenance and less calibration effort. Savings in training costs can be significant where the future work force pool may be lacking a good scientific foundation.

Thirdly, technologically desirable features, such as (1) very accurate elapsed time measurement, (2) data storage for retrieval after the sampling event, (3) real-time transmission of sample data to a central location, (4) on-board calculations of accumulated sample volume, (5) automatic shut off on time or volume and (6) an easily visible digital display on the instrument can all be provided at minimal additional cost.

In an industry that is experiencing an increasing manpower shortage, the automation of air sampling activities has become a wise and prudent business strategy.

All of the world's major manufacturing nations have automated their factories and business offices with microprocessor-controlled technologies. The nuclear industry has wisely employed modern digital electronics in many plant operating systems over the past 30 years. It would be desirable and prudent for industry air monitoring professionals to recommend upgrading their existing air monitoring systems with smart instruments which provide accurate, reliable and comprehensive air monitoring data. For industry management, it is a good, technologically, economically and legally supportable business decision.