The Versatility of Vibrating Element Type Gas Properties Measurement

Industry: Refining
Product: GD40 and GD402

Abstract

Vibrating element type, gas measurement devices are found measuring refinery reformer stream compositions, power generator hydrogen purity, centripetal compressor gas inputs, process heater fuel gas quality and others, in a variety of process control environments. Customers willing to upgrade existing measurement equipment to vibrating element technology, in many cases, achieve better performance, lower maintenance and efficient process control. Plant sites from the companies BP, ConocoPhillips, Georgia Power, and TVA, share examples of versatility and performance of the technology.

Introduction

Vibrating element (VBE) gas measurement technology is a viable alternative to traditional gas measurement methods and a versatile tool for process control. Gas properties analysis is required for many manufacturing processes. Refineries, chemical plants, power plants, pulp and paper mills, and other industries use gas chromatography (GC), infrared (IR), flame ionization detectors (FID), thermal conductivity detectors (TCD) and other technologies to determine process gas properties or gas stream composition. The vibrating element type, gas measurement method is a reasonably matured technology, but only recently has it been called to duty for process control.

Vibrating element type devices are found measuring gas properties in a variety of process control environments. Its

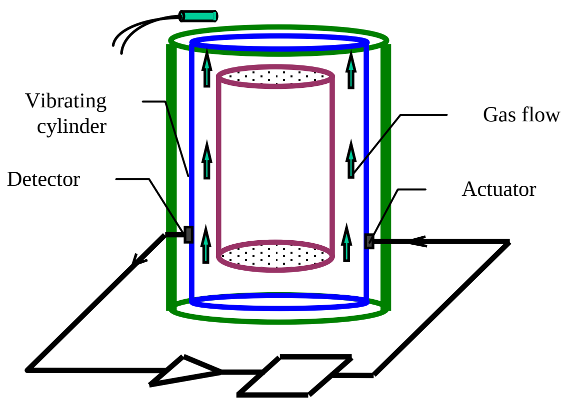

FIGURE 1 – VIBRATING ELEMENT DEVICE, GENERAL

successes are written about in trade magazines such as Mechanical Engineering, Control and Power Engineering. Customers willing to upgrade existing measurement equipment to vibrating element technology achieve better performance, lower maintenance and more efficient process control.

The device works on the general principle that the resonant frequency of a thin wall cylinder will change as the density of the surrounding gas varies. This is also known as the tuning fork method. It is best exemplified in the reaction of the human voice to helium gas. Once inhaled, a person's voice pitch dramatically increases because the helium gas density is much less than air. The person's vocal cords vibrate faster for the same motive force, causing a higher pitch sound. For

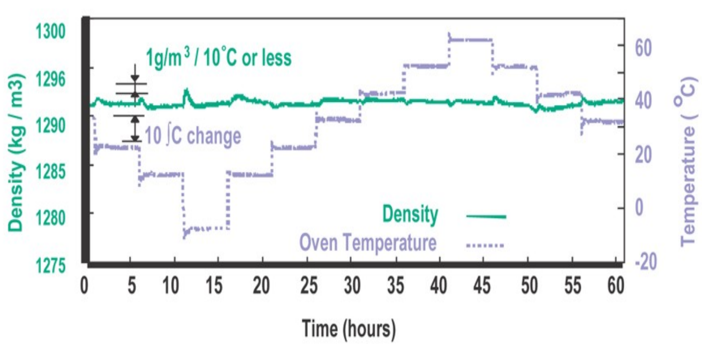

FIGURE 2 - TEMPERATURE RESPONSE TO CHANGES IN AMBIENT TEMPERATURE

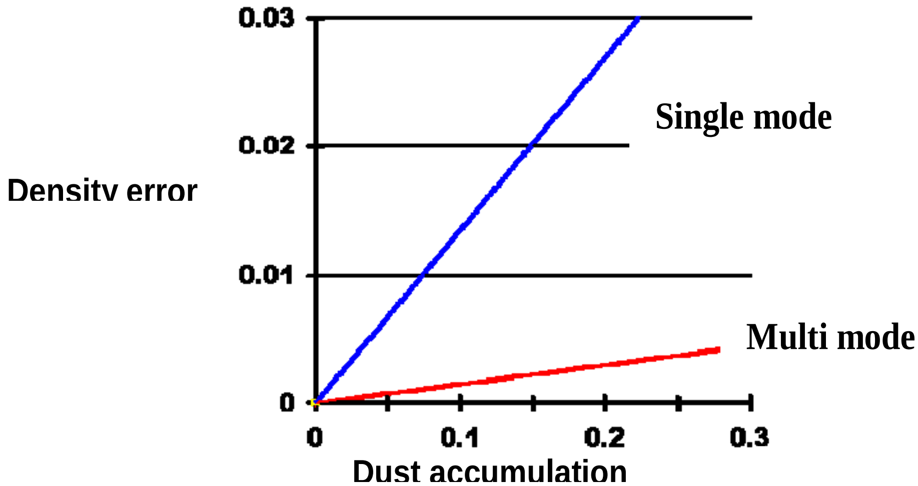

FIGURE 2a – EFFECTS OF MULITPLE VIBRATION FREQUENCY ON SENSOR INTERFERENCE

vibrating element devices, the measurement of the cylinder vibration frequency indicates the density of the surrounding gas. A lighter gas allows the cylinder to vibrate faster.

Piezoelectric elements make the density measurement. One element vibrates the cylinder at two independent frequencies, another measures the resultant vibration frequencies. Gas density is determined from the ratio of the two frequencies. It is important to measure two independent frequencies to maintain accuracy and stability during ambient and gas process temperature changes (Fig 2). The frequency ratio is virtually independent of Young's Modulus and temperature effects on the cylinder material. It is also responsible for the device's resistance to dust, oil or water accumulation on the vibration cylinder (Fig 2a)[4]

Most available devices can output gas density or caloric value. Some can simultaneously output or display multiple parameters including combinations of: Specific Gravity, Density, Caloric value, Molecular Weight, or percent gas concentration (Fig 3). This improved output set increases the versatility of the device to include a large number of applications. The percent gas concentration function is particularly useful for measurements traditionally taken with thermal conductivity devices.

There are many suppliers of thermal conductivity devices. Their products cover a multitude of price and performance ranges. The devices use the thermal conductivity of the process gas stream to cool one side of a Wheat-stone Bridge. The bridge circuit produces more or less output voltage as the thermal conductivity of the gas changes. Generally – thermal conductivity devices require an isothermal environment and stable gas flow rates; many require a constant stream of reference gas. Thermal conductivity devices can be used to measure gas percent concentration, gas density and specific gravity. Some thermal conductivity devices can achieve PPB level gas component resolution and 0.1% reading accuracy.

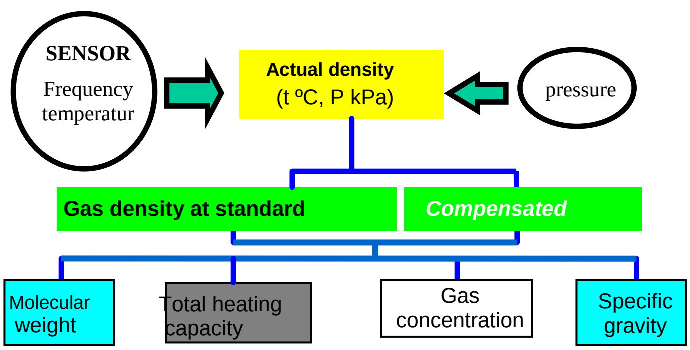

FIGURE 3 – GAS PROPERTIES DERIVED FROM DENSITY

Vibrating element technology is notably suited for field measurement conditions. In contrast to many thermal conductivity devices it does not require reference gas, an isothermal environment, warm up or temperature stabilization time. There is a linear relationship between gas density and the cylinder vibration frequency so calibrations use two (2) off-the-shelf gases. The gas concentration measurement using vibrating element devices, like thermal conductivity, are relegated to binary or pseudo-binary gas streams. The measurement is not species specific for a particular gas in a mixture. The device correlates changes in gas density to changes in gas composition. Measurements for specific gravity or molecular weight are taken directly.

Refineries and chemical plants have a variety of applications for vibrating element technology (Fig.4). Hydrogen (H_2) is a critical element to many of the refinery processes. Hydrogenation, Catalytic reforming, Hydrocracking, and Hyrdotreating are examples where the process yield is dependant on the partial pressure of hydrogen gas (Fig.5). The process efficiency can be compromised and the active catalysts damaged if the purity of the surrounding hydrogen is insufficient. Thus, knowing the process hydrogen concentration is critical to process performance[2,3].

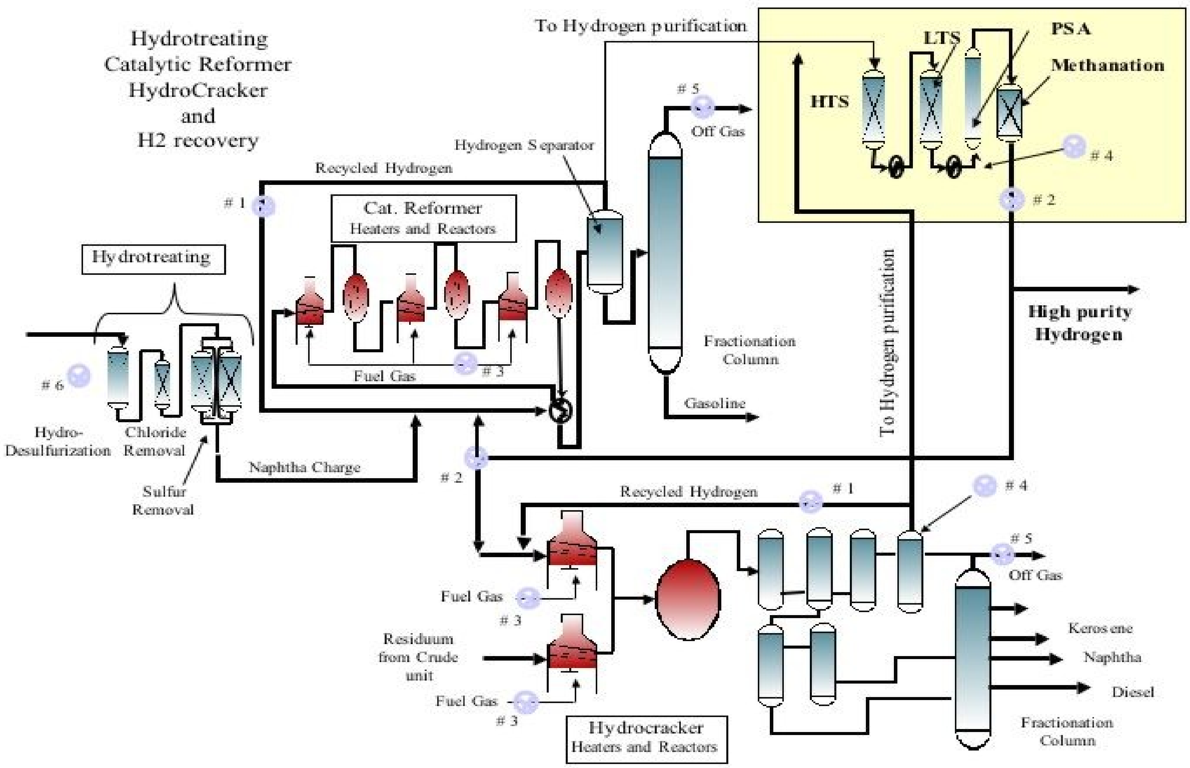

FIGURE 4 – EXAMPLES OF GAS MEASUREMENT LOCATIONS

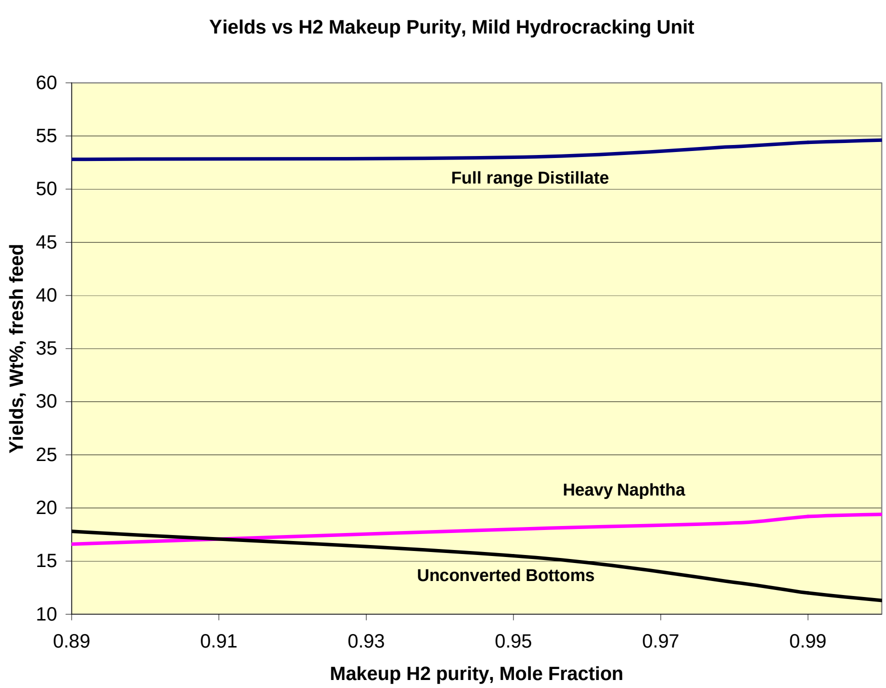

FIGURE 5 – PROCESS PERFORMANCE VS H_2 PURITY

A process engineer for ConocoPhillips, Wood River refinery (IL), explains that hydrogen purity is one key in preventing the loss of catalyst activity on a naphtha reformer [6]. Typically, a catalytic reformer exit stream composition has 75-80% H_2. The remaining background gas is a mixture of Carbon Dioxide (CO_2) and various hydrocarbons. Pure hydrogen gas is mixed with the exit stream to maintain a minimum hydrogen purity level of the exit gas which is returned to the reformer or used as a feed gas to other refinery processes such as a hydrocracking and hydrotreating. The hydrogen gas concentration on Wood River's naphtha reformers is determined from a specific gravity measurement of the hydrogen vent stream from the product separator. The gas specific gravity value is correlated to hydrogen purity and used to control the mixing of exit stream gas with pure hydrogen.

When a thermal conductivity device is used for the reformer hydrogen measurement application, generally it is assumed that the background gas is homogeneous CO2 for the purpose of simple, predictable linearization. The assumption can result in errors as the actual background gas thermal conductivity differs from the assumed value. Some thermal conductivity manufacturers correct for the variety of the background gas by using complex, custom calibration gases. One manufacturer suggests using a seven (7) component calibration gas to compensate for the problem of background gas variation.

Vibrating element technology is preferred in many cases over thermal conductivity for this measurement because of its field adaptability and its ability to compensate for the specific composition of the process background gas. Some vibrating element devices allow the user to program the mean density of the background gas into the gas percent calculation.

There is heightened emphasis on the value of hydrogen and errors in the gas measurement caused by background gas assumptions can be costly.

The Wood River refinery also uses vibrating element devices to correct orifice type flowmeters for changes in fuel gas specific gravity. The correction is important for flow meter accuracy when process changes result in varying fuel gas composition. The refinery uses Foxboro type flowmeters to control fuel mixtures to the plant process heaters. The fuel gas is a composite of refinery tail gas and natural gas (NG). Errors in the flowrate measurements can affect the process heater combustion process; increasing emissions, fuel usage and operational costs (Fig 6). The plants general summary of the two VBE devices installed three (3) years ago is:

> The vibrating element devices work well; better than the previous product. The specific gravity output is a good backup measurement to the plant's gas chromatograph (GC) BTU measurement", is referring to the relationship between specific gravity and fuel BTU value (Fig 7). The VBE devices are faster and more reliable than the GC but not as accurate. A GC has a higher accuracy and can speciate a process stream, but at a cost near four times the cost of a VBE device [5].

Wood River replaced mechanical gravitometers, sighting expensive, extremely complex, 1970's technology and weekly calibration checks as reasons for evolving to VBE devices.

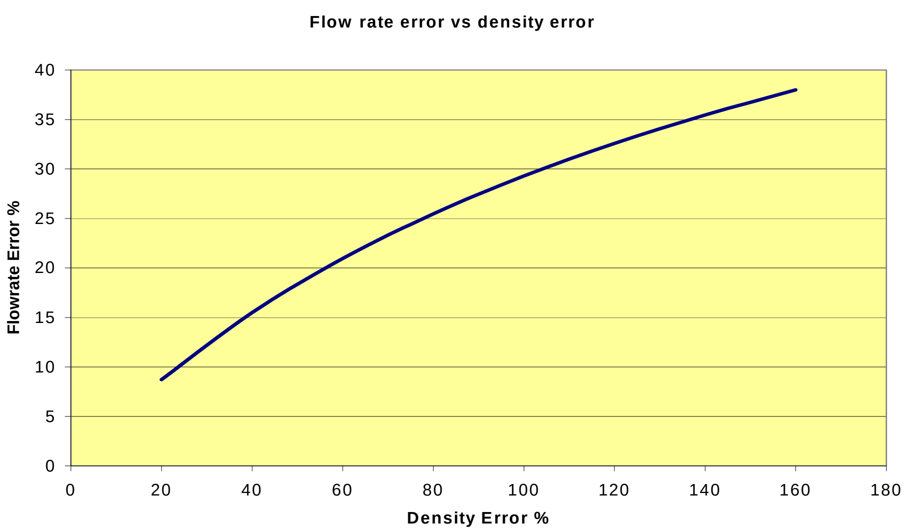

FIGURE 6 – FLOWRATE MEASUREMENT ERROR VS ERROR IN DENSITY

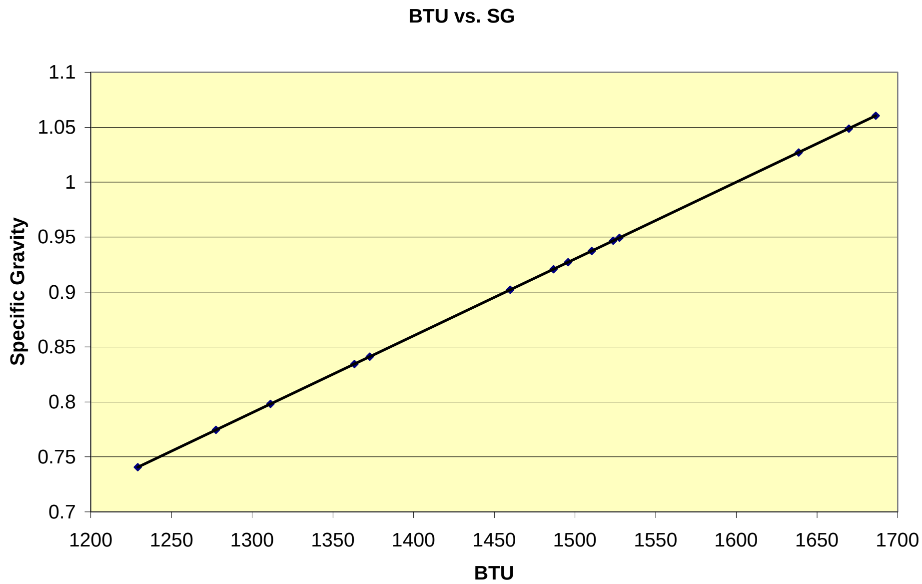

FIGURE 7 – CORRELATION OF BTU TO SPECIFIC GRAVITY

The BP, Texas City refinery (TX) is using vibrating element measurement devices in a similar fuel gas application. The new product replaced mechanical gravitometers, which use purely mechanical means to make the specific gravity measurement. “The old instrument was a nightmare to maintain. It had too many veins, the belts frequently broke, and the accuracy was uncertain. The VBEs are believable, and have temperature and pressure compensation”, says a Texas City, Analyzer Supervisor [7].

Gas compressor surge control is another refinery area where VBE devices are utilized. VBE technology excels in this application because of its resistance to fluid contamination and its fast response time. Thermal conductivity devices advertise 5-40 seconds (T_{90}) response times. VBE devices measure 90% of full scale (T_{90}) in less than five (5) seconds (T_{90}<5s). This is an important distinction when monitoring for sudden process upsets.

A VBE device measures the gas specific gravity (SG) at the inlet to centripetal type gas compressors in many cases. The SG value is used in the compressor control scheme to prevent “free spinning” the compressor when the process gas mixture lightens due to a surge of light hydrocarbons. Two vibrating element devises at Texas City are installed on compressors used in the Coking process. Two VBE devices at Wood River are used on compressors sending recycled hydrogen back to a hydrocracker from a steam methane reformer [5 7].

Both plants agree that the product installations were relatively trouble free and utilized the existing piping and sample systems. It was also agreed that the installation of vibrating element product has reduced the maintenance times and improved the accuracy of the measurements, thus saving their company money and justifying the replacement of the outdated technology.

Another area where vibrating element devices have tremendous support is in the power generation business on hydrogen cooled generators (Fig. 8). Large power generators use pure hydrogen to cool and insulate power generator electical windings. Inexpensive and readily availible, hydrogen is the choice insulator because its low density and high thermal conductivity provide the best environment for generator operation.

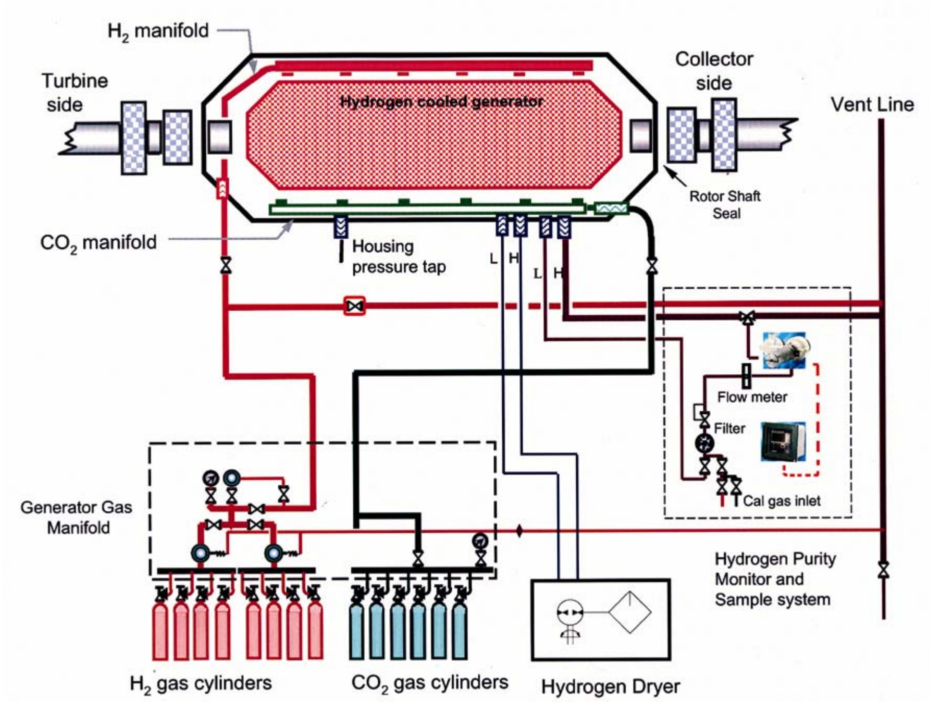

FIGURE 8 -HYDROGEN COOLED GENERATOR VBE APPLICATION

Contaminated H_2 reduces the generator efficiency. The drag on rotating parts increases and the ability to carry heat from the windings decreases as the hydrogen becomes contaminated. Air is the most common contaminate, originating from leaking rotor shaft seals. A 2% change in hydrogen purity can cost thousands of dollars per day in generator operating expenses.

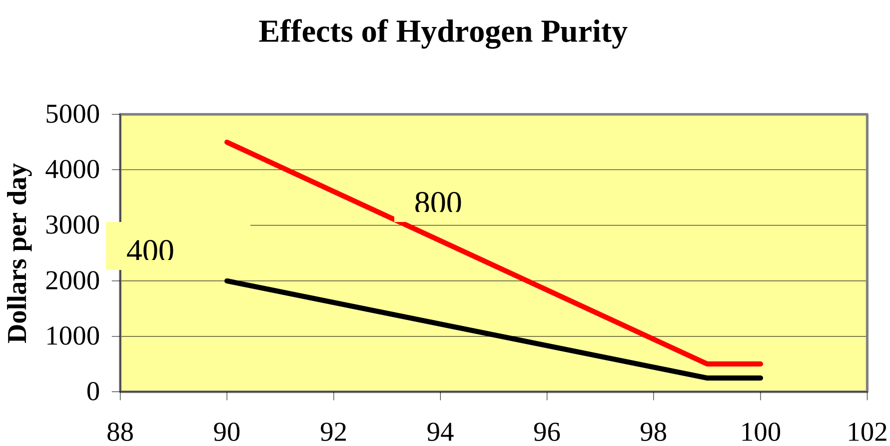

FIGURE 9 – HYDROGEN CONCENTRATION VS. GENERATOR WINDAGE LOSES

Historically, generator hydrogen purity was measured with thermal conductivity or mechanical fan differential devices. Three years ago, Southern Company's, Georgia Power Plant Yates (GA) switched from thermal conductivity analyzers to vibrating element type hydrogen measurement. Plant users site many reasons for the plant wide conversion of seven GE generators totaling near

1300MW. According to the operators, "the thermal conductivity analyzer's accuracy was suspect and generally unreliable". They had difficulty calibrating the thermal conductivity instrument, and as a result could not trust the measurement. "Verifying the accuracy of the old unit was difficult because we could not get support from the vendor… high quality service is the bottom line".

The plant Yates operators went on to discuss reasons for choosing the vibrating element technology. Operators appreciated the simple replacement of their old thermal conductivity systems. They discussed the speed of calibration, "it takes me longer to walk down to the analyzer than it does to calibrate it" says a Yates technician.

TVA, Kingston fossil plant (TN) decided to upgrade their hydrogen gas purity measurement. Kingston replaced nine (9) thermal conductivity analyzers with vibrating element devices. The analyzers are used to measure hydrogen gas purity on five (5) GE 200 MW and four (4) Westinghouse 150MW generators. Kingston's Management team evaluated the recommendations and made a decision to replace the existing hydrogen purity meters. The decision to replace the hydrogen purity monitors was due to excessive maintenance and support issues with the thermal conductivity analyzers. The thermal conductivity systems were the cause of excessive maintenance time and manpower expenditure.

TVA reports that the vibrating element product has improved repeatability and lacks measurement drift. The thermal conductivity systems were experiencing drift on the order of 1% hydrogen between calibration intervals. They required biweekly calibrations to stay within the generator operational tolerances for gas purity. The calibration of the thermal conductivity system required a minimum of 8 man-hours. The new products require less than 3 hours to calibrate all nine. The VBEs have been installed for a year. Kingston Plant has been conducting drift and calibration checks on the old preventative maintenance schedule. The schedule has been modified based on the lack of measurement drift [8].

Conclusion

There are instances where traditional gas measurement can not be replaced. The measurement may require it to be species specific, have better resolution or another unsurpassed performance characteristic. But, in many instances of gas properties measurement for density, specific gravity or gas percent concentration, the vibrating element technology is a viable and proven, cost competitive alternative.

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