Technical Publication

Thermal Flow Meters Help Electric Power Plants Keep Their Cool with Hydrogen Gas

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In all electric power generation plants (gas, solar, coal or nuclear), the fuel source of choice heats a large boiler, which creates steam that drives turbine blades to rotate.

The turbine shaft in turn spins magnets inside the generator, which induces an electrical current in a coil of wires *(Figure 1)*.

It's a high-temperature process both in terms of the boilers and steam, but also at the back end of the process where the electric current generates a large amount of heat that must be managed in order to keep the generator's wire coils cool enough to avoid degradation or failure. Depending on the MVA size of the generator, hydrogen (H_2), air or water is typically used to provide cooling.

In all electric power generators, the wire coils will quickly overheat and degrade if they are not continuously cooled during operation. Helping these wire coils keep their cool continuously extends their life, reduces maintenance and unplanned or emergency shut-downs. Hydrogen is the industry's most efficient coolant, particularly for generators (over 100 mW); because hydrogen has a 15 times higher heat/thermal conductivity efficiency compared to air.

The downside of using H_2 as a coolant is that the size of its molecule is 10 times smaller than a nitrogen molecule, for example, and it's combustible too. A typical generator, therefore, has many potential leak paths and small hydrogen molecules are far more likely to find those leak paths. In addition H_2 is lighter than air, and the escaping gas could therefore rise and accumulate in the roof space of the power plant and could create an unsafe fire condition.

Hydrogen Safety

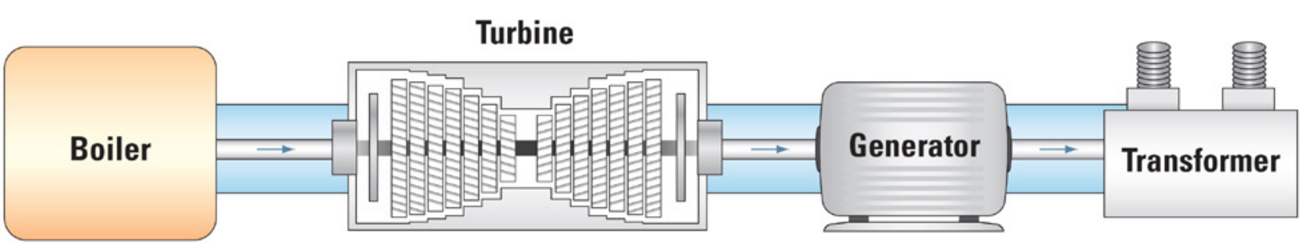
The U.S. Department of Occupational Safety and Health Administration (OSHA) explains, "Hydrogen gas is lighter than ambient air and can concentrate in overhead areas, making it difficult to detect. Because hydrogen gas has a low minimum ignition energy, it can ignite with any small ignition source — even an electrostatic spark from a worker's movement or a tool touching a surface.

> *"In addition, plant operators must continuously monitor the area where the workers are located because hydrogen gas is colorless, odorless, and tasteless, and worker asphyxiation can occur if this gas is not completely purged prior to entering the generator housing or bushing box to perform maintenance."*

H_2 Problems and Solutions

Power plant operators have a known industry acceptable H_2 leak rate, and below this leak rate they assume the hydrogen will be so diluted that it's not causing a hazardous environment. The engineers at an electric power generation plant reached out to Fluid Components International (FCI) to discuss two H_2 measurement challenges with its applications team.

Figure 1: Overview of boiler, turbine, generator, and power output



Problem 1: Hydrogen is stored outside the power plant's turbine area in cylinders, and it flows into a top-up vessel next to the generator *(Figure 2)*. Normally, the leakage of H_2 has been determined at this plant by measuring the pressure of the hydrogen inside the generator.

When the pressure transmitter detects a loss in pressure inside the generator, the control valve opens and H_2 flows into the generator. Plant operators know the volume of the buffer vessel and could calculate the H_2 volume leakage, but due to the very low-pressure measurements required the leakage volume flow calculations weren't always accurate or reliable.

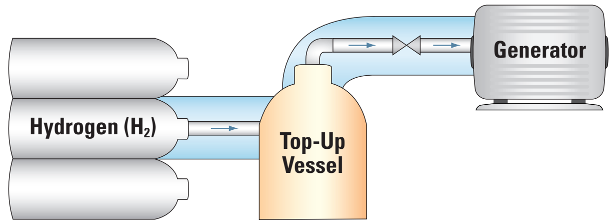


Figure 2: H_2 cylinders, delivery tank, and line to generator

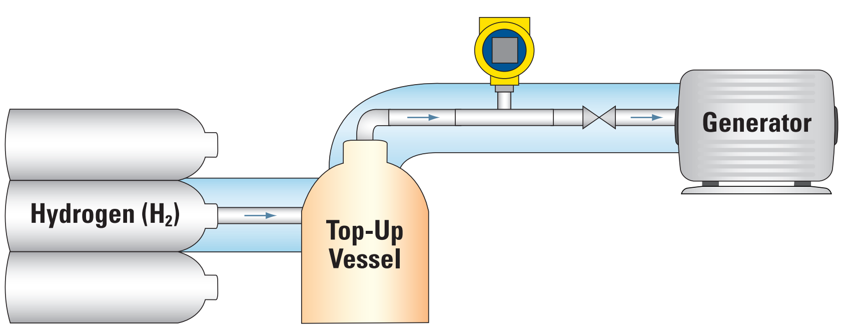
Solution 1: To solve this problem, an FCI ST75V Series Thermal Mass Flow Meter *(Figure 3)* was installed between the top-up vessel and the generator *(Figure 4)*. The thermal meter measures direct gas mass flow without the need for separate temperature and pressure transmitters and a flow computer. The meter's standard accuracy is ±1% of reading +0.5% of full scale.

This meter operates over a wide flow range with a minimum flow rate as low as 0.01SCFM [0,28 Nl/min]. and a wide turndown ratio of 100:1. The wide turndown range-ability allows the plant team to measure the H_2 flow more accurately to the generator under all power demand conditions: from very low flows or leaks to accidental high flow leaks. The meter's in-line configuration and all-welded sensor design also virtually eliminates any H_2 leak paths.

This in-line meter also features a unique built-in VORTAB flow conditioner, which is welded inside the assembly to allow extremely short installation length of 9D (9 x nominal diameter) without sacrificing accuracy.

Figure 3: FCI Model ST75V Series thermal flow meters

Figure 4: H_2 cylinders, delivery tank, and line to generator with flow meter



The meter was calibrated with 100-percent H_2 gas and pressurized to ensure best field accuracy. A calibration certificate was provided to the plant engineers, which is traceable to NIST/ ISO17025 calibration standards. With global safety approvals and excellent performance, the meter has improved the safety of the process by measuring H_2 leakage rates more accurately and with higher repeatability.

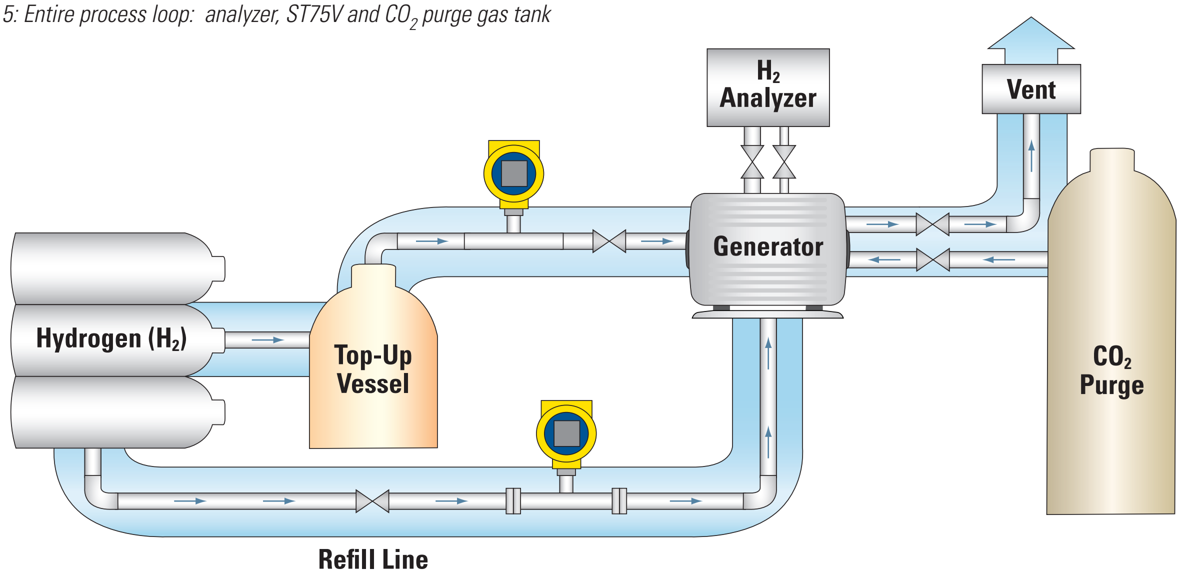
Problem 2: Within the generator there is always a chance that air, which is entrained in the seal/lube oil, could enter the generator and dilute the volume of H_2. Plant operators were using an H_2 analyzer to monitor the percentage of H_2 gas in the generator. If the H_2 percentage dropped below 99 percent, the plant team would then purge the entire generator using CO_2 *(Figure 5)* and then refill the generator with H_2.

Solution 2: A second ST75V Series flow meter was installed on a second H_2 line to measure the H_2 refill rate after purging was complete and also measured the totalized flow volume of H_2 passing from the cylinders back into the generator. This way the team could verify directly that the necessary level of H_2 gas was delivered again to refill the generator and would provide the necessary cooling of the electrical coil.

Both the installed thermal flow meters easily connect with the industry standard HART and Modbus RS485 ASCII/RTU communication protocols for interface with programmable logic controllers (PLCs) and distributed control systems. The outputs available include dual analog (4-20 mA), pulse output and digital, serial I/O.

These meters are available with an easy-to-read local digital display that permits manual meter readings by technicians. It features a 2-line-x-16 character LCD. The display shows the H_2 mass flow in the customer's engineering units. The display's top line is assigned to the mass/standard volumetric flow rate. The second line is user assignable to either totalized flow or the temperature reading, and it can be programmed to alternate these data. The display can be rotated in 90-degree increments for optimum viewing orientation by plant technicians.

Figure 5: Entire process loop: analyzer, ST75V and CO_2 purge gas tank



Theory of Operation

The FCI ST75 Series flow meters are designed with rugged and reliable thermal dispersion sensing technology, which provides direct mass flow measurement. This technology places two thermowell protected platinum RTD temperature sensors in the process stream.

One RTD is heated while the other senses the actual process temperature. The temperature difference between these sensors generates a voltage output, which is proportional to the media cooling affect and can be used to measure the gas mass flow rate *(Figure 6)* without the need for additional pressure or temperature transmitters.

With its direct mass flow sensor technology, the flow meter chosen by the electric power generation plant team also includes built-in real-time temperature compensation. This capability ensures repeatable measurement even in applications where wide process seasonal temperature variations are present, such as power plants in continuous operation throughout the year (summer and winter).

With no moving parts or orifices to plug, foul or wear, thermal mass flow meters are virtually immune to dust and dirt. This trouble-free sensing technology with its rugged packaging results in a nearly maintenance free instrument, which delivers continuous operation and at a lower installed cost over an exceptionally long life with low lifecycle costs too.

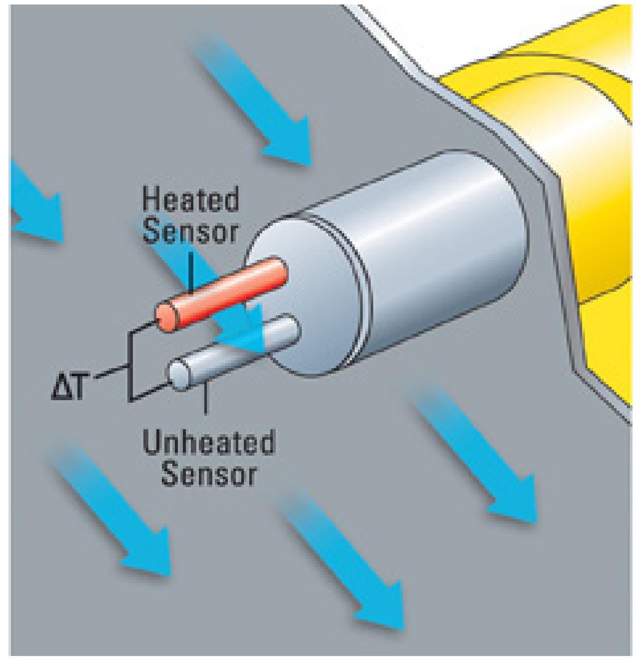


Figure 6: Thermal mass flow measurement theory of operation

Conclusions

The new thermal flow meters have been installed and operating successfully for months at the electric power plant. They were installed and commissioned without any issues. The plant team reports their H_2 flow data are now more consistent (reliable) and that the cooling of the generators is now being accomplished to their satisfaction. ■