

Measuring Off-Gas Mass Flow in the Treatment of Nuclear Waste

Abstract

The Idaho National Engineering and Environmental Laboratory (INEEL) created a technology pilot to trial two new nuclear waste treatment methods advanced by the Department of Energy (DOE). Metering the flow of off-gas from the treatment process is crucial to evaluating the success of the procedure, and essential for satisfying the concerns of oversight groups. However, there were three special challenges involved in measuring the off-gas:

- The off-gas is at partial vacuum (around 9 psia).
- The temperature of the off-gas varies.
- The molecular composition of the off-gas varies.

Only Coriolis measurement technology was capable of effectively measuring the flow of off-gas under these circumstances. And only Coriolis meters from Micro Motion® provided sufficient measurement accuracy to meet the needs of this application.

New DOE Treatment Methods

INEEL operates eight major facilities on an 890 square-mile U.S. government reservation in southern Idaho. One of the main missions of INEEL from the 1950s to the 1990s was to receive, store, and reprocess spent nuclear fuel. The spent fuel was brought to INEEL from nuclear reactors, where it was stored in underground tanks to cool. The fuel was then dissolved in acid and put through a 3-stage separation process. Beginning in 1962, the liquid extraction wastes from the separation went through a calciner process to turn it into a dry powder — a substantially more stable form for storage — which was then placed in stainless steel storage containers.

This procedure was ended in 1992, and by 1998 the liquid wastes had been completely calcined. However, other liquid wastes are still being generated from regular plant operations and decontamination activities, also known as sodium-bearing waste (SBW). The SBW is different enough from the old solvent extraction wastes that the old calcining process cannot be used. The DOE has been investigating treatment solutions for the SBW since the early 1990s.

The public and governmental regulatory attention focused on INEEL's treatment of radioactive wastes is understandably intense. And changing environmental regulations, technical requirements, and political administrations have created

additional challenges to the DOE's adoption of new treatment methods. The implementation of any new process inherently carries ongoing technical and regulatory risks.

In order to best manage this risk, DOE is simultaneously advancing two options for the treatment of SBW:

- Steam reforming
- Updated calcination process

Steam Reforming

Figure 1 illustrates the steam reforming process. SBW from the tank farm is fed into a blending tank, where any necessary additives are combined with the waste before the reforming process begins. The blended waste then goes into a fluidized bed within a reducing environment (a lack of oxygen with an excess of carbon) in the steam reformer itself. The off-gas that comes off the top of the reformer contains some particulates, which are spun out by a cyclone and sent to a scrubber. The remaining gas is sent to a thermal oxidizer to get rid of all the hydrocarbons. After that, the gas goes through HEPA filtration and mercury removal, then out the stack.

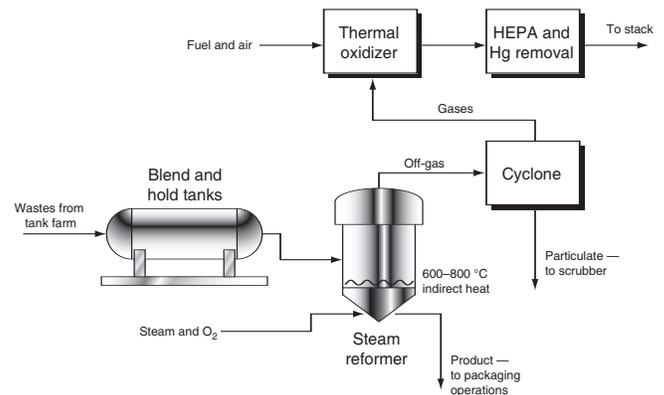


Figure 1. Steam reforming process

Updated Calcination Process

Figure 2 illustrates the updated calcination process. The updated calcination process is similar to the steam reforming process. Some of the differences include:

- There is a need for a substantial level of additives (at the blending tank) to take care of the excess sodium in the SBW.
- The reactor is a kerosene-fueled calcining fluidized bed. The oxidizing atmosphere inside the reactor unfortunately produces a lot of nitrous oxide (NO_x), which must be processed in the off-gas.
- The off-gas treatment is a multi-stage process. First, the NO_x is removed. The middle stage cleanses the off-gas. The final stage is to run oxidizers to destroy any remaining toxins in the off-gas.

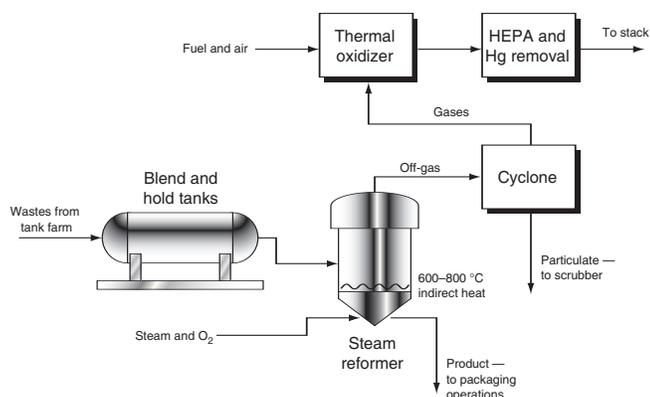


Figure 2. Updated calcining process

Measurement of Off-Gas

Flow meters are necessary on both sides of these systems. On the input side, the meters measure the mass flow of oxygen, along with an oxygen meter, so that the operators can create the proper reducing or oxidizing atmosphere. On the output side, the meters measure mass balance.

Mass balance across the process is a critical measurement in the evaluation of the effectiveness of waste treatment systems. A mass balance measurement taken by measuring the mass flow of off-gas lets the operators know how the process is functioning — how elements introduced to the system are coming out of the system — so that they can make adjustments to the process as it runs. This is also important from a public scrutiny and regulatory standpoint. The public and environmental agencies want to know that the treatment process is doing its job effectively, safely, and with minimal environmental impact. An accurate mass flow measurement of off-gas is indispensable for that reason.

There are several problems with obtaining an accurate measurement of off-gas, however.

- The off-gas is hot and corrosive, so there are material and meter design factors that must be considered.
- The exact composition of the off-gas is generally not known before it flows out of the reactor.

- The off-gas processing part of the system operates under partial vacuum, in order to pull the gas from the top of the steam reforming or calciner.

The INEEL Pilot Plant

INEEL constructed a pilot plant to demonstrate the new treatment methods proposed by the DOE. While designing the processing systems, two flow metering technologies were considered: Coriolis mass flow meters, and orifice plate differential pressure meters.

Orifice Plate Differential Pressure Meters

The principle points in favor of orifice plate differential pressure meters were that they are widely used, understood, and accepted. Orifice plate meters could provide a relatively simple measurement that would be easy to integrate into any control system.

There were, however, several downsides to using orifice plate meters in this application. The design goal of the application was to measure mass balance across the process, and putting together an installation with orifice plate meters that could accurately measure mass flow would prove difficult. Orifice plate meters require a very specific installation of pipe, with a high pressure drop, in order to achieve a good level of accuracy. Furthermore, an orifice plate meter requires a separate temperature and pressure measurement, and a known composition of gas, to calculate mass flow. Fitting two additional instruments into the pipeline was an inconvenience, but not an insurmountable problem. But knowing the composition of the off-gas ahead of time was not easily achieved.

During test runs with the orifice plate meters, the INEEL staff used continuous emissions monitoring equipment to determine the composition of the off-gas. However, the mass flow of that gas could not be used for mass balance purposes. And the emissions monitoring instruments needed to be recalibrated frequently, and proved unreliable when used with a typical off-gas. In addition, determining the accuracy of the calculations after the tests was an extensive effort that took an estimated 40 hours per statistician per run, which added considerable expense to the cost of using orifice plate meters.

Micro Motion Coriolis Meters

Although the Micro Motion Coriolis flow meters were less familiar to the INEEL engineers, they suffered from none of the same problems. Coriolis meters measure mass directly, and were not affected by changes in off-gas pressure, temperature, or concentration of constituents. This eliminated the need for separate instruments and emissions monitoring equipment. The further benefit of the all-in-one metering solution of the Coriolis meter was that its accuracy was consistently quantifiable — the temperature or the composition of the off-gas could change dramatically and it would not affect the Coriolis meter's mass flow accuracy.

Summary

Coriolis flow meters were the only metering technology that could accurately measure mass flow at a partial vacuum with a changing composition off-gas. The consistent, quantifiable accuracy provided by Micro Motion Coriolis meters in the INEEL pilot plant project demonstrated their unique suitability in meeting the DOE's need to treat SBW with minimal environmental impact.

Furthermore, the Micro Motion Coriolis meters saved INEEL the 40 hours of statistician time per run required with orifice plate meters. Assuming a \$50/hour rate for the statisticians, the Micro Motion meters paid for themselves in only 3 or 4 runs.

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