Volatile Organic Compound, Sulfur Dioxide, and Formaldehyde Emission Estimates

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PURPOSE

This Product Information Letter (PIL) summarizes emission factors commonly utilized to estimate emissions of volatile organic compounds (VOC), sulfur dioxide (SO_2), and formaldehyde from gas turbines.

Volatile Organic Compounds

Many permitting agencies require gas turbine users to include emissions of VOC, a subpart of the unburned hydrocarbon (UHC) emissions, during the air permitting process. Volatile organic compounds, non-methane hydrocarbons (NMHC), and reactive organic gases (ROG) are different ways of referring to the non-methane (and non-ethane) portion of an "unburned hydrocarbon" emission estimate.

For natural gas fuel, Solar's customers often use 10-20% of the UHC emission rate to conservatively estimate VOC emissions. Solar can offer a 5 ppm VOC warranty level upon request. For liquid fuel, it is appropriate to estimate that 100% of the UHC estimate is VOC. The emissions estimates are assumed valid for natural gas at ambient temperatures >-4°F (-20C) from 50-100% load (80-100% load for the Saturn® 20 and >-20°F (-29C) and 40-100% for the Titan™ 250) and for liquid fuel from 65-100% load (80-100% for the Saturn 20 and Centaur® 40).

Environmental Protection Agency (EPA's) AP-42[1] document and WebFIRE[2] database also contain VOC emission estimates for gas turbines. These sources are not commonly used by Solar's customers.

Sulfur Dioxide

Sulfur dioxide emissions are produced by conversion of any sulfur in the fuel to SO_2. Solar customers usually either use a mass balance calculation or reference AP-42 to estimate SO_2 emissions. Because Solar does not control the amount of sulfur in the fuel, no SO_2 emissions warranty is available.

The mass balance method assumes that any sulfur in the fuel converts to SO_2. For reference, the typical mass balance equation is shown below.

$$\frac{\text{lb SO2}}{\text{hr}} = \left(\frac{\text{wt\% Sulfur}}{100}\right)\left(\frac{\text{lb fuel}}{\text{Btu}}\right)\left(\frac{10^6\ \text{Btu}}{\text{MMBtu}}\right)\left(\frac{\text{MMBtu fuel}}{\text{hr}}\right)\left(\frac{\text{MW SO2}}{\text{MW Sulfur}}\right)$$

Variables: wt% of sulfur in fuel
Btu/lb fuel (LHV)
MMBtu/hr fuel flow (LHV)

As an alternative to the mass balance calculation, EPA's AP-42 document can be used. AP-42 (Table 3.1-2a, April 2000) suggests emission factors of 0.94S lb/MMBtu (HHV) (where S=Sulfur % in fuel) or 0.0034 lb/MMBtu (HHV) for gas fuel and 1.01S lb/MMBtu (HHV) (where S=Sulfur% in fuel) or 0.33 lb/MMBtu (HHV) for liquid fuel.

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[1]AP-42 is an EPA document containing a compilation of air pollutant emission factors by source category.
[2] WebFIRE is an EPA electronic based repository and retrieval tool for emission factors.

Formaldehyde

For gas turbines, formaldehyde emissions are a result of incomplete combustion and are unstable in the exhaust stream. In this section, regulatory background, recommended emission factors, and testing considerations are discussed.

Regulatory Background and Emissions Factors – U.S. and EU

In 2004 the U.S. EPA published a Maximum Achievable Control Technology (MACT) standard (40 CFR 63 Subpart YYYY) for natural gas fired combustion turbines with a formaldehyde limit of 91 ppb (15% O2). The standard was stayed a few months later for the natural gas subcategories essentially rendering the regulation "on hold". The stay was lifted on March 9, 2022. After ~18 years of not having to comply with the MACT standard, natural gas fired combustion turbines located **at major sources of hazardous air pollutants** need to comply with the standard. The initial compliance date is September 4, 2022. With the lifting of the stay, four of the eight subcategories outlined in the Subpart YYYY must comply with the MACT standard. They are:

- stationary lean premix combustion turbines when firing gas and when firing oil at sites where all turbines fire oil no more than an aggregate total of 1,000 hours annually
- stationary lean premix combustion turbines when firing oil at sites where all turbines fire oil more than an aggregate total of 1,000 hours annually
- stationary diffusion flame combustion turbines when firing gas and when firing oil at sites where all turbines fire oil no more than an aggregate total of 1,000 hours annually
- stationary diffusion flame combustion turbines when firing oil at sites where all turbines fire oil more than an aggregate total of 1,000 hours annually

For U.S. customers with a combustion turbine that must comply with Subpart YYYY, an emission factor of 91 ppb @ 15% O2 (~0.00021 lb/MMBtu HHV) is recommended.

The formaldehyde emissions estimate of 91 ppb @15%O2 (~0.00021 lb/MMbtu HHV) can be used for all new, current production, SoLoNOx models and ratings when firing pipeline quality natural gas or ultra-low sulfur (ULSD) diesel fuel. The emissions estimate is valid for natural gas from 50-100% load (40-100% load for Titan 250) or for liquid fuel from 65-100% load (80-100% load for the Centaur 40) and at ambient temperatures >-4°F (-20C) [> -20 °F (-29C) for Titan 250].

Alternative emission factors for combustion turbines **not** affected by Subpart YYYY (or non-U.S. based combustion turbines) are from U.S. EPA's AP-42 document and are 0.00071 lb/MMBtu (HHV) for natural gas and 0.00028 lb/MMBtu (HHV) for distillate oil[3]. Note that both of the aforementioned formaldehyde emission factors are higher than the MACT standard. Since ~2003 many gas turbine users have used the emission factors found in an EPA memo Revised HAP Emission Factors for Stationary Combustion Turbines[4] for estimating hazardous air pollutant emissions. The memo presents hazardous air pollutant emission factor data in several categories. While the memo presents several formaldehyde emissions factors, the most common formaldehyde emission factor used to estimate emissions from gas turbines from this document is 0.00288 lb/MMBtu HHV (Table 16). Note that this emission factor is an order of magnitude higher than the MACT standard.

In the EU, Germany has established a formaldehyde limit of 5 mg/Nm3 for combustion turbines (13.BImSchV Section 33). This limit applies for operation at 70-100% load and it is anticipated that something similar will be adopted in other EU member states. The 5 mg/Nm3 limit is equivalent to ~0.0038 kg/GJ or ~3.7 ppm.

Formaldehyde Emissions Testing Considerations

Actual emissions of formaldehyde from Solar's gas turbines, in the SoLoNOx operating range, are predicted to be less than 91 ppb @15%O2. However, **the 91 ppb level can only be verified if the proper testing equipment is utilized.** To properly measure formaldehyde emissions, Fourier Transform Infrared (FTIR) instrumentation with limits of detection well below the standard must be utilized. Most "traditional" FTIR systems have formaldehyde

[3] AP-42, Table 3.1-3 for Natural Gas and Table 3.1-4 for Distillate Oil, 4/00.

[4] Revised HAP Emission Factors for Stationary Combustion Turbines, OAR-2002-0060, IV-B-09,8/22/03.

limits of detection in the 120-150 ppb range and are not suitable to measure formaldehyde from combustion turbines.

Solar recommends the MKS Multi Gas 2030 FTIR with StarBoost™ System, the Spectrum WaveRunIR-EXT or an equivalent system with similar path lengths and detection levels.

EPA Method 320 (or equivalent method for non-U.S. testing) should be used to measure formaldehyde. Testing should include three – 120-minute test runs. To ensure accurate formaldehyde measurements, the testing company, in addition to following the requirements of Method 320 (or equivalent method), should take necessary steps to optimize signal-to-noise, verify the FTIR is fully temperature stabilized and purged, ensure the FTIR signal is optimized before testing by maximizing alignment and cleanliness of optics, minimize sampling line bias by using clean sample lines at 250°F to prevent off-gassing and minimize contamination with other compounds, verify absence of sampling system bias via system zero measurements, measure a source specific moisture spectrum while at the test site using a water/N2 delivery systems at +/-10% of turbine moisture content, and use the source specific water spectrum as an interferent in the analysis.