



ENVIRONMENTAL
INTEGRITY PROJECT



Appalachian
Voices

September 21, 2018

Air Pollution Control Board
c/o Office of Regulatory Affairs
Department of Environmental Quality
P.O. Box 1105
Richmond, Virginia 23218

David Paylor, Director
Department of Environmental Quality
1111 East Main Street, Suite 1400
Richmond, VA 23219

Re: Comments on Draft Stationary Source Permit to Construct and Operate Compressor Station 2 for Atlantic Coast Pipeline, LLC # 21599

Dear Director Paylor, Chairman Langford, and Members of the Air Pollution Control Board:

Appalachian Voices is a 501(c)(3) nonprofit organization advocating for healthy communities in Central and Southern Appalachia, with a focus on an equitable and just transition to a clean energy economy. Due to our organizational emphasis on justice and equity in the region, we have a heightened interest in the draft permit for a compressor station project sited in Buckingham County, Virginia. The compressor station proposed by Atlantic Coast Pipeline, LLC (“ACP”) would be sited within an identified environmental justice community whose demographic is 85% African American, undoubtedly creating a disproportionate pollution impact.

The Environmental Integrity Project is a nonprofit, nonpartisan organization that empowers communities and protects public health and the environment by investigating polluters, holding them accountable under the law, and strengthening public policy.

We respectfully offer the following comments to the Department of Environmental Quality (herein “the Department”) regarding the Draft Stationary Source Permit to Construct and Operate Atlantic Coast Pipeline Compressor Station 2 located at 5297 S. James River Hwy, Wingina, in Buckingham County, Virginia.

The Department should replace the proposed stack tests for regulated pollutants with a requirement for continuous emission monitoring systems (CEMS)

The monitoring requirements contained in the Draft Permit are not adequate to ensure compliance with the emissions limits set out therein because they do not require continuous or even frequent measurement of outgoing pollutant concentrations from the compressor turbines. For example, the performance tests set out in Condition 29 of the Draft Permit for emissions of nitrogen oxides (NOx), carbon monoxide (CO), volatile organic compounds (VOC), and particulate matter (PM10 and PM2.5) are only required to be performed upon initial operation and then repeated once every two years thereafter.¹ The Draft Permit states that emissions will be derived from the estimated overall emission contribution from operating limits, rather than direct measurement of pollutant emissions.

These criteria pollutants have a high potential to adversely impact human health in concentrations above federal standards. However, if emissions controls and other equipment cease to perform at the required level, a problem might go undetected for months or years. Continuous emission monitoring systems (CEMS) for regulated pollutants should replace the stack tests set out in Conditions 29, 30, 31, 32, 49, and 50 in order to ensure compliance with the permit's emissions limitations.²

In particular, the Department's potential to emit (PTE) calculations are based on the assumption of near-constant achievement of a 3.75 ppm NOx rate at each compressor turbine and near-constant operation of selective catalytic reduction (SCR). There are several factors that could interfere with achieving this rate in practice. Therefore, it is critical that compliance with the enforceable NOx limit of 3.75 ppm in the Draft Permit is assessed using CEMS for NOx.

The Department must revise the draft permit to prohibit ACP from operating the compressor turbines below 50% capacity except during the limited start-up/shutdown events included in PTE calculations.

As acknowledged in the Department's own engineering analysis, the SoLoNOx control efficiency for the compressor turbines is diminished at low loads (below 50% capacity),³ which results in significant increases in NOx, VOC, and CO emissions as seen in the attached product information letter from the turbine manufacturer.⁴ At operating loads below 50% capacity, CO emissions from the turbines increase to 8,000 ppm, with higher NOx and VOC emissions as well. However, the Department has not included emissions from any low-load operations in its calculation of the compressor station's potential to emit (PTE), other than the limited estimates of start-up and shutdown emissions. With the exception of these start-up and shutdown events,

¹ Commonwealth of Virginia, Department of Environmental Quality, Draft Stationary Source Permit to Construct and Operate 15 (2018), available at https://www.deq.virginia.gov/Portals/0/DEQ/Air/BuckinghamCompressorStation/21599_BCS_DRAFT_Permit.pdf ("Draft Permit").

² See Draft Permit at 15, 22.

³ See Commonwealth of Virginia, Department of Environmental Quality, Intra-Agency Memorandum 4, 10 (2018), available at https://www.deq.virginia.gov/Portals/0/DEQ/Air/BuckinghamCompressorStation/21599_BCS_DRAFT_Analysis.pdf ("Engineering Analysis").

⁴ See Leslie Witherspoon, Solar Turbines, PIL 167 Revision 4, SoLoNOx Products: Emissions in Non-SoLoNOx Modes 2-4 (June 6, 2012) ("PIL 167").

the Department may not exclude hours of low-load operation from PTE calculations unless it prohibits ACP from operating the turbines at low loads in the Permit.

The Engineering Analysis specifically states that the Buckingham Compressor Station “cannot operate below 50% load unless during start-up or shutdown.”⁵ However, the Draft Permit fails to specifically prohibit operation below 50% capacity. The Department may not treat operating capacity above 50% as a limitation on the source’s PTE unless that limitation is set forth in the Permit as an enforceable condition. The Department must revise the Draft Permit to prohibit ACP from operating the compressor station below 50% capacity, or account for low-load emissions increases in PTE calculations.

Emissions Rate Limitations Should Apply During Start-Up and Shutdown Procedures

While the Draft Permit properly limits the total annual hours of start-up and shutdown events for the compressor turbines and the number of hours in which they may take place, it fails to set emission rates on pollutants other than VOCs during these events. The other regulated pollutants limited during operation (CO, NOx, PM, PM10, PM2.5, SO2) should be limited during start-up and shutdown as well. As seen in the turbine manufacturer’s product information letter,⁶ additional NOx, CO, and VOC emissions can occur during start-up and shutdown, and should be similarly limited within the permit conditions.

The Department Must Set Emissions Limits for NOx, VOC, and CO from the Turbines During Temperatures Below 0 degrees Fahrenheit.

Emissions of NOx, VOC, and CO from the turbines can increase significantly at temperatures below 0 degrees Fahrenheit.⁷ The Department has included an estimated 5 hours of increased emissions due to such conditions within the Engineering Analysis. While the Department and ACP cannot predict or control the number of hours with temperatures below 0 degrees Fahrenheit that actually occur each year, the Department must still set emissions limits that apply during these periods.

Emissions limits should not be entirely exempted at abnormally low temperatures, and they must be made enforceable conditions of the Permit. Even if the standard limits cannot be met at temperatures between 0 and -20 degrees Fahrenheit, secondary limitations must be set and enforced. The Department’s Engineering Analysis states that the proposed turbines will use the Cold Ambient Temperature Logic, which guarantees emission rates at temperatures between -20 and 0 degrees Fahrenheit for the turbines.⁸ The Department should set enforceable limits on emissions below 0 degrees Fahrenheit as these are guaranteed, predictable emissions that should be limited to no higher than the manufacturer specified emission rates with control of NOx, CO, and VOC at 58%, 92% and 50%, respectively.⁹

⁵ Engineering Analysis at 4.

⁶ Leslie Witherspoon, Solar Turbines, PIL 170 Revision 5, Emissions Estimates at Start-Up, Shutdown, and Commissioning for SoLoNOx Combustion Products (June 13, 2012) (“PIL 170”).

⁷ See PIL 167 at 1-3.

⁸ Engineering Analysis at 10.

⁹ See PIL 167 at 2.

The Department Should Condition the Permit Upon Pending Greenhouse Gas Regulations

Virginia is poised to begin regulating carbon dioxide emissions from electric power plants through the regulation being developed under Executive Directive 11. This draft regulation would set limits on large stationary sources' CO₂ emissions, but it ignores the complete lifecycle greenhouse gas emissions from production, transportation, and storage of fossil fuels that are ultimately combusted for electricity generation. Ignoring the greenhouse gas emissions from fossil fuel transportation and storage infrastructure is unnecessarily limiting and ultimately self-defeating.

According to analysis by Oil Change International, lifecycle greenhouse gas emissions from the Atlantic Coast Pipeline are estimated at nearly 68 million metric tons annually, or the approximate equivalent of 20 new coal-fired power plants.¹⁰ Methane leakage and emissions from pipeline operation account for more than half of that total. Further, the Federal Energy Regulatory Commission's Environmental Impact Statement for the Atlantic Coast Pipeline states that the Buckingham Compressor Station alone has the potential to emit 323,736 tons of CO₂e annually.¹¹

But Virginia may not ignore fugitive methane emissions from gas infrastructure much longer. Governor Northam announced on September 12, 2018 that his administration intends to develop regulations limiting methane emissions from natural gas infrastructure.¹² Virginia has broad authority under state law to regulate greenhouse gas emissions, and it now appears likely that "due to inaction at the federal level," the Commonwealth will "take action to limit methane pollution within its borders."¹³

To its credit, the Department outlines several sensible process requirements to control both the venting of natural gas and fugitive emissions from leaks in the Draft Permit.¹⁴ These are important first steps. However, because methane emissions from natural gas infrastructure are likely to be regulated in the future, the Department should take additional steps in the Draft Permit to ensure that this compressor station will meet any future standards promulgated, including a numeric emissions limitation. The Department should add a condition to the Draft Permit explicitly reserving the right of the Department and the Air Pollution Control Board to regulate methane emissions from the Buckingham compressor station in conformity with any future regulation published.

If the Department Cannot Demonstrate That Operation of the Buckingham Compressor Station Will Not Have a Disproportionate Adverse Impact on Environmental Justice

¹⁰ Oil Change Int'l, The Atlantic Coast Pipeline: Greenhouse Gas Emission Briefing (Feb. 2017), available at http://priceofoil.org/content/uploads/2017/02/atlantic_coast_pipeline_web_final_v3.pdf.

¹¹ Federal Energy Regulatory Commission, Atlantic Coast Pipeline and Supply Header Project Final Environmental Impact Statement 4-559 (July, 2017).

¹² Press Release, Gov. Ralph Northam, Northam Administration Takes New Steps to Fight Climate Change, Ocean Acidification (Sept. 12, 2018), available at <https://www.governor.virginia.gov/newsroom/all-releases/2018/september/headline-829610-en.html>.

¹³ *Id.*

¹⁴ See Draft Permit at 7-9.

Communities, It Must Reject the Draft Permit in Order to Act Consistently With the Commonwealth Energy Policy

Finally, it is the policy of the Commonwealth to “[e]nsure that development of new, or expansion of existing, energy resources or facilities does not have a disproportionate adverse impact on economically disadvantaged or minority communities.”¹⁵ According to a study conducted by anthropologist Dr. Lakshmi Fjord, the community within a 1.1 mile radius of this proposed compressor station is an environmental justice community where over 85% of households are African-American, 33% are descendants of Freedmen, and the numbers of elderly (70+) and the very young (0-6) are disproportionately higher than other age groups.¹⁶

In taking any discretionary action, such as the decision to approve or reject ACP’s application for a stationary source permit to construct and operate the Buckingham County compressor station, the Department “shall recognize the elements of the Commonwealth Energy Policy and where appropriate, shall act in a manner consistent therewith.”¹⁷ This includes the aforementioned requirement to ensure that new energy resources or facilities do not have a disproportionate adverse impact on economically disadvantaged or minority communities.

If this compressor station receives a permit from the Department and is constructed, its operation will undoubtedly subject an economically disadvantaged and minority community to higher levels of air pollution than experienced by other Virginia citizens, even if ambient air quality standards are still attained statewide. If the Department cannot demonstrate that the Buckingham Compressor Station will not have a disproportionate adverse impact on an environmental justice community, the Department and Board must reject the Draft Permit in order to act in a matter consistent with the Commonwealth Energy Policy.”

While the Commonwealth Energy Policy “shall not be construed to amend, repeal, or override any contrary provision of applicable law,” it is not inconsistent with the state air pollution control laws for the Department and Board to recognize the Commonwealth Energy Policy here (specifically its environmental justice policy under subsection (A)(11)). While the Department and Board may have little or no authority on siting decisions, they have full authority to issue, amend, revoke, terminate, and reissue permits to control the emission of air pollutants in the Commonwealth.¹⁸ In this case, the Department and Board should use their full authority under the state air pollution laws and the Commonwealth Energy Policy to reject the application for Stationary Source Permit to Construct and Operate the Buckingham County Compressor Station.

Alternatively, if there is evidence showing that rejecting the Draft Permit under the Commonwealth Energy Policy subsection (A)(11) is inconsistent with applicable law, the Department and the Board should incorporate into the Draft Permit’s conditions the comments outlined above.

¹⁵ VA Code § 67-102 (A)(11).

¹⁶ Lakshmi Fjord, Report to the Permanent Peoples’ Tribunal Session on Human Rights, Fracking and Climate Change 63 (2018), available at <https://www.tribunalonfracking.org/wp-content/uploads/2018/04/Cvllle-Peoples-Trib-Summary-Report.pdf>.

¹⁷ VA Code § 67-102 (C).

¹⁸ VA Code § 10.1-1322.

Thank you for the opportunity to comment on this important matter.

A handwritten signature in black ink, reading "Tom Cormons". The signature is fluid and cursive, with a long horizontal stroke at the end.

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A handwritten signature in black ink, reading "Eric Schaeffer". The signature is cursive, with a large "E" and a long, sweeping "S".

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SoLoNO_x Products: Emissions in Non-SoLoNO_x Modes

Leslie Witherspoon
Solar Turbines Incorporated

PURPOSE

Solar's gas turbine dry low NO_x emissions combustion systems, known as *SoLoNO_x*[™], have been developed to provide the lowest emissions possible during normal operating conditions. In order to optimize the performance of the turbine, the combustion and fuel systems are designed to reduce NO_x, CO and unburned hydrocarbons (UHC) without penalizing stability or transient capabilities. At very low load and cold temperature extremes, the *SoLoNO_x* system must be controlled differently in order to assure stable operation. The required adjustments to the turbine controls at these conditions cause emissions to increase.

The purpose of this Product Information Letter is to provide emissions estimates, and in some cases warrantable emissions for NO_x, CO and UHC, at off-design conditions.

Historically, regulatory agencies have not required a specific emissions level to be met at low load or cold ambient operating conditions, but have asked what emissions levels are expected. The expected values are necessary to appropriately estimate emissions for annual emissions inventory purposes and for New Source Review applicability determinations and permitting.

COLD AMBIENT EMISSIONS ESTIMATES

Solar's standard temperature range warranty for gas turbines with *SoLoNO_x* combustion is $\geq 0^{\circ}\text{F}$ (-20°C). The *Titan*[™] 250 is an exception, with a lower standard warranty at $\geq -20^{\circ}\text{F}$ (-29°C). At ambient temperatures below 0°F , many of Solar's turbine engine models are controlled to increase pilot fuel to improve flame stability and emissions are higher. Without the increase in pilot fuel at temperatures below 0°F the engines may exhibit combustor rumble, as operation may be near the lean stability limit.

If a cold ambient emissions warranty is requested, a new production turbine configured with the latest combustion hardware is required. For most models this refers to the inclusion of Cold Ambient Fuel Control Logic.

Emissions warranties are not offered for ambient temperatures below -20°F (-29°C). In addition, cold ambient emissions warranties cannot be offered for the *Centaur*[®] 40 turbine.

Table 1 provides expected and warrantable (upon Solar's documented approval) emissions levels for Solar's *SoLoNO_x* combustion turbines. All emissions levels are in ppm at 15% O₂. Refer to Product Information Letter 205 for *Mercury*[™] 50 turbine emissions estimates.

For information on the availability and approvals for cold ambient temperature emissions warranties, please contact Solar's sales representatives.

Table 2 summarizes “expected” emissions levels for ambient temperatures below 0°F (–20°C) for Solar’s *SoLoNOx* turbines that do not have current production hardware or for new production hardware that is not equipped with the cold ambient fuel control logic. The emissions levels are extrapolated from San Diego factory tests and may vary at extreme temperatures and as a result of variations in other parameters, such as fuel composition, fuel quality, etc.

For more conservative NOx emissions estimate for new equipment, customers can refer to the New Source Performance Standard (NSPS) 40CFR60, subpart KKKK, where the allowable NOx emissions level for ambient temperatures < 0°F (–20°F) is 150 ppm NOx at 15% O₂. For pre-February 18, 2005, *SoLoNOx* combustion turbines subject to 40CFR60 subpart GG, a conservative estimate is the appropriate subpart GG emissions level. Subpart GG levels range from 150 to 214 ppm NOx at 15% O₂ depending on the turbine model.

Table 3 summarizes emissions levels for ambient temperatures below –20°F (–29°C) for the *Titan 250*.

Table 1. Warrantable Emissions Between 0°F and –20°F (–20° to –29°C) for New Production

Turbine Model	Fuel System	Fuel	Applicable Load	NOx, ppm	CO, ppm	UHC, ppm
<i>Centaur 50</i>	Gas Only	Gas	50 to 100% load	42	100	50
	Dual Fuel	Gas	50 to 100% load	72	100	50
<i>Taurus™ 60</i>	Gas Only or Dual Fuel	Gas	50 to 100% load	42	100	50
<i>Taurus 65</i>	Gas Only	Gas	50 to 100% load	42	100	50
<i>Taurus 70</i>	Gas Only or Dual Fuel	Gas	50 to 100% load	42	100	50
<i>Mars® 90</i>	Gas Only	Gas	50 to 100% load	42	100	50
<i>Mars 100</i>	Gas Only or Dual Fuel	Gas	50 to 100% load	42	100	50
<i>Titan 130</i>	Gas Only or Dual Fuel	Gas	50 to 100% load	42	100	50
<i>Titan 250</i>	Gas Only	Gas	40 to 100% load	25	50	25
	Gas Only	Gas	40 to 100% load	15	25	25
<i>Centaur 50</i>	Dual Fuel	Liquid	65 to 100% load	120	150	75
<i>Taurus 60</i>	Dual Fuel	Liquid	65 to 100% load	120	150	75
<i>Taurus 70</i>	Dual Fuel	Liquid	65 to 100% load	120	150	75
<i>Mars 100</i>	Dual Fuel	Liquid	65 to 100% load	120	150	75
<i>Titan 130</i>	Dual Fuel	Liquid	65 to 100% load	120	150	75

Table 2. Expected Emissions below 0°F (–20°C) for SoLoNOx Combustion Turbines

Turbine Model	Fuel System	Fuel	Applicable Load	NOx, ppm	CO, ppm	UHC, ppm
<i>Centaur 40</i>	Gas Only or Dual Fuel	Gas	80 to 100% load	120	150	50
<i>Centaur 50</i>	Gas Only	Gas	50 to 100% load	120	150	50
	Dual Fuel	Gas	50 to 100% load	120	150	50
<i>Taurus 60</i>	Gas Only or Dual Fuel	Gas	50 to 100% load	120	150	50
<i>Taurus 65</i>	Gas Only	Gas	50 to 100% load	120	150	50
<i>Taurus 70</i>	Gas Only or Dual Fuel	Gas	50 to 100% load	120	150	50
<i>Mars 90</i>	Gas Only	Gas	80 to 100% load	120	150	50
<i>Mars 100</i>	Gas Only or Dual Fuel	Gas	50 to 100% load	120	150	50
<i>Titan 130</i>	Gas Only or Dual Fuel	Gas	50 to 100% load	120	150	50
<i>Centaur 40</i>	Dual Fuel	Liquid	80 to 100% load	120	150	75
<i>Centaur 50</i>	Dual Fuel	Liquid	65 to 100% load	120	150	75
<i>Taurus 60</i>	Dual Fuel	Liquid	65 to 100% load	120	150	75
<i>Taurus 70</i>	Dual Fuel	Liquid	65 to 100% load	120	150	75
<i>Mars 100</i>	Dual Fuel	Liquid	65 to 100% load	120	150	75
<i>Titan 130</i>	Dual Fuel	Liquid	65 to 100% load	120	150	75

Table 3. Expected Emissions below –20°F (–29°C) for the Titan 250 SoLoNOx Combustion Turbine

Turbine Model	Fuel System	Fuel	Applicable Load	NOx, ppm	CO, ppm	UHC, ppm
<i>Titan 250</i>	Gas Only	Gas	40 to 100% load	70	150	50

COLD AMBIENT PERMITTING STRATEGY

There are several permitting options to consider when permitting in cold ambient climates. Customers can use a tiered permitting approach or choose to permit a single emission rate over all temperatures. Historically, most construction and operating permits were silent on the ambient temperature boundaries for SoLoNOx operation.

Some customers have used a tiered permitting strategy. For purposes of compliance and annual emissions inventories, a digital thermometer is installed to record ambient temperature. The amount of time is recorded that the ambient temperature falls below 0°F. The amount of time below 0°F is then used with the emissions estimates shown in Tables 1 and 2 to estimate “actual” emissions during sub-zero operation.

A conservative alternative to using the NOx values in Tables 1, 2 and 3 is to reference 40CFR60 subpart KKKK, which allows 150 ppm NOx at 15% O₂ for sub-zero operation.

For customers who wish to permit at a single emission rate over all ambient temperatures, inlet air heating can be used to raise the engine inlet air temperature (T₁) above 0°F. With inlet air heating to keep T₁ above 0°F, standard emission warranty levels may be offered.

Inlet air heating technology options include an electric resistance heater, an inlet air to exhaust heat exchanger and a glycol heat exchanger.

If an emissions warranty is desired and ambient temperatures are commonly below –20°F (–29°C), inlet air heating can be used to raise the turbine inlet temperature (T₁) to at least –20°F. In such cases, the values shown in Table 1 can be warranted for new production.

EMISSIONS ESTIMATES IN NON-SOLONOX MODE (LOW LOAD)

At operating loads < 50% (<40% load for the *Titan 250*) on natural gas fuel and < 65% (< 80% load for *Centaur 40*) on liquid fuels, *SoLoNOx* engines are controlled to increase stability and transient response capability. The control steps that are required affect emissions in two ways: 1) pilot fuel flow is increased, increasing NOx emissions, and 2) airflow through the combustor is increased, increasing CO emissions. Note that the load levels are approximate. Engine controls are triggered either by power output for single-shaft engines or gas producer speed for two-shaft engines.

A conservative method for estimating emissions of NOx at low loads is to use the applicable NSPS: 40CFR60 subpart GG or KKKK. For projects that commence construction after February 18, 2005, subpart KKKK is the applicable NSPS and contains a NOx level of 150 ppm @ 15% O₂ for operating loads less than 75%.

Table 4 provides estimates of NOx, CO, and UHC emissions when operating in non-*SoLoNOx* mode for natural gas or liquid fuel. The estimated emissions can be assumed to vary linearly as load is decreased from just below 50% load for natural gas (or 65% load for liquid fuel) to idle.

The estimates in Table 4 apply for any product for gas only or dual fuel systems using pipeline quality natural gas. Refer to Product Information Letter 205 for *Mercury 50* emissions estimates.

Table 4. Estimated Emissions in non-*SoLoNOx* Mode

Ambient	Fuel System	Engine Load	NOx, ppm	CO, ppm	UHC, ppm
Centaur 40/50, Taurus 60/65/70, Mars 90/100, Titan 130					
≥ -20°F (-29°C)	Natural Gas	Less than 50%	70	8,000	800
		Idle	50	10,000	1,000
< -20°F (-29°C)	Natural Gas	Less than 50%	120	8,000	800
		Idle	120	10,000	1,000
Titan 250					
≥ -20°F (-29°C)	Natural Gas	Less than 40%	50	25	20
		Idle	50	2,000	200
< -20°F (-29°C)	Natural Gas	Less than 40%	70	150	50
		Idle	70	2,000	200
Centaur 50, Taurus 60/70, Mars 100, Titan 130					
≥ -20°F (-29°C)	Liquid	Less than 65%	120	1,000	100
		Idle	120	10,000	3,000
< -20°F (-29°C)	Liquid	Less than 65%	120	1,000	150
		Idle	120	10,000	3,000
Centaur 40					
≥ -20°F (-29°C)	Liquid	Less than 80%	120	1,000	100
		Idle	120	10,000	3,000
< -20°F (-29°C)	Liquid	Less than 80%	120	1,000	150
		Idle	120	10,000	3,000

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Volatile Organic Compound, Sulfur Dioxide, and Formaldehyde Emission Estimates

Leslie Witherspoon
Solar Turbines Incorporated

PURPOSE

This Product Information Letter summarizes methods that are available to estimate emissions of volatile organic compounds (VOC), sulfur dioxide (SO₂), and formaldehyde from gas turbines. Emissions estimates of these pollutants are often necessary during the air permitting process.

INTRODUCTION

In absence of site-specific or representative source test data, Solar refers customers to a United States Environmental Protection Agency (EPA) document titled "AP-42" or other appropriate EPA reference documents. AP-42 is a collection of emission factors for different emission sources. The emission factors found in AP-42 provide a generally accepted way of estimating emissions when more representative data are not available. The most recent version of AP-42 (dated April 2000) can be found at:

<http://www.epa.gov/ttn/chief/ap42/ch03/index.html>

Solar does not typically warranty the emission rates for VOC, SO₂ or formaldehyde.

Volatile Organic Compounds

Many permitting agencies require gas turbine users to estimate 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 some of the many ways of referring to the non-methane (and non-ethane) portion of an "unburned hydrocarbon" emission estimate.

For natural gas fuel, Solar's customers use 10-20% of the UHC emission rate to represent VOC

emissions. The estimate of 10-20% is based on a ratio of total non-methane hydrocarbons to total organic compounds. The use of 10-20% provides a conservative estimate of VOC emissions. The balance of the UHC is assumed to be primarily methane.

For liquid fuel, it is appropriate to estimate that 100% of the UHC emission estimate is VOC.

Sulfur Dioxide

Sulfur dioxide emissions are produced by conversion of sulfur in the fuel to SO₂. Since Solar does not control the amount of sulfur in the fuel, we are unable to predict SO₂ emissions without a site fuel composition analysis. Customers generally estimate SO₂ emissions with a mass balance calculation by assuming that any sulfur in the fuel will convert to SO₂. For reference, the typical mass balance equation is shown below.

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

$$\frac{\text{lb SO}_2}{\text{hr}} = \left(\frac{\text{wt\% Sulfur}}{100} \right) \left(\frac{\text{lb fuel}}{\text{Btu}} \right) \left(\frac{10^6 \text{ Btu}}{\text{MMBtu}} \right) \left(\frac{\text{MMBtu fuel}}{\text{hr}} \right) \left(\frac{\text{MW SO}_2}{\text{MW Sulfur}} \right)$$

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 0.0034 lb/MMBtu for gas fuel (HHV*) and 0.033 lb/MMBtu for liquid fuel (HHV).

*LHV = Lower Heating Value; HHV = Higher Heating Value

Formaldehyde

In gas turbines, formaldehyde emissions are a result of incomplete combustion. Formaldehyde

in the exhaust stream is unstable and very difficult to measure. In addition to turbine characteristics including combustor design, size, maintenance history, and load profile, the formaldehyde emission level is also affected by:

- Ambient temperature
- Humidity
- Atmospheric pressure
- Fuel quality
- Formaldehyde concentration in the ambient air
- Test method measurement variability
- Operational factors

The emission factor data in Table 1 is an excerpt from an EPA memo: "Revised HAP Emission

Factors for Stationary Combustion Turbines, 8/22/03." The memo presents hazardous air pollutant (HAP) emission factor data in several categories including: mean, median, maximum, and minimum. The emission factors in the memo are a compilation of the HAP data EPA collected during the Maximum Achievable Control Technology (MACT) standard development process. The emission factor documentation shows there is a high degree of variability in formaldehyde emissions from gas turbines, depending on the manufacturer, rating size of equipment, combustor design, and testing events. To estimate formaldehyde emissions from gas turbines, users should use the emission factor(s) that best represent the gas turbines actual / planned operating profile. Refer to the memo for alternative emission factors.

Table 1. EPA's Total HAP and Formaldehyde Emission Factors for <50 MW Lean-Premix Gas Turbines burning Natural Gas

(Source: Revised HAP Emission Factors for Stationary Combustion Turbines, OAR-2002-0060, IV-B-09, 8/22/03)

Pollutant	Engine Load	95% Upper Confidence of Mean, lb/MMBtu HHV	95% Upper Confidence of Data, lb/MMBtu HHV	Memo Reference
Total HAP	> 90%	0.00144	0.00258	Table 19
Total HAP	All	0.00160	0.00305	Table 16
Formaldehyde	> 90%	0.00127	0.00241	Table 19
Formaldehyde	All	0.00143	0.00288	Table 16

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Emission Estimates at Start-up, Shutdown, and Commissioning for SoLoNO_x Combustion Products

Leslie Witherspoon
Solar Turbines Incorporated

PURPOSE

The purpose of this Product Information Letter (PIL) is to provide emission estimates for start-up and shutdown events for *Solar*[®] gas turbines with *SoLoNO_x*[™] dry low emissions combustion systems. The commissioning process is also discussed.

INTRODUCTION

The information presented in this document is representative for both generator set (GS) and compressor set/mechanical drive (CS/MD) combustion turbine applications. Operation of duct burners and/or any add-on control equipment is not accounted for in the emissions estimates. Emissions related to the start-up, shutdown, and commissioning of combustion turbines will not be guaranteed or warranted.

Combustion turbine start-up occurs in one of three modes: cold, warm, or hot. On large, utility size, combustion turbines, the start-up time varies by the “mode”. The start-up duration for a hot, warm, or cold *Solar* turbine is less than 10 minutes in simple-cycle and most combined heat and power applications.

Heat recovery steam generator (HRSG) steam pressure is usually 250 psig or less. At 250 psig or less, thermal stress within the HRSG is minimized and, therefore, firing ramp-up is not limited. However, some combined heat and power plant applications will desire or dictate longer start-up times, therefore emissions assuming a 60-minute start are also estimated.

A typical shutdown for a *Solar* turbine is <10 minutes. Emissions estimates for an elongated shutdown, 30-minutes, are also included.

Start-up and shutdown emissions estimates for the *Mercury*[™] 50 engine are found in PIL 205.

For start-up and shutdown emissions estimates for conventional combustion turbines, landfill gas, digester gas, or other alternative fuel applications, contact Solar's Environmental Programs Department.

START-UP SEQUENCE

The start-up sequence, or getting to *SoLoNO_x* combustion mode, takes three steps:

1. Purge-crank
2. Ignition and acceleration to idle
3. Loading / thermal stabilization

During the “purge-crank” step, rotation of the turbine shaft is accomplished with a starter motor to remove any residual fuel gas in the engine flow path and exhaust. During “igni-

tion and acceleration to idle,” fuel is introduced into the combustor and ignited in a diffusion flame mode and the engine rotor is accelerated to idle speed.

The third step consists of applying up to 50% load¹ while allowing the combustion flame to transition and stabilize. Once 50% load is achieved, the turbine transitions to *SoLoNOx* combustion mode and the engine control system begins to hold the combustion primary zone temperature and limit pilot fuel to achieve the targeted nitrogen oxides (NO_x), carbon monoxide (CO), and unburned hydrocarbons (UHC) emission levels.

Steps 2 and 3 are short-term transient conditions making up less than 10 minutes.

SHUTDOWN PROCESS

Normal, planned cool down/shutdown duration varies by engine model. The *Centaur*[®] 40, *Centaur* 50, *Taurus*[™] 60, and *Taurus* 65 engines take about 5 minutes. The *Taurus* 70, *Mars*[®] 90 and 100, *Titan*[™] 130 and *Titan* 250 engines take about 10 minutes. Typically, once the shutdown process starts, the emissions will remain in *SoLoNOx* mode for approximately 90 seconds and move into a transitional mode for the balance of the estimated shutdown time (assuming the unit was operating at full-load).

START-UP AND SHUTDOWN EMISSIONS ESTIMATES

Tables 1 through 5 summarize the estimated pounds of emissions per start-up and shutdown event for each product. Emissions estimates are presented for both GS and CS/MD applications on both natural gas and liquid fuel (diesel #2). The emissions estimates are calculated using empirical exhaust characteristics.

COMMISSIONING EMISSIONS

Commissioning generally takes place over a two-week period. Static testing, where no combustion occurs, usually requires one week and no emissions are expected. Dynamic testing, where combustion will occur, will see the engine start and shutdown a number of times and a variety of loads will be placed on the system. It is impossible to predict how long the turbine will run and in what combustion / emissions mode it will be running. The dynamic testing period is generally followed by one to two days of “tune-up” during which the turbine is running at various loads, most likely within low emissions mode (warranted emissions range).

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¹ 40% load for the *Titan* 250 engine on natural gas. 65% load for all engines on liquid fuel (except 80% load for the *Centaur* 40).

Table 1. Estimation of Start-up and Shutdown Emissions (lbs/event) for SoLoNOx Generator Set Applications
10 Minute Start-up and 10 Minute Shutdown
Natural Gas Fuel

Data will NOT be warranted under any circumstances

	Centaur 40 4701S				Centaur 50 6201S				Taurus 60 7901S				Taurus 65 8401S			
	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2
	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)
Total Emissions per Start (lbs)	0.6	58.1	3.3	359	0.8	75.0	4.3	454	0.8	78.5	4.5	482	0.9	85.8	4.9	523
Total Emissions per Shutdown (lbs)	0.3	25.5	1.5	160	0.4	31.1	1.8	194	0.4	34.7	2.0	217	0.4	38.2	2.2	237

	Taurus 70 10801S				Mars 90 13002S GSC				Mars 100 16002S GSC				Titan 130 20501S				Titan 250 30002S			
	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2
	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)
Total Emissions per Start (lbs)	1.1	103.9	5.9	634	1.4	129.0	7.4	868	1.6	151.2	8.6	952	2.1	195.6	11.2	1,194	2.5	22.7	1.5	1,925
Total Emissions per Shutdown (lbs)	1.3	110.7	6.3	689	1.7	147.9	8.4	912	1.9	166.8	9.5	1,026	2.4	210.0	12.0	1,303	3.0	19.9	1.5	1,993

Assumes ISO conditions: 59F, 60% RH, sea level, no losses

Assumes unit is operating at full load prior to shutdown.

Assumes natural gas fuel; ES 9-98 compliant.

Table 2. Estimation of Start-up and Shutdown Emissions (lbs/event) for SoLoNOx Generator Set Applications
60 Minute Start-up and 30 Minute Shutdown
Natural Gas Fuel

Data will NOT be warranted under any circumstances

	Centaur 40 4701S				Centaur 50 6201S				Taurus 60 7901S				Taurus 65 8401S			
	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2
	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)
Total Emissions per Start (lbs)	4.1	219.4	13.0	3,420	5.0	272.4	16.1	4,219	5.7	299.8	17.8	4,780	6.1	326.5	19.3	5,074
Total Emissions per Shutdown (lbs)	1.8	121.1	7.1	1,442	2.3	163.3	9.5	1,834	2.5	163.5	9.6	1,994	2.6	177.2	10.4	2,119

	Taurus 70 10801S				Mars 90 13002S				Mars 100 16002S				Titan 130 20501S				Titan 250 30002S			
	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2
	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)
Total Emissions per Start (lbs)	7.6	410.3	24.2	6,164	10.5	570.8	33.7	8,641	11.3	583.5	34.6	9,691	13.8	740.4	43.8	11,495	14.6	75.5	7.3	16,253
Total Emissions per Shutdown (lbs)	3.3	223.0	13.0	2,588	4.3	277.0	16.2	3,685	4.8	308.1	18.0	4,056	6.0	405.3	23.7	4,826	6.2	52.6	4.1	7,222

Assumes ISO conditions: 59F, 60% RH, sea level, no losses.

Assumes unit is operating at full load prior to shutdown.

Assumes natural gas fuel; ES 9-98 compliant.

Table 3. Estimation of Start-up and Shutdown Emissions (lbs/event) for SoLoNOx CS/MD Applications
10 Minute Start-up and 10 Minute Shutdown
Natural Gas Fuel

Data will NOT be warranted under any circumstances

	Centaur 40 4702S				Centaur 50 6102S				Taurus 60 7802S			
	NOx (lbs)	CO (lbs)	UHC (lbs)	CO2 (lbs)	NOx (lbs)	CO (lbs)	UHC (lbs)	CO2 (lbs)	NOx (lbs)	CO (lbs)	UHC (lbs)	CO2 (lbs)
Total Emissions per Start (lbs)	0.7	64.4	3.7	392	0.8	69.1	4.0	469	0.7	64.3	3.7	410
Total Emissions per Shutdown (lbs)	0.3	30.2	1.7	181	0.4	35.4	2.0	217	0.4	33.0	1.9	204

	Taurus 70 10302S				Mars 90 13002S CSMD				Mars 100 16002S CSMD				Titan 130 20502S				Titan 250 30002S			
	NOx (lbs)	CO (lbs)	UHC (lbs)	CO2 (lbs)	NOx (lbs)	CO (lbs)	UHC (lbs)	CO2 (lbs)	NOx (lbs)	CO (lbs)	UHC (lbs)	CO2 (lbs)	NOx (lbs)	CO (lbs)	UHC (lbs)	CO2 (lbs)	NOx (lbs)	CO (lbs)	UHC (lbs)	CO2 (lbs)
Total Emissions per Start (lbs)	0.8	73.1	4.2	519	1.2	109.3	6.2	805	1.4	123.5	7.1	829	1.9	176.9	10.1	1,161	2.6	26.2	1.7	1,794
Total Emissions per Shutdown (lbs)	1.1	93.4	5.3	575	1.5	132.6	7.6	817	1.7	149.2	8.5	920	2.4	207.6	11.9	1,272	2.9	19.1	1.4	1,918

Assumes ISO conditions: 59F, 60% RH, sea level, no losses.

Assumes unit is operating at full load prior to shutdown.

Assumes natural gas fuel; ES 9-98 compliant.

**Table 4. Estimation of Start-up and Shutdown Emissions (lbs/event) for SoLoNOx Generator Set
10 Minute Start-up and 10 Minute Shutdown
Liquid Fuel (Diesel #2)**

Data will NOT be warranted under any circumstances

	Centaur 40 4701S				Centaur 50 6201S				Taurus 60 7901S			
	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2
	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)
Total Emissions per Start (lbs)	1.3	44.5	7.4	473	1.7	59.0	9.8	601	1.7	59.8	9.9	636
Total Emissions per Shutdown (lbs)	0.6	17.3	2.8	211	0.7	21.2	3.4	256	0.8	23.5	3.8	286

	Taurus 70 10801S				Mars 100 16002S GSC				Titan 130 20501S			
	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2
	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)
Total Emissions per Start (lbs)	2.3	78.5	13.0	823	3.4	114.1	18.8	1,239	4.3	147.5	24.4	1,547
Total Emissions per Shutdown (lbs)	2.5	73.6	12.0	889	3.8	111.4	18.1	1,331	4.7	139.1	22.6	1,677

Assumes ISO conditions: 59F, 60% RH, sea level, no losses.

Assumes unit is operating at full load prior to shutdown.

Assumes #2 Diesel fuel; ES 9-98 compliant.

**Table 5. Estimation of Start-up and Shutdown Emissions (lbs/event) for SoLoNOx Generator Set
60 Minute Start-up and 30 Minute Shutdown
Liquid Fuel (Diesel #2)**

Data will NOT be warranted under any circumstances

	Centaur 40 4701S				Centaur 50 6201S				Taurus 60 7901S			
	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2
	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)
Total Emissions per Start (lbs)	11.7	194.7	30.9	4,255	15.2	271.9	43.3	5,302	14.7	282.6	45.0	5,962
Total Emissions per Shutdown (lbs)	4.4	84.7	13.6	1,816	6.7	164.3	27.0	2,334	6.3	159.0	26.0	2,515

	Taurus 70 10801S				Mars 100 16002S				Titan 130 20501S			
	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2	NOx	CO	UHC	CO2
	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)
Total Emissions per Start (lbs)	18.4	360.3	57.4	7,375	29.1	552.0	87.7	11,685	34.4	677.0	108.0	13,731
Total Emissions per Shutdown (lbs)	8.0	207.8	34.1	3,156	12.3	302.6	49.4	4,970	15.0	388.5	63.7	5,876

Assumes ISO conditions: 59F, 60% RH, sea level, no losses.

Assumes unit is operating at full load prior to shutdown.

Assumes #2 Diesel fuel; ES 9-98 compliant.