

June 29, 2018

BY: OVERNIGHT MAIL & EMAIL

Mr. Patrick Corbett
Central Office
Virginia Department of Environmental Quality
1111 East Main St., Suite 1400
Richmond, VA 23219

Subject: Atlantic Coast Pipeline, L.L.C.
Buckingham Compressor Station
Minor New Source Permit Application Update
Response to June 25, 2018 Information Request

Dear Mr. Corbett:

Atlantic Coast Pipeline, L.L.C. (ACP) filed the original application for the new Buckingham Compressor Station on September 16, 2015 and submitted application updates on May 25, 2016, August 7, 2017, and May 25, 2018 to address changes to the compressor station. ACP previously responded to four information requests. Specifically, ACP responded to a September 5, 2017 information request on October 10, 2017; a November 1, 2017 information request on January 8, 2018; a March 5, 2018 information request on March 13, 2018; and a March 22, 2018 information request on March 29, 2018. The purpose of this letter is to respond to the information requests in your letter dated June 25, 2018. The information requests and responses are provided below with reference to attachments as needed.

- 1. A signed Document Certification Form related to all information:*

Response

The signed Document of Certification Form, as requested, is included in Attachment 1 and signed by the ACP authorized representative, Leslie Hartz.

- 2. Please describe the operation of the following pieces of equipment: station scrubbers as referenced in 4.2.3 and suction separators as shown on the diagram, both in Appendix H of the May 25, 2018 submittal.*

Response

The station scrubbers and suction separators are the same piece of equipment just identified differently in Section 4.2.3 and the diagram in Appendix H. The ultra-efficient suction separator (or station scrubber) device provides a means of removing solid particles, oils, and condensed liquids from the natural gas pipeline upstream of measurement, compression, and processing equipment. The suction separators at the Buckingham Compressor Station are designed for 99.9% particle and droplet removal 0.3 micron and larger from the gas stream throughout its range of operation. Liquids

collected inside the suction separator are then pushed through steel piping to the station's 1,000 gallon hydrocarbon storage tank for collection and removal offsite. These vessels are fitted with liquid level gauges and high liquid level alarms to alert station personnel of any problems with the transfer of liquids to the hydrocarbon storage tank. The vessels are also fitted with a thermal relief valve that complies with the requirements of ASME Boiler and Pressure Vessel Code, Section VIII, Division I UG-119 (Nameplate) and UG-129 (Markings). The Vent Gas Reduction (VGR) system discharges to upstream of the Station Suction Separator so that any VGR compressor lube oil introduced to the gas stream may be removed prior to being reintroduced to the main compressor units.

3. *Please confirm there are no dehydrators at the stationary source (M&R or Compressor Station).*

Response

ACP will not install any dehydration units at the Buckingham Compressor Station or the Woods Corner M&R.

4. *Please explain how the emissions from start-up purging were derived.*

Response

The blowdown/purge volumes for each unit during startup were initially based on conservative numbers provided when the application was initially submitted in 2015. Subsequently, the engineering design of the facility had been finalized and details values of each unit's case piping and operational parameters were determined. Therefore, the purge volumes for each unit associated with the startup of a unit and associated emission estimates were updated accordingly. As previously provided, when a unit shuts down and their case piping is blown down, then at the next startup, the unit's case piping must be purged with natural gas to evacuate any entrained air in the system that cannot be introduced into the transmission pipeline. Based on the updated values, the purge volumes were estimated on the amount of gas required to purge the units case piping, approximately 2 to 3 times the volume of each units case piping.

5. *Please explain how the 280 scf natural gas emissions per capped event was derived.*

Response

Previously, ACP had provided a total volume of gas released during a full test of the Emergency Shutdown (ESD) system that would occur once every 5 years with a capped ESD system test occurring the other years. Subsequently, ACP has now committed to conducting all of the ESD system tests utilizing the capped method. Based on this commitment, the maximum annual gas released is significantly reduced when conducting these tests.

Block valves will be permanently installed immediately downstream of the ESD blowdown valve. During the capped ESD test, these block valves are closed and the ESD test is initiated to ensure that the ESD blowdown valves have moved to the correct

position. Once the test has been documented and the ESD blowdown valves demonstrated to have worked properly, the ESD blowdown valves are closed and the gas trapped between the ESD blowdown valves and the block valve is released through the a vent valve by opening the ESD blowdown valves. Therefore, the only gas released from the system during a capped ESD test is the gas trapped in the piping between the ESD blowdown valves and the block valve. That volume of gas released is the based on the pipe diameter and pressure of the gas between the valves.

6. *Please fix the inconsistency between Appendix C, Tables C-3A and C-3B with respect to the volume of gas vented during shutdown and the piping pressure used to calculate the values.*

Response

The volume of gas presented in Table C-3B of the emission calculations associated with the blowdown of the units has been corrected to reflect the blowdown volume based on 1,400 psig (1,414.7 psia). The updated potential emission calculations (Appendix C of the Application) are presented in Attachment 2.

7. *Please explain in detail the decision matrix for delaying repair of a leak if the delay has less impact than a venting event, as described in the leak detection and repair procedure outlined on page 51 of the May 25, 2018 application.*

Response

In accordance with updated application for the Buckingham Compressor Station submitted on May 25, 2018, ACP proposed a compliance demonstration methodology for the Vent Gas Reduction (VGR) system to ensure the system is operating as designed—free of leaks and effective at holding turbine(s) in a pressurized hold mode. As described in Section 7 on page 51 of the updated application, the VGR system will be inspected annually utilizing an optical gas imaging device (e.g. FLIR camera). Leaks identified during the inspection will be repaired as soon as practicable. A first attempt to repair will be conducted no later than 5 calendar days after the leak is detected and the repair will be completed no later than 30 calendar days after lead is detected. Leaks may be placed on delay of repair (DoR) in the event that the leak or defect has been detected and is technically infeasible to repair without a shutdown, or if it is determined that emissions resulting from the immediate repair would be greater than the fugitive emissions likely to result from delay of repair.

Therefore, if a leak is detected, ACP will evaluate if the repair can be made within the 30 calendar days without having to shutdown the station/units or if a blowdown is required to make the repair. If a shutdown of the station/units is required that affects operations then leaking component will be placed on DoR until the station/unit can be shutdown not affecting operational demands. If a blowdown is required to make the repair, then (1) an estimated leak rate will be determined, (2) the estimated volume of gas required to be

released to blowdown the system will be determined, and (3) when the next unit shutdown for maintenance is scheduled. If the estimated gas released associated with the leak occurring until the next scheduled shutdown are less than the amount of gas required to be released to blowdown the system, then of the leaking component will be placed on DoR until the next scheduled shutdown to avoid an additional blowdown and the associated increased emissions.

8. *Please explain why there are differences between the turbine specifications on the vendor SCR design sheet submitted on May 25, 2018 versus the previously submitted design sheet. Please confirm the correct specification sheet to be used.*

Response

As part of the May 25, 2018 application, Dominion updated the emissions data for the Solar combustion turbines. These values were obtained from the turbine manufacturer, Solar and the control device manufacturer (Peerless) to ensure the most up to date design values were relied upon in the application, including the reflection of lower overall NO_x and CO emissions specifications for the units.

Specifically, Dominion requested that Solar confirm / provide final design pre-control performance expectations. These data [e.g. pre-control exhaust gas data (flowrate, temperature, composition) and pre-control mass emission rates (NO_x and CO, in lb/hr)] are the data used by Peerless in their data sheets and performance predictions. The new SCR design sheet also reflects the updated control efficiencies for SCR (~58% NO_x reduction to achieve 3.75 ppm) and Oxidation Catalyst (92% CO reduction to achieve 2 ppm).

Finally, the new SCR design sheet includes a load (50%, 75%, and 100%) and temperature (<0, 0, 59, and 100 deg. F) analysis to show stack parameters used for emissions modeling, where the previous SCR design sheet only included data for 100% load at 0 deg. F and 100 deg. F.

The SCR design sheet submitted in the May 25, 2018 application is the correct specification sheet to be used and is attached (for convenience) in Attachment 3 included with this response.

9. *PIL-170 has been updated with regard to emissions from start-up and shutdown. Please explain why the older information is more appropriate for the stationary source. If ACP determines the new information is more appropriate, please update the calculations.*

Response

ACP utilized the most current Product Information Letter (PIL) 170 “*Emission Estimates at Start-up, Shutdown, and Commissioning for SoLoNO_x Combustion Products*”, Revision 5, 13 June 2012, for emissions associated with start-up and shutdown at the time the initial application was submitted in September 16, 2015. For consistency purposes

these emission rates from PIL 170 Revision 5 were used throughout the various submittals. After discussions with Solar, they indicated that the most current PIL 170 to utilize for the turbines to be installed at the Buckingham Compressor Station is PIL 170 Revision 8, 21 February 2018. Therefore, the emissions associated with start-up and shutdown for the turbines have been updated based on the emission rates provided in the PIL 170 Revision 8, 21 February 2018. The associated emissions calculations have been updated accordingly and are presented in Attachment 2. Also, included in Attachment 3 is the updated PIL 170 Revision 8, 21 February 2018.

10. *Please ensure the calculations for venting events are based on the absolute pressure in the piping and provide that pressure for each calculation.*

Response

All of the calculations that ACP has previously provided associated with venting events were based on absolute pressure. The pressure values indicated in the emission calculations is the gauge pressure; however, when volumes of gas are estimated they are adjusted to absolute pressure. The potential emission calculations (Appendix C of the Application) have been updated to show gauge and the associated absolute pressure as presented in Attachment 2.

In addition to the information provided above, ACP would like to further discuss conditions that DEQ may wish to establish in the air permit associated with pigging operations. These operations are associated with maintenance activities for the reliable and safe operations of pipelines. They occur very infrequently, approximately once every five (5) to seven (7) years and the emissions associated with these events will be very small, less than 1 ton VOC. When pigging operations are conducted, the procedure to inspect the line typically involves four (4) pigging devices and is conducted over a four days period. The four (4) pigging events typically consist of one (1) to two (2) cleaning pigs, a caliper pig, and a smart pig. In the event the line needs an additional cleaning pig to inspect the line or the caliper/smart pig needs to be rerun, ACP does not wish to be restricted to four (4) events in any 12 month period. This type of condition could result in a potential maintenance issue in which we are not able to effectively conduct an inspection of the pipeline to ensure the safe reliability of the pipeline operations. Therefore, since emissions associated with this activity are de minimis in nature, ACP requests that the emissions from these operations be estimated, recorded and included with the actual annual emissions for the station to demonstrate that ACP is in compliance with the station's annual VOC potential-to-emit. However, if DEQ wishes to have a specific limit associated with the pigging operations, then ACP suggests that VOC emissions from pigging operations shall not exceed 2.7 tons per year. This limit corresponds with the emission limit recently established in the Pennsylvania Department of Environmental Protection's recently issued General Permit GP-5 for Natural Gas Compression Stations, Processing Plants, and Transmission Stations. If the emissions are estimated to exceed 2.7 tons per year then ACP would be required to use an add-on control to control emissions as needed to comply with the VOC emission limit of 2.7 tons of VOC per year.

Mr. Patrick Corbett
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June 29, 2018
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If you have questions about this submittal, please do not hesitate to contact Mr. T.R. Andrade at (804) 273-2882 or at Thomas.R.Andrake@dominionenergy.com.

Sincerely,



Richard Gangle
Director Environmental Services

RG/tra

Attachments: Attachment 1 – Document Certification Statement
Attachment 2 – Potential Emissions Calculations (Appendix C of the Application)
Attachment 3 – SCR Vendor Design Specification Sheet
Attachment 4 – Solar PIL 170 Revision 8, 21 February 2018


CC: Ms. Cheryl Mayo, Virginia Department of Environmental Quality

Attachment 1
Document Certification Statement

DOCUMENT CERTIFICATION STATEMENT

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering and evaluating the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

I certify that I understand that the existence of a permit under [Article 6 of the Regulations] does not shield the source from potential enforcement of any regulation of the board governing the major NSR program and does not relieve the source of the responsibility to comply with any applicable provision of the major NSR regulations.

SIGNATURE:  DATE: 6/29/18

NAME: Leslie Hartz

TITLE: VP Pipeline Construction

COMPANY: Atlantic Coast Pipeline, LLC

PHONE: (804) 771-4468

EMAIL: Leslie.hartz@dominionenergy.com

ADDRESS: 707 E. Main Street
Richmond, VA 23219

Attachment 2
Potential Emissions Calculations
(Appendix C of the Application)

Table C-1 Permit to Construct Application Project Equipment List
ACP Buckingham Compressor Station - Buckingham County, Virginia

Emission Point ID	Source	Manufacturer	Model/Type	Rated Capacity
CT-01	Compressor Turbine	Solar Turbines	Mars 100-16000S	15,900 hp
CT-02	Compressor Turbine	Solar Turbines	Taurus 70-10802S	11,107 hp
CT-03	Compressor Turbine	Solar Turbines	Titan 130-20502S	20,500 hp
CT-04	Compressor Turbine	Solar Turbines	Centaur 50-6200LS	6,276 hp
WH-01	Boiler	Hurst	S45-G-152-60W	6.384 MMBtu/hr
LH-01	Line Heater	ETI	WB HTR	21.22 MMBtu/hr
LH-02	Line Heater	ETI	WB HTR	21.22 MMBtu/hr
LH-03	Line Heater	ETI	WB HTR	21.22 MMBtu/hr
LH-04	Line Heater	ETI	WB HTR	21.22 MMBtu/hr
EG-01	Emergency Generator	Caterpillar	G3516C	2,175 hp
FUG-01	Fugitive Leaks - Blowdowns	-	-	-
FUG-02	Fugitive Leaks - Piping	-	-	-
TK-1	Accumulator Tank	-	-	2,500 gal
TK-2	Hydrocarbon (Waste Oil) Tank	--	--	1,000 gal
TK-3	Ammonia Tank	--	--	13,400 gal

Notes:

1. The rated capacity for the compressor turbines represents the ISO rated capacity.

Table C-2 Potential Emissions From Combustion Sources
ACP Buckingham Compressor Station - Buckingham County, Virginia

Turbine Operational Parameters:

Normal Hours of Operation:	8,722
Hours at Low Load (<50%):	0
Hours of Low Temp. (< 0 deg. F):	5
Hours of Start-up/Shut-down:	33.3
Total Hours of Operation (hr/yr):	8,760

Emergency Generator Operational Hours:

Normal Hours of Operation:	500
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Boiler/Heater Operational Parameters:

Normal Hours of Operation:	8,760
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Pre-Control Potential to Emit

Combustion Sources	Power Rating	Units	Fuel	Criteria Pollutants (tpy)								GHG Emissions (tpy)				Ammonia (tpy)	HAP (tpy)
				NOx	CO	VOC	SO2	PMF	PMF-10	PMF-2.5	PMC	CO2	CH4	N2O	CO2e	NH3	Total HAP
Solar Mars 100 Turbine	15,900	hp	Natural Gas	20.4	34.6	1.98	2.12	3.58	3.58	3.58	8.86	74,015	5.35	1.87	74,705	8.09	1.73
Solar Taurus 70 Turbine	11,107	hp	Natural Gas	13.5	22.8	1.31	1.40	2.37	2.37	2.37	5.85	48,856	3.53	1.23	49,312	5.75	1.14
Solar Titan 130 Turbine	20,500	hp	Natural Gas	24.8	41.9	2.40	2.57	4.34	4.34	4.34	10.7	89,662	6.49	2.26	90,499	10.2	2.09
Solar Centaur 50L Turbine	6,276	hp	Natural Gas	8.68	14.6	0.838	0.897	1.52	1.52	1.52	3.76	31,420	2.27	0.792	31,713	3.57	0.732
Hurst S45 Boiler	6.384	MMBtu/hr	Natural Gas	1.37	2.30	0.151	0.091	0.052	0.052	0.052	0.156	3,290	0.063	0.060	3,309	0	0.052
ETI Line Heater 1 (Woods Corner)	21.22	MMBtu/hr	Natural Gas	0.929	3.44	0.501	0.304	0.112	0.112	0.112	0.335	10,935	0.210	0.200	11,000	0	0.172
ETI Line Heater 2 (Woods Corner)	21.22	MMBtu/hr	Natural Gas	0.929	3.44	0.501	0.304	0.112	0.112	0.112	0.335	10,935	0.210	0.200	11,000	0	0.172
ETI Line Heater 3 (Woods Corner)	21.22	MMBtu/hr	Natural Gas	0.929	3.44	0.501	0.304	0.112	0.112	0.112	0.335	10,935	0.210	0.200	11,000	0	0.172
ETI Line Heater 4 (Woods Corner)	21.22	MMBtu/hr	Natural Gas	0.929	3.44	0.501	0.304	0.112	0.112	0.112	0.335	10,935	0.210	0.200	11,000	0	0.172
Caterpillar G3516C EGen (Woods Corner)	2,175	hp	Natural Gas	0.599	2.40	0.599	0.012	0.144	0.144	0.144	0.037	531	4.80	0	651	0	0.657
Total (tons/yr)				73.1	132	9.27	8.29	12.5	12.5	12.5	30.8	291,513	23.3	7.02	294,187	27.6	7.09

Turbine Control Efficiencies

Control Technology	NOx	CO	VOC
Selective Catalytic Reduction	58%	-	-
Oxidation Catalyst	-	92%	50%

Post-Control Potential to Emit

Combustion Sources	Power Rating	Units	Fuel	Criteria Pollutants (tpy)								GHG Emissions (tpy)				Ammonia (tpy)	HAP (tpy)
				NOx	CO	VOC	SO2	PMF	PMF-10	PMF-2.5	PMC	CO2	CH4	N2O	CO2e	NH3	Total HAP
Solar Mars 100 Turbine	15,900	hp	Natural Gas	8.52	2.77	0.989	2.12	3.58	3.58	3.58	8.86	74,015	5.35	1.87	74,705	8.09	0.863
Solar Taurus 70 Turbine	11,107	hp	Natural Gas	5.63	1.83	0.653	1.40	2.37	2.37	2.37	5.85	48,856	3.53	1.23	49,312	5.75	0.570
Solar Titan 130 Turbine	20,500	hp	Natural Gas	10.3	3.35	1.20	2.57	4.34	4.34	4.34	10.7	89,662	6.49	2.26	90,499	10.2	1.05
Solar Centaur 50L Turbine	6,276	hp	Natural Gas	3.62	1.17	0.419	0.897	1.52	1.52	1.52	3.76	31,420	2.27	0.792	31,713	3.57	0.366
Hurst S45 Boiler	6.384	MMBtu/hr	Natural Gas	1.37	2.30	0.151	0.091	0.052	0.052	0.052	0.156	3,290	0.063	0.060	3,309	0	0.052
ETI Line Heater 1 (Woods Corner)	21.22	MMBtu/hr	Natural Gas	0.929	3.44	0.501	0.304	0.112	0.112	0.112	0.335	10,935	0.210	0.200	11,000	0	0.172
ETI Line Heater 2 (Woods Corner)	21.22	MMBtu/hr	Natural Gas	0.929	3.44	0.501	0.304	0.112	0.112	0.112	0.335	10,935	0.210	0.200	11,000	0	0.172
ETI Line Heater 3 (Woods Corner)	21.22	MMBtu/hr	Natural Gas	0.929	3.44	0.501	0.304	0.112	0.112	0.112	0.335	10,935	0.210	0.200	11,000	0	0.172
ETI Line Heater 4 (Woods Corner)	21.22	MMBtu/hr	Natural Gas	0.929	3.44	0.501	0.304	0.112	0.112	0.112	0.335	10,935	0.210	0.200	11,000	0	0.172
Caterpillar G3516C EGen (Woods Corner)	2,175	hp	Natural Gas	0.599	2.40	0.599	0.012	0.144	0.144	0.144	0.037	531	4.80	0	651	0	0.657
Total (tons/yr)				33.8	27.6	6.01	8.29	12.5	12.5	12.5	30.8	291,513	23.3	7.02	294,187	27.6	4.24

Notes:

- Turbine emissions are calculated by the following formula: ER * Run Hours / 2000 * (1 - Control Efficiency)
 ER = Emission Rate for particular equipment and pollutant (lbs/hr)
 2000 = The amount of lbs in a ton
- Caterpillar G3516C EGen emissions are calculated by the following formula: Power Rating * Run Hours * EF / 2000
 Power Rating = Engine rating (hp)
 EF = Emission Factor from either manufacturer's data or AP-42 (lb/hp-hr)
 2000 = The amount of lbs in a ton
- Hurst S45 Boiler and ETI Line Heater emissions calculated by the following formula: EF * Power Rating * Run Hours / HHV / 2000
 EF = Emission Factor from either manufacturer's data or AP-42 (lb/MMscf)
 Power Rating = Boiler/Heater heat capacity (MMBtu/hr)
 HHV = Natural Gas High Heating Value (1020 MMBtu/MMscf)
 2000 = The amount of lbs in a ton
- Turbines are equipped with Selective Catalytic Reduction (SCR) and oxidation catalyst for control of NOx (58%), CO (92%), and VOC (50%)
- Caterpillar G3516C EGen hp taken from manufacturer data
- Hurst S45 Boiler assumed to have low-NOx burners
- See the "HAP Emissions" worksheet for a more detailed breakdown of HAP emissions
- See Emissions Factors table for Emissions Factors for each operating scenario
- Each start-up/shut-down event assumed to last 10 minutes

Table C-3A Event Based Potential Emissions From Combustion Sources
ACP Buckingham Compressor Station - Buckingham County, Virginia

Startup Emissions

Combustion Sources	Power Rating	Units	Fuel	Startup Events	Criteria Pollutants (tpy)								GHG Emissions (tpy)				Ammonia	HAP
					NOx	CO	VOC	SO2	PMF	PMF-10	PMF-2.5	PMC	CO2	CH4	N2O	CO2e	NH3	Total HAP
Solar Mars 100 Turbine	15,900	hp	Natural Gas	100	0.050	2.30	0.200	5.00E-04	8.64E-04	8.64E-04	8.64E-04	0.002	19.3	0.800	0.004	40.3	0.015	0.130
Solar Taurus 70 Turbine	11,107	hp	Natural Gas	100	0.050	4.40	0.900	5.00E-04	8.64E-04	8.64E-04	8.64E-04	0.002	19.1	3.50	0.007	108	0.011	0.245
Solar Titan 130 Turbine	20,500	hp	Natural Gas	100	0.050	2.75	0.350	0.001	0.002	0.002	0.002	0.004	33.1	1.50	0.004	71.8	0.019	0.150
Solar Centaur 50L Turbine	6,276	hp	Natural Gas	100	0.015	1.05	0.150	5.00E-04	4.32E-04	4.32E-04	4.32E-04	0.001	9.20	0.700	0.002	27.1	0.007	0.060
Total (tons/yr)					0.165	10.5	1.60	0.003	0.004	0.004	0.004	0.009	80.6	6.50	0.016	248	0.053	0.585

Shutdown Emissions

Combustion Sources	Power Rating	Units	Fuel	Shutdown Events	Criteria Pollutants (tpy)								GHG Emissions (tpy)				Ammonia	HAP
					NOx	CO	VOC	SO2	PMF	PMF-10	PMF-2.5	PMC	CO2	CH4	N2O	CO2e	NH3	Total HAP
Solar Mars 100 Turbine	15,900	hp	Natural Gas	100	0.050	0.328	0.125	0.001	0.001	0.001	0.001	0.004	33.8	1.05	0.007	62.0	0.015	0.115
Solar Taurus 70 Turbine	11,107	hp	Natural Gas	100	0.050	0.248	0.200	5.00E-04	0.001	0.001	0.001	0.002	23.7	1.60	0.005	65.0	0.011	0.085
Solar Titan 130 Turbine	20,500	hp	Natural Gas	100	0.100	0.364	0.225	0.002	0.002	0.002	0.002	0.005	47.3	1.85	0.007	95.6	0.019	0.128
Solar Centaur 50L Turbine	6,276	hp	Natural Gas	100	0.050	0.148	0.125	5.00E-04	7.20E-04	7.20E-04	7.20E-04	0.002	15.9	0.900	0.003	39.3	0.007	0.050
Total (tons/yr)					0.250	1.09	0.675	0.004	0.005	0.005	0.005	0.013	121	5.40	0.021	262	0.053	0.378
Total SUSD Emissions (tons/yr)					0.415	11.6	2.28	0.006	0.009	0.009	0.009	0.022	201	11.9	0.037	510	0.105	0.963

Compressor Blowdown Emissions - Controlled

Source Designation:	FUG-01
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Blowdown Startup Events (April 2018 Update: Values updated to reflect compressor purge volumes)

		CT-01	CT-02	CT-03	CT-04
Blowdown from Startup	scf/event	3,768	1,884	4,083	1,095
Volumetric flow rate	scf-lbmol	385	385	385	385
Gas Molecular Weight	lb-lbmol	17.17	17.17	17.17	17.17
Startup Blowdown	lb/event	168	84.0	182	48.8

Blowdown Shutdown Events (December 2017 Update: Values updated to reflect VGR system limiting blowdown volume, based on blowing down from 30 PSIG [44.7 PSIA])

		CT-01	CT-02	CT-03	CT-04
Blowdown from Shutdown	scf/event	12,087	5,142	13,443	2,600
Volumetric flow rate	scf-lbmol	385	385	385	385
Methane Molecular Weight	lb-lbmol	17.17	17.17	17.17	17.17
Shutdown Blowdown	lb/event	539	229	600	116

Gas Composition

Pollutant	Molecular Weight (lb/lb-mol)	Molar (Volume) Fraction (mol%)	Wt. Fraction ^[1] (wt. %)
Total Stream Molecular Weight	17.17		
Non-VOC			
Carbon Dioxide	44.01	1.041%	2.67%
Nitrogen	28.01	0.994%	1.62%
Methane	16.04	94.206%	88.00%
Ethane	30.07	2.923%	5.12%
VOC			
Propane	44.10	0.546%	1.40%
n-Butane	58.12	0.084%	0.28%
IsoButane	58.12	0.079%	0.27%
n-Pentane	72.15	0.022%	0.09%
IsoPentane	72.15	0.024%	0.10%
n-Hexane	86.18	0.032%	0.16%
n-Heptane	100.21	0.049%	0.29%
Total VOC Fraction	53.28	0.836%	2.59%
Total HAP Fraction	86.18	0.032%	0.16%

Table C-3A Event Based Potential Emissions From Combustion Sources
ACP Buckingham Compressor Station - Buckingham County, Virginia

Blowdown from Startup Events

Combustion Sources	Startup Events	VOC	GHG Emissions (tpy)			HAPs
			CO2	CH4	CO2e	
Solar Mars 100 Turbine	10	0.022	0.022	0.739	18.5	0.001
Solar Taurus 70 Turbine	10	0.011	0.011	0.370	9.25	6.75E-04
Solar Titan 130 Turbine	10	0.024	0.024	0.801	20.1	0.001
Solar Centaur 50L Turbine	10	0.006	0.007	0.215	5.38	3.92E-04
Total (tons/yr)		0.063	0.064	2.13	53.2	0.004

Blowdown from Shutdown Events

Combustion Sources	Shutdown Events	VOC	GHG Emissions (tpy)			HAPs
			CO2	CH4	CO2e	
Solar Mars 100 Turbine	10	0.070	0.072	2.37	59.4	0.004
Solar Taurus 70 Turbine	10	0.030	0.031	1.01	25.3	0.002
Solar Titan 130 Turbine	10	0.078	0.080	2.64	66.0	0.005
Solar Centaur 50L Turbine	10	0.015	0.015	0.510	12.8	9.31E-04
Total (tons/yr)		0.192	0.198	6.53	163	0.012

Site-Wide Blowdown Events (April 2018 Update: The gas vented from the site wide blowdown event reflects the amount vented during a capped event for testing of the ESD system.)

Site-Wide Blowdown	280	scf/event
Volumetric flow rate	385	scf-lbmol
Site-Wide Blowdown	12.5	lb/event

Blowdown from Site-Wide Events

Sources	Site-Wide Events	VOC	GHG Emissions (tpy)			HAPs
			CO2	CH4	CO2e	
ACP-2	1	1.62E-04	1.67E-04	0.005	0.138	1.00E-05
Total (tons/yr)		1.62E-04	1.67E-04	0.005	0.138	1.00E-05

Blowdown from Pigging Events (June 2018 Update: Values based on 1200 PSIG [1214.7 PSIA])

Gas Vented Per Launcher Event	1,563	lb/event
Gas Vented Per Receiver Event	1,630	lb/event

Sources	Pigging Events	VOC	GHG Emissions (tpy)			HAPs
			CO2	CH4	CO2e	
Pig Launcher	4	0.081	0.083	2.75	68.9	0.005
Pig Receiver	4	0.085	0.087	2.87	71.8	0.005
Total (tons/yr)		0.166	0.170	5.62	141	0.010

Total Blowdown Emissions (ton/yr)	0.421	0.433	14.3	357	0.026
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Total Uncontrolled Blowdown Emissions (ton/yr)	64.1	65.9	2,174	54,412	3.97
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Total Blowdown Emission Control Efficiency	99.3%	99.3%	99.3%	99.3%	99.3%
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Table C-3B Potential Uncontrolled Emissions From Blowdowns
ACP Buckingham Compressor Station - Buckingham County, Virginia

Compressor Blowdown Emissions - Uncontrolled

Source Designation:	FUG-01
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Blowdown Startup Events (April 2018 Update: Values updated to reflect compressor purge volumes)

		CT-01	CT-02	CT-03	CT-04
Blowdown from Startup	scf/event	3,768	1,884	4,083	1,095
Volumetric flow rate	scf-lbmol	385	385	385	385
Gas Molecular Weight	lb-lbmol	17.17	17.17	17.17	17.17
Startup Blowdown	lb/event	168	84.0	182	48.8

Blowdown Shutdown Events (May 2018 Update: Values updated to reflect blowdown volume, based on blowing down from 1400 PSIG [1414.7 PSIA])

		CT-01	CT-02	CT-03	CT-04
Blowdown from Shutdown	scf/event	382,546	162,739	425,469	82,284
Volumetric flow rate	scf-lbmol	385	385	385	385
Methane Molecular Weight	lb-lbmol	17.17	17.17	17.17	17.17
Shutdown Blowdown	lb/event	17,062	7,258	18,977	3,670

Gas Composition

Pollutant	Molecular Weight (lb/lb-mol)	Molar (Volume) Fraction (mol%)	Wt. Fraction ⁽¹⁾ (wt. %)
Total Stream Molecular Weight	17.17		
Non-VOC			
Carbon Dioxide	44.01	1.041%	2.67%
Nitrogen	28.01	0.994%	1.62%
Methane	16.04	94.206%	88.00%
Ethane	30.07	2.923%	5.12%
VOC			
Propane	44.10	0.546%	1.40%
n-Butane	58.12	0.084%	0.28%
Isobutane	58.12	0.079%	0.27%
n-Pentane	72.15	0.022%	0.09%
IsoPentane	72.15	0.024%	0.10%
n-Hexane	86.18	0.032%	0.16%
n-Heptane	100.21	0.049%	0.29%
Total VOC Fraction	53.28	0.836%	2.59%
Total HAP Fraction	86.18	0.032%	0.16%

Blowdown from Startup Events

Combustion Sources	Startup Events	VOC	GHG Emissions (tpy)			HAPs
			CO2	CH4	CO2e	
Solar Mars 100 Turbine	100	0.218	0.224	7.39	185	0.013
Solar Taurus 70 Turbine	100	0.109	0.112	3.70	92.5	0.007
Solar Titan 130 Turbine	100	0.236	0.243	8.01	201	0.015
Solar Centaur 50L Turbine	100	0.063	0.065	2.15	53.8	0.004
Total (tons/yr)		0.626	0.644	21.3	532	0.039

Blowdown from Shutdown Events

Combustion Sources	Shutdown Events	VOC	GHG Emissions (tpy)			HAPs
			CO2	CH4	CO2e	
Solar Mars 100 Turbine	100	22.1	22.8	751	18,791	1.37
Solar Taurus 70 Turbine	100	9.41	9.68	319	7,994	0.583
Solar Titan 130 Turbine	100	24.6	25.3	835	20,899	1.52
Solar Centaur 50L Turbine	100	4.78	4.90	161	4,042	0.295
Total (tons/yr)		60.9	62.7	2,067	51,725	3.771

Site-Wide Blowdown Events (December 2017 Update: Total potential site-wide blowdown event volume updated based detailed design and reflects all equipment and piping at the station pressurized to maximum extent prior to the event. This site wide event occurs once every 5 years.)
 Values based on blowing down from 1400 PSIG [1414.7 PSIA].

Site-Wide Blowdown	4,100,000	scf/event
Volumetric flow rate	385	scf-lbmol
Site-Wide Blowdown	182,866	lb/event

Blowdown from Site-Wide Events

Sources	Site-Wide Events	VOC	GHG Emissions (tpy)			HAPs
			CO2	CH4	CO2e	
ACP-2	1	2.37	2.44	80.5	2,014	0.147
Total (tons/yr)		2.37	2.44	80.5	2,014	0.147

Blowdown from Pigging Events (June 2018 Update: Values based on 1200 PSIG [1214.7 PSIA])

Gas Vented Per Launcher Event	1,563	lb/event
Gas Vented Per Receiver Event	1,630	lb/event

Sources	Pigging Events	VOC	GHG Emissions (tpy)			HAPs
			CO2	CH4	CO2e	
Pig Launcher	4	0.081	0.083	2.75	68.9	0.005
Pig Receiver	4	0.085	0.087	2.87	71.8	0.005
Total (tons/yr)		0.166	0.170	5.62	141	0.010

Total Blowdown Emissions (tons/yr)	64.1	65.9	2,174	54,412	3.97
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Table C-4 Combustion Source Criteria Pollutant Emission Factors
ACP Buckingham Compressor Station - Buckingham County, Virginia

Solar Turbine Normal Operation Emission Factors (lb/hr)																
Equipment Name	Fuel	Units	NOx	CO	VOC	SO2	PMF	PMF-10	PMF-2.5	PMC	CO2	CH4	N2O	CO2e	NH3	Total HAP
Solar Centaur 50L Turbine	Natural Gas	lb/hr	1.99	3.35	0.192	0.206	0.348	0.348	0.348	0.861	7,201	0.520	0.181	7,268	0.818	0.168
Solar Taurus 70 Turbine	Natural Gas	lb/hr	3.09	5.22	0.299	0.320	0.542	0.542	0.542	1.34	11,197	0.810	0.283	11,301	1.32	0.261
Solar Mars 100 Turbine	Natural Gas	lb/hr	4.67	7.91	0.453	0.485	0.821	0.821	0.821	2.03	16,963	1.23	0.428	17,121	1.85	0.395
Solar Titan 130 Turbine	Natural Gas	lb/hr	5.67	9.58	0.549	0.588	0.996	0.996	0.996	2.46	20,549	1.49	0.519	20,741	2.33	0.479

- Notes
(1) Pre-Control Emission Rates for NOx, CO, VOC, PMF, PMC, and CO2 taken from Solar Turbine Data at 100% load and 0 degrees F
(2) Emission Factors for SO2, CH4, N2O, and HAP taken from AP-42 in (lbs/MMBtu) and multiplied by turbine fuel throughput by Solar Turbine at 100% load and 0 degree F to get Emission Rates
(3) Assume PMF=PMF-10+PMF-2.5; Filterable and Condensable based on Solar Turbine Emission Factor and ratio of AP-42 Table 3.1 factors
(4) NH3 emission rates based on a 10 ppm ammonia slip from the SCR based on manufacturer information
(5) CO2e emission rate calculated by multiplying each GHG (CO2, CH4, N2O) by its Global Warming Potential (GWP) and adding them together
(6) CO2 GWP = 1; CH4 GWP = 25; N2O GWP = 298 [40 CFR Part 98]

Solar Turbine Alternate Operation Emission Factors (lb/hr)								
Equipment Name	Fuel	Units	< 0 degrees F			Solar Turbine Low Load F		
			NOx	CO	VOC	NOx	CO	VOC
Solar Centaur 50L Turbine	Natural Gas	lb/hr	9.27	13.4	0.384	15.4	1,340	7.68
Solar Taurus 70 Turbine	Natural Gas	lb/hr	14.4	20.9	0.598	24.0	2,088	12.0
Solar Mars 100 Turbine	Natural Gas	lb/hr	21.8	31.6	0.906	36.4	3,164	18.1
Solar Titan 130 Turbine	Natural Gas	lb/hr	26.5	38.3	1.10	44.1	3,832	22.0

- Notes
(1) Pre-Control low temperature Emission Rates for NOx, CO, VOC. Conservatively assume 42 ppm NOx, 100 ppm CO, and 5 ppm VOC (10% of UHC) per Table 1 of Solar PIL 167 dated 6/6/2012
(2) Pre-Control low load Emission Rates for NOx, CO, VOC. Conservatively assume 70 ppm NOx, 10,000 ppm CO, and 100 ppm VOC (10% of UHC) per Table 4 of Solar PIL 167 dated 6/6/2012
(3) Alternate Operation Emission Factor = Normal Operation Emission Factor * (ppm alternate operation) / (ppm normal operation)
Example calculation - Centaur 50L NOx (lb/hr) @ < 0 deg. F = 1.99 lb/hr * (42 ppm / 9 ppm) = 9.27 lb/hr

Solar Turbine Start-up Emission Factors (lb/event)																
Equipment Name	Fuel	Units	NOx	CO	VOC	SO2	PMF	PMF-10	PMF-2.5	PMC	CO2	CH4	N2O	CO2e	NH3	Total HAP
Solar Centaur 50L Turbine	Natural Gas	lb/event	0.3	21	3	0.01	0.009	0.009	0.009	0.021	184	14	0.03	543	0.136	1.2
Solar Taurus 70 Turbine	Natural Gas	lb/event	1	88	18	0.01	0.017	0.017	0.017	0.043	381	70	0.13	2,170	0.220	4.9
Solar Mars 100 Turbine	Natural Gas	lb/event	1	46	4	0.01	0.017	0.017	0.017	0.043	385	16	0.07	806	0.309	2.6
Solar Titan 130 Turbine	Natural Gas	lb/event	1	55	7	0.02	0.032	0.032	0.032	0.078	662	30	0.08	1,436	0.388	3.0

- Notes
(1) Start-up Emissions of NOx, CO, VOC, CO2, and CH4 based on Solar Turbines Incorporated Product Information Letter 170: Emission Estimates at Start-up, Shutdown, and Commissioning for SoLoNox Combustion Products (21 February 2018).
(2) Start-up Emissions of SO2, PM, N2O, and HAP based on Solar estimations.
(3) NH3 emission rates based on a 10 ppm ammonia slip from the SCR based on manufacturer information and a start-up duration of 10 minutes.
(4) CO2e emission rate calculated by multiplying each GHG (CO2, CH4, N2O) by its Global Warming Potential (GWP) and adding them together.
(5) CO2 GWP = 1; CH4 GWP = 25; N2O GWP = 298 [40 CFR Part 98].

Solar Turbine Shutdown Emission Factors (lb/event)																
Equipment Name	Fuel	Units	NOx	CO	VOC	SO2	PMF	PMF-10	PMF-2.5	PMC	CO2	CH4	N2O	CO2e	NH3	Total HAP
Solar Centaur 50L Turbine	Natural Gas	lb/event	1	37	5	0.01	0.014	0.014	0.014	0.036	318	18	0.06	786	0.136	2.0
Solar Taurus 70 Turbine	Natural Gas	lb/event	1	62	8	0.01	0.020	0.020	0.020	0.050	473	32	0.09	1,300	0.220	3.4
Solar Mars 100 Turbine	Natural Gas	lb/event	1	82	5	0.02	0.029	0.029	0.029	0.071	676	21	0.13	1,240	0.309	4.6
Solar Titan 130 Turbine	Natural Gas	lb/event	2	91	9	0.03	0.043	0.043	0.043	0.107	945	37	0.14	1,912	0.388	5.1

- Notes
(1) Shut-down Emissions of NOx, CO, VOC, CO2, and CH4 based on Solar Turbines Incorporated Product Information Letter 170: Emission Estimates at Start-up, Shutdown, and Commissioning for SoLoNox Combustion Products (21 February 2018).
(2) Shut-down Emissions of SO2, PM, N2O, and HAP based on Solar estimations.
(3) NH3 emission rates based on a 10 ppm ammonia slip from the SCR based on manufacturer information and a shut-down duration of 10 minutes.
(4) CO2e emission rate calculated by multiplying each GHG (CO2, CH4, N2O) by its Global Warming Potential (GWP) and adding them together.
(5) CO2 GWP = 1; CH4 GWP = 25; N2O GWP = 298 [40 CFR Part 98].

Engine and Boiler Emission Factors																
Equipment Type	Fuel	Units	NOx	CO	VOC	SO2	PMF	PMF-10	PMF-2.5	PMC	CO2	CH4	N2O	CO2e	NH3	Total HAP
Hurst S45 Boiler	Natural Gas	lb/MMscf	50	84	5.5	3.33	1.9	1.9	1.9	5.7	120,000	2.3	2.2	120,713	0	1.89
ETI Line Heater	Natural Gas	lb/MMscf	10.2	37.7	5.5	3.33	1.22	1.22	1.22	3.67	120,000	2.3	2.2	120,713	0	1.89
Caterpillar G3516C EGen	Natural Gas	lb/hp-hr	1.10E-03	4.41E-03	1.10E-03	2.25E-05	2.65E-04	2.65E-04	2.65E-04	6.84E-05	0.977	8.82E-03	0	1.20	0	1.21E-03

- Notes
(1) Emission factors for Hurst S45 Boiler taken from AP-42 Tables 1.4-1 & 1.4-2
(2) Hurst S45 Boiler assumed to have low-NOx burners
(3) NOx, CO, PMF, PMF-10, PMF-2.5, and PMC emission factors for ETI Line Heater provided by ETI and converted to lb/MMscf using 1020 MMBtu/MMscf
(4) For ETI Line Heater, assumed 75% of PM is PMC and 25% of PM is PMF; based on ratio of PMF and PMC emission factors from AP-42 Table 1.4-2
(5) VOC, SO2, CO2, CH4, and N2O emission factors for ETI Line Heater from AP-42 Table 1.4-2
(6) NOx, CO, VOC, CO2, and CH4 emission factors for Caterpillar EGen taken from Caterpillar manufacturer data
(7) SO2, PMF, PMF-10, PMF-2.5, PMC, and N2O emission factors for Caterpillar EGen taken from AP-42 Table 3.2-1 and converted using Caterpillar manufacturer fuel data
(8) Assume PMF=PMF-10+PMF-2.5
(9) CO2e emission rate calculated by multiplying each GHG (CO2, CH4, N2O) by its Global Warming Potential (GWP) and adding them together
(10) CO2 GWP = 1; CH4 GWP = 25; N2O GWP = 298 [40 CFR 98]
(11) See the "HAP Emissions" worksheet for a more detailed breakdown of HAP emissions
(12) SO2 emission factors for Hurst S45 Boiler, ETI Line Heater, and Caterpillar EGen were scaled up based on the sulfur content of the natural gas.

Table C-4 Combustion Source Criteria Pollutant Emission Factors
ACP Buckingham Compressor Station - Buckingham County, Virginia

Controlled Solar Turbine Normal Operation Emission Factors (lb/hr)						
Equipment Name	Fuel	Units	NOx	CO	VOC	Total HAP
Solar Centaur 50L Turbine	Natural Gas	lb/hr	0.828	0.268	0.096	0.084
Solar Taurus 70 Turbine	Natural Gas	lb/hr	1.29	0.418	0.150	0.131
Solar Mars 100 Turbine	Natural Gas	lb/hr	1.95	0.633	0.227	0.198
Solar Titan 130 Turbine	Natural Gas	lb/hr	2.36	0.766	0.275	0.240

Notes

- Control efficiency of SCR and Oxidation Catalyst applied during normal operations.

Controlled Solar Turbine Alternate Operation Emission Factors (lb/hr)								
Equipment Name	Fuel	Units	< 0 degrees F			Solar Turbine Low Load F Operation		
			NOx	CO	VOC	NOx	CO	VOC
Solar Centaur 50L Turbine	Natural Gas	lb/hr	3.86	1.07	0.192	6.44	107	3.84
Solar Taurus 70 Turbine	Natural Gas	lb/hr	6.01	1.67	0.299	10.0	167	5.98
Solar Mars 100 Turbine	Natural Gas	lb/hr	9.09	2.53	0.453	15.1	253	9.06
Solar Titan 130 Turbine	Natural Gas	lb/hr	11.0	3.07	0.549	18.4	307	11.0

Notes

- Control efficiency of SCR and Oxidation Catalyst applied during low temperature (< 0 deg. F) and low load operations.

Controlled Solar Turbine Start-up Emission Factors						
Equipment Name	Fuel	Units	NOx	CO	VOC	Total HAP
Solar Centaur 50L Turbine	Natural Gas	lb/event	0.3	21	3	1.2
Solar Taurus 70 Turbine	Natural Gas	lb/event	1	88	18	4.9
Solar Mars 100 Turbine	Natural Gas	lb/event	1	46	4	2.6
Solar Titan 130 Turbine	Natural Gas	lb/event	1	55	7	3.0
Solar Centaur 50L Turbine	Natural Gas	lb/hr	0.990	21.9	3.16	1.27
Solar Taurus 70 Turbine	Natural Gas	lb/hr	2.07	89.4	18.2	5.01
Solar Mars 100 Turbine	Natural Gas	lb/hr	2.62	48.1	4.38	2.76
Solar Titan 130 Turbine	Natural Gas	lb/hr	2.97	57.6	7.46	3.20

Notes

- Control efficiency of SCR and Oxidation Catalyst not applied during start-up operations.
- Lb/hr rates based on one start-up event (10 minutes) and 50 minutes of normal (NOx, HAP) or low temperature operation (CO, VOC)

Controlled Solar Turbine Shutdown Emission Factors						
Equipment Name	Fuel	Units	NOx	CO	VOC	Total HAP
Solar Centaur 50L Turbine	Natural Gas	lb/event	1	2.96	2.50	1.00
Solar Taurus 70 Turbine	Natural Gas	lb/event	1	4.96	4.00	1.70
Solar Mars 100 Turbine	Natural Gas	lb/event	1	6.56	2.50	2.30
Solar Titan 130 Turbine	Natural Gas	lb/event	2	7.28	4.50	2.55
Solar Centaur 50L Turbine	Natural Gas	lb/hr	1.69	3.85	2.66	1.07
Solar Taurus 70 Turbine	Natural Gas	lb/hr	2.07	6.35	4.25	1.81
Solar Mars 100 Turbine	Natural Gas	lb/hr	2.62	8.67	2.88	2.46
Solar Titan 130 Turbine	Natural Gas	lb/hr	3.97	9.83	4.96	2.75

Notes

- Control efficiency of SCR not applied during shutdown operations.
- Control efficiency of Oxidation Catalyst applied during shutdown operations.
- Lb/hr rates based on one shutdown event (10 minutes) and 50 minutes of normal (NOx, HAP) or low temperature operation (CO, VOC)

**Table C-5 Hazardous Air Pollutant (HAP) Emissions From Combustion Sources
ACP Buckingham Compressor Station - Buckingham County, Virginia**

		Annual HAP Emissions (lb/yr)						
Quantity @ ACP-2		1	1	1	1	1	4	1
Pollutant	HAP?	Solar Centaur 50L Turbine	Solar Titan 130 Turbine	Solar Taurus 70 Turbine	Solar Mars 100 Turbine	Hurst S45 Boiler	ETI Line Heater	Caterpillar G3516C Egen
		6,276 hp	20,500 hp	11,107 hp	15,900 hp	6.384 MMBTU/hr	21.22 MMBTU/hr	2,175 bhp
Methanol	Yes							6.862
Methylcyclohexane	No							0.935
Methylene Chloride	Yes							0.407
n-Nonane	No							0.085
n-Octane	No							0.206
Naphthalene	Yes					0.033	0.111	0.266
PAH	Yes							0.371
Pentane (or n-Pentane)	No					142.551	473.830	4.234
Perylene	No							0.000
Phenanthrene	No					0.001	0.003	0.010
Phenol	Yes							0.116
Propane	No					87.724	291.588	79.413
Propylene Oxide	Yes							
Pyrene	No					0.000	0.001	0.002
Styrene	Yes							0.152
Tetrachloroethane	No							
Toluene	Yes					0.186	0.620	2.665
Vinyl Chloride	Yes							0.068
Xylene	Yes							0.742
Arsenic	Yes					0.011	0.036	
Barium	No					0.241	0.802	
Beryllium	Yes					0.001	0.002	
Cadmium	Yes					0.060	0.200	
Chromium	Yes					0.077	0.255	
Cobalt	Yes					0.005	0.015	
Copper	No					0.047	0.155	
Manganese	Yes					0.021	0.069	
Mercury	Yes					0.014	0.047	
Molybdenum	No					0.060	0.200	
Nickel	Yes					0.115	0.383	
Selenium	Yes					0.001	0.004	
Vanadium	No					0.126	0.419	
Zinc	No					1.590	5.285	
Lead	Yes					0.027	0.091	
Total HAPs		734.478	2,100.035	1,143.798	1,731.861			1,314.305
Total HAP/unit (lb/yr)		734	2,100	1,144	1,732	104	344	1,314
Total HAP/unit (TPY)		0.367	1.05	0.572	0.866	0.052	0.172	0.657

Hazardous Air Pollutant

Notes:

- (1) Emissions above are on a per unit basis
- (2) Calculations for the Caterpillar G3516C Egen assume 500 hours of operation; all other calculations assume 8,760 hours of operation
- (3) Heat rates for Solar Turbines taken from Solar Datasheets
- (4) Solar turbines have a 50% HAP control efficiency due to the Oxidation Catalyst

Table C-6 Combustion Source HAP Emission Factors
ACP Buckingham Compressor Station - Buckingham County, Virginia

Pollutant	HAP?	Solar Centaur 50L Turbine	Solar Titan 130 Turbine	Solar Taurus 70 Turbine	Solar Mars 100 Turbine	Hurst S45 Boiler; ETI Line Heater	Caterpillar G3516C Egen
		lb/MMBtu	lb/MMBtu	lb/MMBtu	lb/MMBtu	lb/MMscf	lb/hp-hr
1,1,2,2-Tetrachloroethane	Yes						1.69E-07
1,1,2-Trichloroethane	Yes						1.34E-07
1,1-Dichloroethane	Yes						9.95E-08
1,2,3-Trimethylbenzene	No						9.01E-08
1,2,4-Trimethylbenzene	No						2.82E-07
1,2-Dichloroethane	Yes						1.07E-07
1,2-Dichloropropane	Yes						1.13E-07
1,3,5-Trimethylbenzene	No						4.58E-08
1,3-Butadiene	Yes						2.09E-06
1,3-Dichloropropene	Yes						1.11E-07
2,2,4-Trimethylpentane	Yes						2.15E-06
2-Methylnaphthalene	No					2.40E-05	5.44E-08
3-Methylchloranthrene	No					1.80E-06	
7,12-Dimethylbenz(a)anthracene	No					1.60E-05	
Acenaphthene	No					1.80E-06	3.38E-09
Acenaphthylene	No					1.80E-06	8.07E-09
Acetaldehyde	Yes						1.97E-05
Acrolein	Yes						1.98E-05
Anthracene	No					2.40E-06	1.83E-09
Benz(a)anthracene	No					1.80E-06	8.55E-10
Benzene	Yes					2.10E-03	4.94E-06
Benzo(a)pyrene	No					1.20E-06	1.45E-11
Benzo(b)fluoranthene	No					1.80E-06	2.17E-11
Benzo(e)pyrene	No						5.95E-11
Benzo(g,h,i)perylene	No					1.20E-06	6.31E-11
Benzo(k)fluoranthene	No					1.80E-06	1.08E-11
Biphenyl	Yes						1.01E-08
Butane	No					2.10E+00	1.21E-05
Butyr/Isobutyraldehyde	No						1.11E-06
Carbon Tetrachloride	Yes						1.54E-07
Chlorobenzene	Yes						1.13E-07
Chloroethane	Yes						
Chloroform	Yes						1.20E-07
Chrysene	No					1.80E-06	1.71E-09
Cyclohexane	No						7.84E-07
Cyclopentane	No						2.41E-07
Dibenzo(a,h)anthracene	No					1.20E-06	
Dichlorobenzene	Yes					1.20E-03	
Ethane	No					3.10E+00	1.80E-04
Ethylbenzene	Yes						2.75E-07
Ethylene Dibromide	Yes						1.87E-07
Fluoranthene	No					3.00E-06	9.19E-10
Fluorene	No					2.80E-06	4.30E-09
Formaldehyde	Yes	2.88E-03	2.88E-03	2.88E-03	2.88E-03	7.50E-02	1.15E-03
Hexane (or n-Hexane)	Yes					1.80E+00	1.13E-06
Indeno(1,2,3-c,d)pyrene	No					1.80E-06	2.53E-11
Isobutane	No						9.54E-06

Table C-6 Combustion Source HAP Emission Factors
ACP Buckingham Compressor Station - Buckingham County, Virginia

Pollutant	HAP?	Solar Centaur 50L Turbine	Solar Titan 130 Turbine	Solar Taurus 70 Turbine	Solar Mars 100 Turbine	Hurst S45 Boiler; ETI Line Heater	Caterpillar G3516C Egen
		lb/MMBtu	lb/MMBtu	lb/MMBtu	lb/MMBtu	lb/MMscf	lb/hp-hr
Methanol	Yes						6.31E-06
Methylcyclohexane	No						8.60E-07
Methylene Chloride	Yes						3.74E-07
n-Nonane	No						7.84E-08
n-Octane	No						1.89E-07
Naphthalene	Yes					6.10E-04	2.45E-07
PAH	Yes						3.41E-07
Pentane (or n-Pentane)	No					2.60E+00	3.89E-06
Perylene	No						1.26E-11
Phenanthrene	No					1.70E-05	8.98E-09
Phenol	Yes						1.07E-07
Propane	No					1.60E+00	7.30E-05
Propylene Oxide	Yes						
Pyrene	No					5.00E-06	1.49E-09
Styrene	Yes						1.39E-07
Tetrachloroethane	No						
Toluene	Yes					3.40E-03	2.45E-06
Vinyl Chloride+A32	Yes						6.28E-08
Xylene	Yes						6.82E-07
Arsenic	Yes					2.00E-04	
Barium	No					4.40E-03	
Beryllium	Yes					1.20E-05	
Cadmium	Yes					1.10E-03	
Chromium	Yes					1.40E-03	
Cobalt	Yes					8.40E-05	
Copper	No					8.50E-04	
Manganese	Yes					3.80E-04	
Mercury	Yes					2.60E-04	
Molybdenum	No					1.10E-03	
Nickel	Yes					2.10E-03	
Selenium	Yes					2.40E-05	
Vanadium	No					2.30E-03	
Zinc	No					2.90E-02	
Lead	Yes					5.00E-04	
Total Haps		3.05E-03	3.05E-03	3.05E-03	3.05E-03	1.89E+00	1.21E-03

Hazardous Air Pollutant

Notes:

- (1) Emission factors for Solar turbines from Solar PIL 168 Revision 4 (dated 14 May 2012)
- (2) Emission factors for Hurst S45 Boiler and ETI Line Heater from AP-42 Tables 1.4-2, 1.4-3, and 1.4-4
- (3) Emission factors for Caterpillar G3516C Egen from AP-42 Table 3.2-1; formaldehyde emission factor from Caterpillar manufacturer data
- (4) Emission factors for Solar natural gas turbines and Caterpillar natural gas emergency generators converted using 1 kWh = 3412 Btu and 1 kw = 1.341 hp

Table C-7 Potential Emissions From Fugitive Leaks
ACP Buckingham Compressor Station - Buckingham County, Virginia

Fugitive Emissions (FUG)

Source Designation:	FUG-02
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Operational Parameters:

Annual Hours of Operation (hr/yr):	8,760
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Pipeline Natural Gas Fugitive Emissions

Equipment	Service	Emission Factor ^[1]	Source Count ^[2]	Total HC Potential Emissions		VOC Weight Fraction	VOC Emissions	CO ₂ Weight Fraction	CO ₂ Emissions	CH ₄ Weight Fraction	CH ₄ Emissions	HAP Weight Fraction	HAP Emissions
		kg/hr/source		lb/hr	tpy	tpy	tpy	tpy	tpy	tpy	tpy	tpy	
Valves	Gas	4.50E-03	755	7.49	32.8	0.026	0.851	0.027	0.875	0.880	28.9	1.61E-03	0.053
Pump Seals	Gas	2.40E-03		0.000	0.000	0.026	0.000	0.027	0.000	0.880	0.000	1.61E-03	0.000
Others (compressors and others)	Gas	8.80E-03	4	0.078	0.340	0.026	0.009	0.027	0.009	0.880	0.299	1.61E-03	5.46E-04
Connectors	Gas	2.00E-04	4	0.002	0.008	0.026	2.00E-04	0.027	2.06E-04	0.880	0.007	1.61E-03	1.24E-05
Flanges	Gas	3.90E-04	509	0.438	1.92	0.026	0.050	0.027	0.051	0.880	1.69	1.61E-03	0.003
Open-ended lines	Gas	2.00E-03		0.000	0.000	0.026	0.000	0.027	0.000	0.880	0.000	1.61E-03	0.000
Total				8.01	35.1	-	0.910	-	0.936	-	30.9	-	0.056

1. EPA Protocol for Equipment Leaks Emissions Estimate (EPA-453/R-95-017) Table 2-4: Oil and Gas Production Operations Emission Factors.
2. Component count based on Basic Systems Engineering Estimate.
3. Source count for fugitive emissions includes equipment from ACP-2 and the Woods Corner M&R station.

Equations:

Potential Emissions (lb/hr) = Emission Factor (kg/hr/source) * Source Count * (2.20462 lb/1 kg)

Potential Emissions (tons/yr) = (lb/hr)_{potential} * Hours of Operation (hr/yr) * (1 ton/2,000 lb)

Gas Composition

Pollutant	Molecular Weight (lb/lb-mol)	Molar (Volume) Fraction (mol %)	Weight Fraction (wt %)
Total Stream Molecular Weight	17.17		
Non-VOC			
Carbon Dioxide	44.01	1.041%	2.67%
Nitrogen	28.01	0.994%	1.62%
Methane	16.04	94.21%	88.00%
Ethane	30.07	2.923%	5.12%
VOC			
Propane	44.10	0.546%	1.40%
n-Butane	58.12	0.084%	0.28%
IsoButane	58.12	0.079%	0.27%
n-Pentane	72.15	0.022%	0.09%
IsoPentane	72.15	0.024%	0.10%
n-Hexane	86.18	0.032%	0.16%
n-Heptane	100.21	0.049%	0.29%
Total VOC Fraction			2.59%
Total HAP Fraction			0.16%

Gas speciation based on a natural gas hydrocarbon composition from Engineering Technology Incorporated Combustion Analysis.

Table C-8A Tank Emissions

ACP Buckingham Compressor Station - Buckingham County, Virginia

Source Designation:	TK-1, TK-2, TK-3
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Tank Parameters

Source	Type of Tank	Contents	Capacity	Throughput	Tank Diam.	Tank Length	Paint Color	Paint Condition
			(gal)	gal/yr	ft	ft		
TK-1	Horizontal, fixed	Lube Oil	2,500	12,500	5.33	15.0	Light Grey	Good
TK-2	Horizontal, fixed	Produced Fluids	1,000	5,000	4.00	9.83	Light Grey	Good

Total Emissions

Source	VOC Emissions								GHG Emissions			
	Flashing Losses		Working Losses		Breathing Losses		Total Losses		CO2		CH4	
	lb/hr	tpy	lb/hr	tpy	lb/hr	tpy	lb/hr	tpy	lb/hr	tpy	lb/hr	tpy
TK-1 ^[1]	NA	NA	9.70E-07	4.25E-06	4.00E-06	1.75E-05	4.97E-06	2.18E-05	0	0	0	0
TK-2 ^[2]	NA	NA					0.033	0.144	0.002	0.009	0.004	0.017

1. Losses were calculated for TK-1 using EPA's TANKS 4.09d software with default breather vent settings.
2. Losses were calculated for TK-2 using E&P Tanks Software. See attached for output.
3. Losses (Emissions) from TK-3 13,400-gallon Ammonia tank assumed to be insignificant.

Table C-8B Tank Unloading Emissions

ACP Buckingham Compressor Station - Buckingham County, Virginia

Source Designation:	LR-1, LR-2
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Chemical Parameters

Chemical	Vapor Mol. Weight ^[1]	Avg. Vapor Pressure ^[1]	Avg. Temperature ^[2]	Saturation Factor ^[3]	Throughput ^[4]
	(lb/lb-mol)	(psia)	(deg. R)		Mgal/yr
Waste Oil	380	0.0001	519.67	0.6	12.5
Pipeline Liquids	65.06	7.7	519.67	0.6	0.500

References:

1. Vapor molecular weight and vapor pressure based on EPA Tanks output for TK-1 and E&P output for TK-2.
2. Based on average ambient temperature data for the area.
3. Saturation Factor based on "Submerged Loading; dedicated normal service" in Table 5.2-1 of AP-42, Ch. 5.2.
4. Throughput based upon expected percent of hydrocarbons. The pipeline liquids tank contains water, with potential for trace oil, estimated at 10% oil max.

Total Potential Emissions

Source	Total Loading Losses ^[1]		Pump Capacity ^[2]	Max Hourly Losses ³
	Average	Annual		
	(lbs/Mgal)	(tpy)	(gal/min)	lb/hr
Waste Oil Truck Loading	5.47E-04	3.42E-06	90	0.001
Pipeline Liquids Truck Loading	7.21	0.002	90	0.720

References:

1. AP-42, Ch. 5.2, Equation 1 (Loading Loss = 12.46 x (Saturation Factor x TVP x Molecular Weight) / Temp.)
2. Assumed pump rate.
3. Emissions based upon expected percent of hydrocarbons in throughput liquid. The pipeline liquids tank contains water with potential for trace oil, estimated at 10% oil max.

Speciated Potential Emissions

Source	Contents	VOC Weight Fraction ^[1] (%)	HAP Weight Fraction ^[1] (%)	Total VOC Emissions		Total HAP Emissions		CO2/VOC Ratio	CH4/VOC Ratio	Total CO2 Emissions		Total CH4 Emissions	
				lb/hr	tpy	lb/hr	tpy			lb/hr	tpy	lb/hr	tpy
Waste Oil Truck Loading	Waste Oil	100%	100%	0.001	3.42E-06	0.001	3.42E-06	---	---	0	0	0	0
Pipeline Liquids Truck Loading	Pipeline Liquids	100%	6.94%	0.720	0.002	0.050	1.25E-04	6.25%	11.8%	0.045	1.13E-04	0.085	2.13E-04

References:

1. VOC and HAP weight fractions are based on TK-1 and TK-2 tank emissions speciation. Assumed 100% HAP for TK-1 to be conservative.
2. CO2/VOC and CH4/VOC Ratios based on TK-1 tank emissions.

Table C-9 Project Potential Emissions

ACP Buckingham Compressor Station - Buckingham County, Virginia

Source	ID	Criteria Pollutants (tpy)								GHG Emissions (tpy)				Ammonia (tpy)	HAP (tpy)
		NOx	CO	VOC	SO2	PMF	PMF-10	PMF-2.5	PMC	CO2	CH4	N2O	CO2e	NH3	Total HAP
Solar Mars 100 Turbine	CT-01	8.62	5.39	1.31	2.12	3.58	3.58	3.58	8.87	74,068	7.20	1.88	74,808	8.12	1.11
Solar Taurus 70 Turbine	CT-02	5.73	6.47	1.75	1.40	2.37	2.37	2.37	5.86	48,899	8.63	1.24	49,485	5.77	0.900
Solar Titan 130 Turbine	CT-03	10.5	6.46	1.77	2.57	4.35	4.35	4.35	10.8	89,742	9.84	2.27	90,666	10.2	1.32
Solar Centaur 50L Turbine	CT-04	3.68	2.37	0.694	0.898	1.52	1.52	1.52	3.76	31,445	3.87	0.796	31,779	3.58	0.476
Hurst S45 Boiler	WH-01	1.37	2.30	0.151	0.091	0.052	0.052	0.052	0.156	3,290	0.063	0.060	3,309	0	0.052
ETI Line Heater 1 (Woods Corner)	LH-01	0.929	3.44	0.501	0.304	0.112	0.112	0.112	0.335	10,935	0.210	0.200	11,000	0	0.172
ETI Line Heater 2 (Woods Corner)	LH-02	0.929	3.44	0.501	0.304	0.112	0.112	0.112	0.335	10,935	0.210	0.200	11,000	0	0.172
ETI Line Heater 3 (Woods Corner)	LH-03	0.929	3.44	0.501	0.304	0.112	0.112	0.112	0.335	10,935	0.210	0.200	11,000	0	0.172
ETI Line Heater 4 (Woods Corner)	LH-04	0.929	3.44	0.501	0.304	0.112	0.112	0.112	0.335	10,935	0.210	0.200	11,000	0	0.172
Caterpillar G3516C EGen (Woods Corner)	EG-01	0.599	2.40	0.599	0.012	0.144	0.144	0.144	0.037	531	4.80	0	651	0	0.657
Fugitive Leaks - Blowdowns	FUG-01	-	-	0.421	-	-	-	-	-	0.433	14.3	-	357	-	0.026
Fugitive Leaks - Piping	FUG-02	-	-	0.910	-	-	-	-	-	0.936	30.9	-	772	-	0.056
Accumulator (Waste Oil) Tank	TK-1	-	-	2.52E-05	-	-	-	-	-	-	-	-	-	-	2.52E-05
Pipeline Fluids Tank	TK-2	-	-	0.146	-	-	-	-	-	0.009	0.017	-	0.439	-	0.010
Total (tons/yr)		34.2	39.2	9.77	8.30	12.5	12.5	12.5	30.8	291,715	80.4	7.05	295,827	27.7	5.30

Source	ID	Criteria Pollutants (lb/hr)								GHG Emissions (lb/hr)				Ammonia (lb/hr)	HAP (lb/hr)
		NOx	CO	VOC	SO2	PMF	PMF-10	PMF-2.5	PMC	CO2	CH4	N2O	CO2e	NH3	Total HAP
Solar Mars 100 Turbine	CT-01	9.09	48.1	4.38	0.485	0.821	0.821	0.821	2.03	16,963	22.0	0.487	17,121	1.85	4.93
Solar Taurus 70 Turbine	CT-02	6.01	89.4	18.2	0.320	0.542	0.542	0.542	1.34	11,197	70.7	0.365	11,588	1.32	5.12
Solar Titan 130 Turbine	CT-03	11.2	57.6	7.46	0.588	0.996	0.996	0.996	2.46	20,549	38.2	0.572	20,741	2.33	5.50
Solar Centaur 50L Turbine	CT-04	4.22	21.9	3.16	0.206	0.348	0.348	0.348	0.861	7,201	18.4	0.211	7,268	0.818	2.14
Hurst S45 Boiler	WH-01	0.313	0.526	0.034	0.021	0.012	0.012	0.012	0.036	751	0.014	0.014	756	0	0.012
ETI Line Heater 1 (Woods Corner)	LH-01	0.212	0.785	0.114	0.069	0.025	0.025	0.025	0.076	2,496	0.048	0.046	2,511	0	0.039
ETI Line Heater 2 (Woods Corner)	LH-02	0.212	0.785	0.114	0.069	0.025	0.025	0.025	0.076	2,496	0.048	0.046	2,511	0	0.039
ETI Line Heater 3 (Woods Corner)	LH-03	0.212	0.785	0.114	0.069	0.025	0.025	0.025	0.076	2,496	0.048	0.046	2,511	0	0.039
ETI Line Heater 4 (Woods Corner)	LH-04	0.212	0.785	0.114	0.069	0.025	0.025	0.025	0.076	2,496	0.048	0.046	2,511	0	0.039
Caterpillar G3516C EGen (Woods Corner)	EG-01	2.40	9.59	2.40	0.049	0.577	0.577	0.577	0.149	2,124	19.2	0	2,604	0	2.63
Fugitive Leaks - Blowdowns	FUG-01	-	-	82.8	-	-	-	-	-	85.2	2,810	-	70,330	-	5.13
Fugitive Leaks - Piping	FUG-02	-	-	0.208	-	-	-	-	-	0.214	7.05	-	176	-	0.013
Accumulator Tank	TK-1	-	-	0.001	-	-	-	-	-	-	-	-	-	-	0.001
Hydrocarbon (Waste Oil) Tank	TK-2	-	-	0.753	-	-	-	-	-	0.045	0.085	-	2.17	-	0.052
Total (lb/hr)¹		34.1	230	120	1.95	3.40	3.40	3.40	7.19	68,857	2,986	1.83	140,630	6.32	25.7

1. Total hourly emission rates represent a worst case value for the purposes of the permit application and do not represent total hourly emissions under normal operation.

Table C-10 Toxic Air Pollutant (TAP) Emissions from Sources Subject to Rule 6-5
ACP Buckingham Compressor Station - Buckingham County, Virginia

Pollutant	CAS No.	TLV (mg/m ³) ¹			Exemption Threshold (ET) ¹	
		TWA	STEL	CEIL	Hourly lb/hr	Annual ton/yr
1,3-Butadiene	106990	22	-	-	1.452	3.19
2,2,4-Trimethylpentane	540841	350	-	-	22.8	50.75
Acetaldehyde	75070	180	270	-	8.91	26.1
Acrolein	107028	0.23	0.69	-	0.02277	0.03335
Benzene	71432	32	-	-	2.112	4.64
Ethylbenzene	100414	434	543	-	17.919	62.93
Formaldehyde	50000	1.2	2.5	-	0.0825	0.174
Hexane	110543	176	-	-	11.616	25.52
Naphthalene	91203	52	79	-	2.607	7.54
PAH ²	---	52	79	-	2.607	7.54
Propylene Oxide	75569	48	-	-	3.168	6.96
Toluene	108883	377	565	-	18.645	54.665
Xylenes	1330207	434	651	-	21.483	62.93

Pollutant	Potential Hourly Emissions (lb/hr) ³												Total	ET	
	CT-01	CT-02	CT-03	CT-04	Stn. Suctn. 1	Stn. Suctn. 2	Stn. Dischrg. 1	Stn. Dischrg. 2	Launcher	Receiver	TK-1	TK-2			
1,3-Butadiene	2.94E-04	4.22E-04	2.31E-04	1.45E-04	---	---	---	---	---	---	---	---	---	0.001	1.452
2,2,4-Trimethylpentane	---	---	---	---	---	---	---	---	---	---	0.001	0.000	---	0.001	22.8
Acetaldehyde	0.027	0.039	0.022	0.014	---	---	---	---	---	---	---	---	---	0.102	8.91
Acrolein	0.004	0.006	0.003	0.002	---	---	---	---	---	---	---	---	---	0.016	0.02277
Benzene	0.008	0.012	0.006	0.004	---	---	---	---	---	---	0.001	0.000	---	0.032	2.112
Ethylbenzene	0.022	0.031	0.017	0.011	---	---	---	---	---	---	0.001	0.000	---	0.083	17.919
Formaldehyde	2.56	4.70	3.09	1.17	---	---	---	---	---	---	---	---	---	11.5	0.0825
Hexane ⁴	0.003	0.003	0.003	0.003	---	---	---	---	---	2.62	0.001	0.002	---	2.63	11.616
Naphthalene	8.90E-04	0.001	7.00E-04	4.39E-04	---	---	---	---	---	---	---	---	---	0.003	2.607
PAH	0.002	0.002	0.001	7.44E-04	---	---	---	---	---	---	---	---	---	0.006	2.607
Propylene Oxide	0.020	0.028	0.016	0.010	---	---	---	---	---	---	---	---	---	0.074	3.168
Toluene	0.089	0.128	0.070	0.044	---	---	---	---	---	---	0.001	0.000	---	0.332	18.645
Xylenes	0.044	0.063	0.034	0.022	---	---	---	---	---	---	0.001	0.000	---	0.164	21.483

Pollutant	Potential Annual Emissions (ton/yr) ³												Total	ET	
	CT-01	CT-02	CT-03	CT-04	Stn. Suctn. 1	Stn. Suctn. 2	Stn. Dischrg. 1	Stn. Dischrg. 2	Launcher	Receiver	TK-1	TK-2			
1,3-Butadiene	1.45E-04	1.07E-04	1.64E-04	6.17E-05	---	---	---	---	---	---	---	---	---	4.79E-04	3.19
2,2,4-Trimethylpentane	---	---	---	---	---	---	---	---	---	---	2.52E-05	0.000	---	2.52E-05	50.75
Acetaldehyde	0.014	0.010	0.015	0.006	---	---	---	---	---	---	---	---	---	0.045	26.1
Acrolein	0.002	0.002	0.002	9.19E-04	---	---	---	---	---	---	---	---	---	0.007	0.03335
Benzene	0.004	0.003	0.005	0.002	---	---	---	---	---	---	2.52E-05	0.000	---	0.013	4.64
Ethylbenzene	0.011	0.008	0.012	0.005	---	---	---	---	---	---	2.52E-05	0.000	---	0.036	62.93
Formaldehyde	1.04	0.848	1.25	0.448	---	---	---	---	---	---	---	---	---	3.59	0.174
Hexane ⁴	0.020	0.017	0.020	0.015	1.91E-06	1.91E-06	1.55E-06	1.55E-06	0.005	0.005	2.52E-05	0.010	---	0.092	25.52
Naphthalene	4.39E-04	3.25E-04	4.97E-04	1.87E-04	---	---	---	---	---	---	---	---	---	0.001	7.54
PAH	7.44E-04	5.50E-04	8.41E-04	3.16E-04	---	---	---	---	---	---	---	---	---	0.002	7.54
Propylene Oxide	0.010	0.007	0.011	0.004	---	---	---	---	---	---	---	---	---	0.032	6.96
Toluene	0.044	0.032	0.050	0.019	---	---	---	---	---	---	2.52E-05	0.000	---	0.145	54.665
Xylenes	0.022	0.016	0.024	0.009	---	---	---	---	---	---	2.52E-05	0.000	---	0.071	62.93

Table C-10 Toxic Air Pollutant (TAP) Emissions from Sources Subject to Rule 6-5
ACP Buckingham Compressor Station - Buckingham County, Virginia

Emissions Modeling Summary							
Unit/Stack ID	Formaldehyde		Hexane				
	lb/hr	ton/yr	Normal	Startup	Shutdown	Pig Launching	Pig Receiving
			lb/hr	lb/hr	lb/hr	lb/hr	lb/hr
CT-01	2.56	1.04	---	---	---	---	---
CT-02	4.70	0.848	---	---	---	---	---
CT-03	3.09	1.25	---	---	---	---	---
CT-04	1.17	0.448	---	---	---	---	---
CT Bldg. A ⁵	---	---	0.006	0.006	0.006	0.006	0.006
CT Bldg. B ⁵	---	---	0.006	0.006	0.006	0.006	0.006
CT-01 Vent	---	---	---	0.270	0.866	---	---
CT-02 Vent	---	---	---	0.135	0.368	---	---
CT-03 Vent	---	---	---	0.292	0.963	---	---
CT-04 Vent	---	---	---	0.078	0.186	---	---
Launcher	---	---	---	---	---	2.51	---
Receiver	---	---	---	---	---	---	2.62
WH-01	4.69E-04	0.002	0.011	0.011	0.011	0.011	0.011
LH-01	0.002	0.007	0.037	0.037	0.037	0.037	0.037
LH-02	0.002	0.007	0.037	0.037	0.037	0.037	0.037
LH-03	0.002	0.007	0.037	0.037	0.037	0.037	0.037
LH-04	0.002	0.007	0.037	0.037	0.037	0.037	0.037
EG-01	2.49	0.623	0.002	0.002	0.002	0.002	0.002
TK-1	---	---	0.001	0.001	0.001	0.001	0.001
TK-2	---	---	0.002	0.002	0.002	0.002	0.002
TOTAL	14.0	4.24	0.180	0.956	2.56	2.69	2.80

Key:

Potential Emissions Exceed Exemption Threshold

Notes:

1. TLV and ET values from "Toxics_Spreadsheet.xlsx", downloaded from the Virginia DEQ - Air Toxics website.
2. PAH not listed in Virginia DEQ toxics spreadsheet; to be conservative, assumed the same TLV and ET values as naphthalene.
3. Calculated as follows:
 CT-01 through CT-04; Stn. Suctn. 1 and 2; Stn. Dischrg. 1 and 2; Launcher and Receiver: From Tables C-11 and C-12.
 TK-1: From E&P Tanks.
 TK-2: HAP composition unknown; assumed 100% of VOC emissions for each HAP commonly emitted from hydrocarbon tanks.
4. Turbine hourly rates are from fugitive emissions. Maximum event emissions occur during pig receiving events. Startup, shutdown, sitewide, launching, and receiving events would not coincide in the same hour. For TK-1, assumed all loading rack HAP emissions are hexane.
5. Each compressor building houses two turbines. Fugitive emissions are emitted from building vents instead of the turbine combustion exhaust.

Table C-11 Toxic Air Pollutant (TAP) Emissions from Combustion Turbines - Combustion
ACP Buckingham Compressor Station - Buckingham County, Virginia

Hourly Emissions - Normal Operations						
Pollutant	CAS No.	Emission Factor (lb/MMBtu) ¹	Emission Rates (lb/hr) ^{2,3}			
			CT-01	CT-02	CT-03	CT-04
			129.64	85.62	157.2	54.98
			MMBtu/hr	MMBtu/hr	MMBtu/hr	MMBtu/hr
1,3-Butadiene	106990	4.30E-07	2.79E-05	1.84E-05	3.38E-05	1.18E-05
Acetaldehyde	75070	4.00E-05	0.003	0.002	0.003	0.001
Acrolein	107028	6.40E-06	4.15E-04	2.74E-04	5.03E-04	1.76E-04
Benzene	71432	1.20E-05	7.78E-04	5.14E-04	9.43E-04	3.30E-04
Ethylbenzene	100414	3.20E-05	0.002	0.001	0.003	8.80E-04
Formaldehyde	50000	2.88E-03	0.187	0.123	0.226	0.079
Naphthalene	91203	1.30E-06	8.43E-05	5.57E-05	1.02E-04	3.57E-05
PAH	---	2.20E-06	1.43E-04	9.42E-05	1.73E-04	6.05E-05
Propylene Oxide	75569	2.90E-05	0.002	0.001	0.002	7.97E-04
Toluene	108883	1.30E-04	0.008	0.006	0.010	0.004
Xylenes	1330207	6.40E-05	0.004	0.003	0.005	0.002

Event Emissions - Startup						
Pollutant	CAS No.		Emission Rates (lb/event) ⁴			
			CT-01	CT-02	CT-03	CT-04
			2.6	4.9	3.0	1.2
Total HAP	---		2.6	4.9	3.0	1.2
Formaldehyde	50000		2.4	4.6	2.9	1.1
Non-Formaldehyde HAP	---		0.2	0.3	0.1	0.1

Event Emissions - Startup						
Pollutant	CAS No.	Non-Formaldehyde HAP Composition ⁵	Emission Rates (lb/event) ⁶			
			CT-01	CT-02	CT-03	CT-04
			2.71E-04	4.07E-04	1.36E-04	1.36E-04
1,3-Butadiene	106990	0.136%	2.71E-04	4.07E-04	1.36E-04	1.36E-04
Acetaldehyde	75070	12.6%	0.025	0.038	0.013	0.013
Acrolein	107028	2.02%	0.004	0.006	0.002	0.002
Benzene	71432	3.78%	0.008	0.011	0.004	0.004
Ethylbenzene	100414	10.1%	0.020	0.030	0.010	0.010
Formaldehyde	50000	---	2.40	4.60	2.90	1.10
Naphthalene	91203	0.410%	8.19E-04	0.001	4.10E-04	4.10E-04
PAH	---	0.693%	0.001	0.002	6.93E-04	6.93E-04
Propylene Oxide	75569	9.14%	0.018	0.027	0.009	0.009
Toluene	108883	41.0%	0.082	0.123	0.041	0.041
Xylenes	1330207	20.2%	0.040	0.061	0.020	0.020

Event Emissions - Shutdown						
Pollutant	CAS No.		Emission Rates (lb/event) ⁴			
			CT-01	CT-02	CT-03	CT-04
			4.6	3.4	5.1	2.0
Total HAP	---		4.6	3.4	5.1	2.0
Formaldehyde	50000		4.3	3.2	4.8	1.9
Non-Formaldehyde HAP	---		0.3	0.2	0.3	0.1

Event Emissions - Shutdown						
Pollutant	CAS No.	Non-Formaldehyde HAP Composition ⁵	Emission Rates (lb/event) ^{6,7}			
			CT-01	CT-02	CT-03	CT-04
			2.03E-04	1.36E-04	2.03E-04	6.78E-05
1,3-Butadiene	106990	0.136%	2.03E-04	1.36E-04	2.03E-04	6.78E-05
Acetaldehyde	75070	12.6%	0.019	0.013	0.019	0.006
Acrolein	107028	2.02%	0.003	0.002	0.003	0.001
Benzene	71432	3.78%	0.006	0.004	0.006	0.002
Ethylbenzene	100414	10.1%	0.015	0.010	0.015	0.005
Formaldehyde	50000	---	2.15	1.60	2.40	0.950
Naphthalene	91203	0.410%	6.15E-04	4.10E-04	6.15E-04	2.05E-04
PAH	---	0.693%	0.001	6.93E-04	0.001	3.47E-04
Propylene Oxide	75569	9.14%	0.014	0.009	0.014	0.005
Toluene	108883	41.0%	0.061	0.041	0.061	0.020
Xylenes	1330207	20.2%	0.030	0.020	0.030	0.010

Total HAP Emission Factor (lb/MMBtu)	
AP-42	1.03E-03
Solar Data	3.05E-03

Formaldehyde Emission Factor (lb/MMBtu)	
AP-42	7.10E-04
Solar Data	2.88E-03

Non-Formaldehyde HAP Emission Factor (lb/MMBtu)	
AP-42	3.17E-04
Solar Data	1.70E-04

VOC Control Device Efficiency ¹⁰	
Ox. Cat.	50%

Worst Case Schedule (hr/yr) ¹⁰	
Normal Ops.	8,726.7
Startup	16.7
Shutdown	16.7

Max. Events (event/yr) ¹¹	
Startup	100
Shutdown	100

Table C-11 Toxic Air Pollutant (TAP) Emissions from Combustion Turbines - Combustion
ACP Buckingham Compressor Station - Buckingham County, Virginia

Maximum Hourly Emissions						
Pollutant	CAS No.		Emission Rates (lb/hr) ⁸			
			CT-01	CT-02	CT-03	CT-04
1,3-Butadiene	106990		2.94E-04	4.22E-04	2.31E-04	1.45E-04
Acetaldehyde	75070		0.027	0.039	0.022	0.014
Acrolein	107028		0.004	0.006	0.003	0.002
Benzene	71432		0.008	0.012	0.006	0.004
Ethylbenzene	100414		0.022	0.031	0.017	0.011
Formaldehyde	50000		2.56	4.70	3.09	1.17
Naphthalene	91203		8.90E-04	0.001	7.00E-04	4.39E-04
PAH	---		0.002	0.002	0.001	7.44E-04
Propylene Oxide	75569		0.020	0.028	0.016	0.010
Toluene	108883		0.089	0.128	0.070	0.044
Xylenes	1330207		0.044	0.063	0.034	0.022

Maximum Annual Emissions						
Pollutant	CAS No.		Emission Rates (ton/yr) ⁹			
			CT-01	CT-02	CT-03	CT-04
1,3-Butadiene	106990		1.45E-04	1.07E-04	1.64E-04	6.17E-05
Acetaldehyde	75070		0.014	0.010	0.015	0.006
Acrolein	107028		0.002	0.002	0.002	9.19E-04
Benzene	71432		0.004	0.003	0.005	0.002
Ethylbenzene	100414		0.011	0.008	0.012	0.005
Formaldehyde	50000		1.04	0.848	1.25	0.448
Naphthalene	91203		4.39E-04	3.25E-04	4.97E-04	1.87E-04
PAH	---		7.44E-04	5.50E-04	8.41E-04	3.16E-04
Propylene Oxide	75569		0.010	0.007	0.011	0.004
Toluene	108883		0.044	0.032	0.050	0.019
Xylenes	1330207		0.022	0.016	0.024	0.009

Notes:

- Emission factors (except formaldehyde) from AP-42 Chapter 3, Section 3.1, Table 3.1-3. Formaldehyde emission factor from Solar PIL 168 Revision 4 (dated 14 May 2012)
- Calculated as: [Fuel Flow (MMBtu/hr) * Emission Factor (lb/MMBtu) * (1 - Control Efficiency)]
- Based on lower heating value (LHV) of fuel in Solar Turbines Emissions Estimates.
- Based on Solar estimations.
- Calculated based on AP-42 Chapter 3, Section 3.1, Table 3.1-3 emission factors. An example is shown below for toluene.
 Non-Formaldehyde HAP Composition of Toluene:
 = Toluene Emission Factor / Total Non-Formaldehyde HAP Emission Factor
 = 1.30E-04 lb/MMBtu / 3.17E-04 lb/MMBtu
 = 41.0%
- Calculated as (except for formaldehyde): [Non-Formaldehyde HAP Composition * Non-Formaldehyde HAP Emission Rate (lb/event)]
- Assume oxidation catalyst control for shutdown events.
- Emissions from startup and shutdown events are higher than emissions from normal operations. Startup and shutdown events are 10 minutes in duration each. However, only one startup or shutdown event would occur in a given hour. Therefore, maximum hourly emissions are calculated as the maximum of the following:
 [Startup Event Emission Rate (lb/event) * 1 event/hr + Normal Operation Emission Rate (lb/hr) * 1 hr / 60 min * 50 min]
 [Shutdown Event Emission Rate (lb/event) * 1 event/hr + Normal Operation Emission Rate (lb/hr) * 1 hr / 60 min * 50 min]
- Calculated as: [Normal Operations Emission Rate (lb/hr) * Worst-Case Normal Operations Schedule (hr/yr) + Startup Emission Rate (lb/event) * Max. Startup Events (event/yr) + Shutdown Emission Rate (lb/event) * Max. Shutdown Events (event/yr)] * 1 ton/2,000 lb
- From Table C-2.
- From Table C-3.

Table C-12 Toxic Air Pollutant (TAP) Emissions from Combustion Turbines - Blowdowns & Fugitives
ACP Buckingham Compressor Station - Buckingham County, Virginia

Hexane Emissions - Blowdown from Startup Events				
Parameter	CT-01 Vent	CT-02 Vent	CT-03 Vent	CT-04 Vent
Blowdown Gas (lb/event) ¹	168	84.0	182	48.8
Hexane Emissions (lb/event) ²	0.270	0.135	0.292	0.078

Hexane Emissions - Blowdown from Shutdown Events				
Parameter	CT-01 Vent	CT-02 Vent	CT-03 Vent	CT-04 Vent
Blowdown Gas (lb/event) ¹	539	229	600	116
Hexane Emissions (lb/event) ²	0.866	0.368	0.963	0.186

Hexane Emissions - Blowdown from Sitewide Events								
Parameter	CT-01 Vent	CT-02 Vent	CT-03 Vent	CT-04 Vent	Stn. Suctn. 1	Stn. Suctn. 2	Stn. Dischrg. 1	Stn. Dischrg. 2
Blowdown Gas (lb/event) ³	1.37	0.624	1.62	0.250	2.37	2.37	1.94	1.94
Hexane Emissions (lb/event) ²	0.002	0.001	0.003	4.01E-04	0.004	0.004	0.003	0.003

Hexane Emissions - Fugitive Leaks				
Parameter	CT-01	CT-02	CT-03	CT-04
Fugitive Leak Gas (lb/hr) ⁴	2.00	2.00	2.00	2.00
Hexane Emissions (lb/hr) ⁵	0.003	0.003	0.003	0.003

Hexane Emissions - Pigging Events		
Parameter	Launcher	Receiver
Fugitive Leak Gas (lb/event) ¹	1,563	1,630
Hexane Emissions (lb/event) ²	2.51	2.62

Maximum Hourly Hexane Emissions - Blowdowns and Pigging										
Parameter	CT-01 Vent	CT-02 Vent	CT-03 Vent	CT-04 Vent	Stn. Suctn. 1	Stn. Suctn. 2	Stn. Dischrg. 1	Stn. Dischrg. 2	Launcher	Receiver
Hexane Emissions (lb/hr) ⁶	---	---	---	---	---	---	---	---	---	2.62

Maximum Hourly Hexane Emissions - Fugitives				
Parameter	CT-01	CT-02	CT-03	CT-04
Hexane Emissions (lb/hr)	0.003	0.003	0.003	0.003

Maximum Annual Hexane Emissions - Blowdowns and Pigging										
Parameter	CT-01 Vent	CT-02 Vent	CT-03 Vent	CT-04 Vent	Stn. Suctn. 1	Stn. Suctn. 2	Stn. Dischrg. 1	Stn. Dischrg. 2	Launcher	Receiver
Hexane Emissions (ton/yr) ⁷	0.006	0.003	0.006	0.001	1.91E-06	1.91E-06	1.55E-06	1.55E-06	0.005	0.005

Maximum Annual Hexane Emissions - Fugitives				
Parameter	CT-01	CT-02	CT-03	CT-04
Hexane Emissions (ton/yr) ⁸	0.014	0.014	0.014	0.014

Notes:

- From Table C-3.
- Calculated as: [Blowdown Gas * Hexane Gas Composition]
- Calculated as: [Maximum Sitewide Blowdown Gas * Sitewide Blowdown Gas Stack Distribution].
- From Table C-7. Distributed the total facility-wide fugitive leaks evenly across each turbine.
- Calculated as: [Fugitive Leak Gas * Hexane Gas Composition]
- Maximum event emissions occur during pig receiving events. Startup, shutdown, sitewide, launching, and receiving events would not coincide in the same hour.
- Calculated as: [Startup Event Emissions (lb/event) * Max. Startup Events (event/yr) + Shutdown Event Emissions (lb/event) * Max. Shutdown Events (event/yr) + Sitewide Event Emissions (lb/event) * Max. Sitewide Events (event/yr)] * 1 ton / 2,000 lb
 Launcher and Receiver emissions calculated as: Pigging Event Emissions (lb/event) * Pigging Events (event/yr) * 1 ton / 2,000 lb
- Calculated as: [Fugitive Leak Emissions (lb/hr) * Operating Schedule (hr/yr)] * 1 ton / 2,000 lb
- Based on engineering assumptions. Assumed vol. % is equivalent to wt. %.

Gas Composition (wt. %) ¹	
Hexane	0.161%

Maximum Sitewide Blowdown Gas (lb) ¹	
Per Event	12.5
Per Hour	12.5

Sitewide Blowdown Gas Stack Distribution (wt. %) ⁹	
CT-01 Vent	11%
CT-02 Vent	5%
CT-03 Vent	13%
CT-04 Vent	2%
Stn. Suctn. 1	19%
Stn. Suctn. 2	19%
Stn. Dischrg. 1	15.5%
Stn. Dischrg. 2	15.5%

Max. Blowdown Events (event/yr) ¹	
Startup	10
Shutdown	10
Sitewide	1

Operating Schedule (hr/yr) ⁴	
Fug. Leaks	8,760

Pigging Events (event/yr) ¹	
Pig Launcher	4
Pig Receiver	4

Attachment 3
SCR Vendor Design Specification Sheet

DESIGN SUMMARY (PRIMARY EMISSION SOURCE WITH COOLING AIR SKID)

ENQUIRY DETAILS	
Enquiry Number	700211
Dated Revision	5
Date of Revision	30-Apr-2018
Engineer	B Gletzl
Details of Revision	Update

PROJECT DETAILS	
Project Name	ACP DOM BUCKINGHAM
Client	DOMINION
End Client	ACP-DOMINION
Application	Simple Cycle
Number of SCRs	4

PROCESS DATA		T-70 Buckingham										C-50 Buckingham														
		Case 25	Case 26	Case 27	Case 28	Case 29	Case 30	Case 31	Case 32	Case 33	Case 34	Case 35	Case 36	Case 37	Case 38	Case 39	Case 40	Case 41	Case 42	Case 43	Case 44	Case 45	Case 46	Case 47	Case 48	
Design Case		-20	0	59	100	-20	0	59	100	-20	0	59	100	-20	0	59	100	-20	0	59	100	-20	0	59	100	
Customer Design Case	Percent	50%	50%	50%	50%	75%	75%	75%	75%	100%	100%	100%	100%	50%	50%	50%	50%	75%	75%	75%	75%	100%	100%	100%	100%	
Percent Load	Percent	50%	50%	50%	50%	75%	75%	75%	75%	100%	100%	100%	100%	50%	50%	50%	50%	75%	75%	75%	75%	100%	100%	100%	100%	
Fuel Case		NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	
EXHAUST GAS EMISSIONS DATA (BEFORE COOLING)																										
Exhaust Gas Mass Flowrate, Wet	lb/h	198513	198513	169254	148260	224320	224320	192967	164067	237484	237484	213302	183855	140425	140425	120608	104180	154053	154053	134139	116535	162463	162463	145994	128506	
Exhaust Gas Volumetric Flowrate, Wet	ACFM	113500	113500	102640	94261	126718	126718	114118	102350	132814	132814	127596	115788	77111	77111	70504	63816	85433	85433	78069	71059	91698	91698	88033	80961	
Exhaust Gas Temperature	degrees F	885.0	885.0	962.0	1015.0	868.0	868.0	925.0	986.0	854.0	854.0	940.0	999.0	834.0	834.0	912.0	962.0	845.0	845.0	905.0	955.0	867.0	867.0	952.0	1000.0	
Exhaust Gas Composition																										
Component	MW																									
O2	31.999	vol% (wet)	15.21	15.21	14.85	14.47	14.80	14.80	14.54	14.05	14.36	14.36	14.04	13.63	15.78	15.78	15.42	14.92	15.29	15.29	15.03	14.57	14.75	14.75	14.41	14.03
H2O	18.015	vol% (wet)	5.18	5.18	6.23	8.86	5.54	5.54	6.52	9.24	5.93	5.93	6.96	9.60	4.67	4.67	5.73	8.47	5.11	5.11	6.08	8.78	5.58	5.58	6.62	9.25
N2	28.013	vol% (wet)	76.03	76.03	75.27	73.14	75.89	75.89	75.14	72.99	75.74	74.97	72.86	76.23	76.23	75.46	73.29	76.06	76.06	75.32	73.18	75.88	75.88	75.12	72.99	
CO2	44.010	vol% (wet)	2.67	2.67	2.75	2.65	2.86	2.86	2.90	2.85	3.06	3.06	3.13	3.04	2.41	2.41	2.49	2.44	2.63	2.63	2.67	2.60	2.88	2.88	2.95	2.86
Ar	39.948	vol% (wet)	0.91	0.91	0.90	0.87	0.91	0.91	0.90	0.87	0.91	0.91	0.90	0.87	0.91	0.91	0.90	0.88	0.91	0.91	0.91	0.87	0.91	0.91	0.90	0.87
Emissions from the Source	@ %O2	15	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	
Reference applicable for ppmvd and mg/Nm3 (dry)																										
Nox as NO2	ppmvd	42.00	9.00	9.00	9.00	42.00	9.00	9.00	9.00	42.00	9.00	9.00	9.00	42.00	9.00	9.00	9.00	42.00	9.00	9.00	9.00	42.00	9.00	9.00	9.00	
Nox as NO2	lb/h	10.47	2.24	1.97	1.69	12.68	2.72	2.38	2.01	14.42	3.09	2.84	2.41	6.64	1.42	1.27	1.09	8.01	1.72	1.52	1.30	9.27	1.99	1.84	1.58	
CO	ppmvd	100.00	25.00	25.00	25.00	100.00	25.00	25.00	25.00	100.00	25.00	25.00	25.00	100.00	25.00	25.00	25.00	100.00	25.00	25.00	25.00	100.00	25.00	25.00	25.00	
CO	lb/h	15.16	3.79	3.34	2.85	18.36	4.59	4.02	3.40	20.88	5.22	4.81	4.07	9.64	2.41	2.15	1.84	11.60	2.90	2.57	2.20	13.40	3.35	3.10	2.67	
SO2	ppmvd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
SO2	lb/h	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
SO3	ppmvd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
SO3	lb/h	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
COOLING AIR DATA																										
Cooling Air Mass Flowrate, Wet	lb/h	39162.6	40220.8	58787.0	69699.9	38681.1	39726.3	55325.8	68690.3	36092.4	37067.7	66398.0	76772.4	29407.4	30258.0	45158.4	52457.8	34909.6	35919.5	48566.4	49451.6	42401.2	43627.7	56334.1	56993.6	
Cooling Air Volumetric Flowrate, Wet	ACFM	7236	7767	12763	16141	7147	7672	12011	15907	6668	7158	14415	17778	5433	5843	9804	12148	6450	6937	10544	11452	7834	8425	12230	13198	
Ambient Air Temperature	degrees F	-20.00	0.00	59.00	100.00	-20.00	0.00	59.00	100.00	-20.00	0.00	59.00	100.00	-20.00	0.00	59.00	100.00	-20.00	0.00	59.00	100.00	-20.00	0.00	59.00	100.00	
Relative Humidity	Percent	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	
EXHAUST GAS EMISSIONS DATA (AFTER COOLING)																										
Exhaust Gas Mass Flowrate, Wet	lb/h	237676	238734	228041	217960	263001	264046	248293	232757	273576	274552	279700	260627	169832	170683	165766	156638	188963	189972	182705	165987	204864	206091	202328	185500	
Exhaust Gas Volumetric Flowrate, Wet	ACFM	118270	118792	113674	109329	130984	131499	123894	116892	136378	136859	139636	132046	80936	81338	79137	75250	90114	90591	87280	81576	97751	98330	98804	93129	
Exhaust Gas Temperature (after cooling)	degrees F	750.00	750.00	750.00	750.00	750.00	750.00	750.00	750.00	750.00	750.00	750.00	750.00	750.00	750.00	750.00	750.00	750.00	750.00	750.00	750.00	750.00	750.00	750.00	750.00	
Exhaust Gas Composition																										
Component	MW																									
O2	31.999	vol% (wet)	16.15	16.17	16.36	16.27	15.69	15.71	15.91	15.83	15.22	15.24	15.61	15.53	16.67	16.69	16.86	16.66	16.33	16.35	16.53	16.22	16.02	16.05	16.16	15.89
H2O	18.015	vol% (wet)	4.34	4.33	4.89	7.26	4.74	4.73	5.30	7.66	5.16	5.15	5.56	7.92	3.87	3.86	4.45	6.93	4.18	4.17	4.74	7.32	4.44	4.43	5.07	7.60
N2	28.013	vol% (wet)	76.36	76.36	75.79	73.76	76.20	76.20	75.62	73.61	76.04	76.04	75.52	73.51	76.54	76.54	75.96	73.89	76.42	76.43	75.84	73.74	76.33	76.33	75.72	73.63
CO2	44.010	vol% (wet)	2.24	2.23	2.06	1.82	2.45	2.44	2.27	2.03	2.67	2.66	2.40	2.16	2.00	1.99	1.83	1.64	2.15	2.14	1.97	1.84	2.30	2.28	2.15	2.00
Ar	39.948	vol% (wet)	0.91	0.91	0.91	0.88	0.91	0.91	0.91	0.88	0.91	0.91	0.88	0.91	0.91	0.89	0.91	0.89	0.91	0.91	0.91	0.88	0.91	0.91	0.91	0.88
Emissions from the Source	@ %O2	15	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	
Reference applicable for ppmvd and mg/Nm3 (dry)																										
Nox as NO2	ppmvd	42.00	9.00	9.01	9.04	42.00	9.00	9.01	9.04	42.00	9.00	9.01	9.04	42.00	9.00	9.01	9.04	42.00	9.00	9.01	9.04	42.00	9.00	9.01	9.04	
Nox as NO2	lb/h	10.47	2.24	1.98	1.69	12.70	2.72	2.38	2.01	14.42	3.09	2.84	2.41	6.67	1.43	1.27	1.09	8.01	1.72	1.52	1.30	9.27	1.99	1.84	1.58	
CO	ppmvd	100.00	25.00	25.02	25.11	100.00	25.00	25.02	25.10	100.00	25.00	25.02	25.10	100.00	25.00	25.02	25.10	100.00	25.00	25.02	25.11	100.00	25.00	25.03	25.11	
CO	lb/h	15.18	3.80	3.35	2.86	18.41	4.60	4.02	3.40	20.90	5.23	4.81	4.07	9.66	2.42	2.15	1.85	11.61	2.90	2.57	2.20	13.44	3.36	3.11	2.67	
SO2	ppmvd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
SO2	lb/h	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
SO3	ppmvd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
SO3	lb/h	0.00	0.0																							

Attachment 4

Solar PIL170 “Emission Estimates at Start-up, Shutdown, and Commissioning for SoLoNOx
Combustion Products”, Revision 8, 21 February 2018

Emission Estimates at Start-up, Shutdown, and Commissioning for SoLoNOx 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 *SoLoNOx*[™] dry low emissions combustion systems.¹ 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.

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 estimates related to the start-up, shutdown, and commissioning of combustion turbines will not be warranted. The estimates in this document are based on limited engine testing and analysis. The engine testing was conducted at idle and other non-*SoLoNOx* mode load points. An actual SU/SD event was not measured.

The estimates are most commonly used for potential to emit calculations to determine air permitting status. **Solar discourages customers from accepting the estimates as start-up and shutdown event permit limits with or without source testing requirements.** Accurately measuring emissions during a – non-steady state - start-up or shutdown event with steady state source test methods may prove to be very challenging. In the event customers take permit limits and accept compliance testing permit conditions, Solar recommends adding significant margin to the estimates in this document.

START-UP PROCESS

Combustion turbine start-up occurs in one of three modes: cold, warm, or hot. The nominal start-up duration for a hot, warm, or cold start is the same for a *Solar* turbine.

The start-up and shutdown time for a *Solar* turbine in a simple-cycle or combined heat and power application is the same. 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/ramp-down is not limited. However, some combined heat and power plant applications will desire or dictate longer start-up/shutdown times due to external requirements.

The start-up sequence and attaining *SoLoNOx* combustion mode, takes three steps:

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

¹ Start-up and shutdown emissions estimates for the *Mercury*[™] 50 engine are found in PIL 205.

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 "ignition 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% load² 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 maintain the combustion primary zone temperature and limit pilot fuel to achieve the targeted nitrogen oxides (NOx), carbon monoxide (CO), and unburned hydrocarbons (UHC) emission levels.

SHUTDOWN PROCESS

Normal, planned cool down/shutdown duration varies by engine model. Once the shutdown process starts the engine unloads and moves into a cooldown mode.

START-UP AND SHUTDOWN EMISSIONS ESTIMATES

Tables 1 through 5 summarize the estimated pounds of emissions per start-up and shutdown event for *SoLoNOx* products. The mass emissions estimates are calculated using exhaust characteristics at ISO conditions in conjunction with ppm emissions estimates at various load points. The estimates in Tables 1 and 2 are representative of new production units ordered from 2006 up until the implementation of Enhanced Emissions Control. Tables 3 and 4 summarize emissions estimates for turbine models equipped with Enhanced Emissions Control. Enhanced Emissions Control is a new control regime that will result in lower CO and UHC values at lower loads thus reducing the estimated emissions per start-up and shutdown sequence. The *Titan*[™] 250 and the *Titan* 130 22401/22402 ratings have always been equipped with Enhanced Emissions Control. As testing is completed and other models/ratings are qualified and able to be equipped with the updated controls, PIL170 will be updated. Reference PIL 220, specifically pages 7 and 8, for additional information about Enhanced Emissions Control. Table 5 summarizes start-up and shutdown emissions estimates for liquid fuel applications.

Please contact Environmental Programs, Leslie Witherspoon (858.694.6609) or Anthony Pocengal (858.505.8554) for support.

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, typically includes a number of engine start and shutdown cycles 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 final commissioning during which the turbine is running at various loads.

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This information is intended as a general overview and is not intended to be, and should not be used as, a substitute for obtaining advice in any specific situation. This document is accurate as of the publication date and any discussion of a particular issue may become outdated.

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² 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
Nominal Start-up and Shutdown, Natural Gas Fuel**

Production Units from 2006 and without Enhanced Emissions Control

Data will NOT be warranted under any circumstances.

	Centaur 40 4701S					Centaur 50 6201S					Taurus 60 7901S					Taurus 65 8701S				
	NOx	CO	UHC	VOC	CO2	NOx	CO	UHC	VOC	CO2	NOx	CO	UHC	VOC	CO2	NOx	CO	UHC	VOC	CO2
Total Emissions per Start (lbs)	2	158	83	17	247	1	67	84	17	333	1	86	110	22	338	1	74	67	13	376
Total Emissions per Shutdown (lbs)	2	149	74	15	286	1	65	75	15	367	1	79	92	18	392	1	73	54	11	435

	Taurus 70 10801S					Mars 90 13000S GSC					Mars 100 15000/16000S GSC					Titan 130 20501S				
	NOx	CO	UHC	VOC	CO2	NOx	CO	UHC	VOC	CO2	NOx	CO	UHC	VOC	CO2	NOx	CO	UHC	VOC	CO2
Total Emissions per Start (lbs)	1	78	67	13	544	1	84	41	8	640	1	81	39	8	669	3	172	138	28	832
Total Emissions per Shutdown (lbs)	1	77	52	10	513	1	91	33	7	711	1	91	33	7	775	3	169	111	22	961

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

Assumes unit is operating at >50% 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 CS/MD Applications
Nominal Start-up and Shutdown, Natural Gas Fuel**

Production Units from 2006 and without Enhanced Emissions Control

Data will NOT be warranted under any circumstances.

	Centaur 40 4702S					Centaur 50 6102S					Taurus 60 7802S				
	NOx	CO	UHC	VOC	CO2	NOx	CO	UHC	VOC	CO2	NOx	CO	UHC	VOC	CO2
Total Emissions per Start (lbs)	1	48	24	5	188	0.3	21	17	3	184	0.4	22	17	3	180
Total Emissions per Shutdown (lbs)	1	81	37	7	285	1	37	23	5	318	1	40	25	5	319
	Taurus 70 10802S					Mars 90 13000S CS/MD					Mars 100 15000S/16000S CS/MD				
	NOx	CO	UHC	VOC	CO2	NOx	CO	UHC	VOC	CO2	NOx	CO	UHC	VOC	CO2
Total Emissions per Start (lbs)	1	88	88	18	381	1	45	20	4	437	1	46	20	4	385
Total Emissions per Shutdown (lbs)	1	62	40	8	473	1	79	26	5	674	1	82	26	5	676
	Titan 130 20502S														
	NOx	CO	UHC	VOC	CO2										
Total Emissions per Start (lbs)	1	55	37	7	662										
Total Emissions per Shutdown (lbs)	2	91	46	9	945										

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

Assumes unit is operating at >50% 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 Generator Set Applications
Nominal Start-up and Shutdown, Natural Gas Fuel**

Production Units with Enhanced Emissions Control

Data will NOT be warranted under any circumstances.

	Taurus 70 10801S/11101S GSC (Post 2/2018 Orders)					Mars 100 16000S GSC (Post 8/2017 Orders)				
	NOx (lbs)	CO (lbs)	UHC (lbs)	VOC (lbs)	CO2 (lbs)	NOx (lbs)	CO (lbs)	UHC (lbs)	VOC (lbs)	CO2 (lbs)
Total Emissions per Start (lbs)	1	39	50	10	544	1	31	23	5	669

Total Emissions per Shutdown (lbs)	1	26	32	6	513	1	24	20	4	775
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	Titan 130 20501S GSC (Post 2/2018 Orders)					Titan 130 22401S GSC (All Units)					Titan 250 30000S GSC (All Units)				
	NOx (lbs)	CO (lbs)	UHC (lbs)	VOC (lbs)	CO2 (lbs)	NOx (lbs)	CO (lbs)	UHC (lbs)	VOC (lbs)	CO2 (lbs)	NOx (lbs)	CO (lbs)	UHC (lbs)	VOC (lbs)	CO2 (lbs)
Total Emissions per Start (lbs)	2	78	89	18	832	1	41	47	9	883	2	38	14	3	1445
Total Emissions per Shutdown (lbs)	2	56	64	13	961	2	30	34	7	1005	2	23	9	2	1200

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

Assumes unit is operating at >50% 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 CS/MD Applications
Nominal Start-up and Shutdown, Natural Gas Fuel**

Production Units with Enhanced Emissions Control

Data will NOT be warranted under any circumstances.

Taurus 70 10802S CS/MD (Post 2/2018 Orders)					
	NOx (lbs)	CO (lbs)	UHC (lbs)	VOC (lbs)	CO2 (lbs)
Total Emissions per Start (lbs)	1	37	52	10	381
Total Emissions per Shutdown (lbs)	1	13	17	3	473

	Mars 100 16000S CS/MD (Post 8/2017 Orders)					Titan 130 22402S CS/MD (All Unitss)					Titan 250 30000S CS/MD (All Units)				
	NOx (lbs)	CO (lbs)	UHC (lbs)	VOC (lbs)	CO2 (lbs)	NOx (lbs)	CO (lbs)	UHC (lbs)	VOC (lbs)	CO2 (lbs)	NOx (lbs)	CO (lbs)	UHC (lbs)	VOC (lbs)	CO2 (lbs)
Total Emissions per Start (lbs)	1	17	12	2	385	1	27	31	6	690	2	32	12	2	1135
Total Emissions per Shutdown (lbs)	1	23	16	3	676	1	24	27	5	1044	2	21	8	2	1122

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

Assumes unit is operating at >50% load prior to shutdown.

Assumes natural gas fuel; ES 9-98 compliant.

**Table 5. Estimation of Start-up and Shutdown Emissions (lbs/event) for SoLoNOx Generator Set Applications
Nominal Start-up and 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	VOC	CO2	NOx	CO	UHC	VOC	CO2	NOx	CO	UHC	VOC	CO2
Total Emissions per Start (lbs)	4	140	23	23	419	3	130	22	22	472	4	147	25	25	483

Total Emissions per Shutdown (lbs)	4	126	21	21	452	3	103	17	17	536	4	116	19	19	580
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	Taurus 70 10801S					Mars 100 16000S GSC					Titan 130 20501S				
	NOx	CO	UHC	VOC	CO2	NOx	CO	UHC	VOC	CO2	NOx	CO	UHC	VOC	CO2
Total Emissions per Start (lbs)	6	251	42	42	754	4	119	20	20	854	8	336	57	57	1164

Total Emissions per Shutdown (lbs)	4	144	24	24	737	5	128	20	20	1135	8	265	44	44	1374
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	Titan 130 22401S					Titan 250 30000S				
	NOx	CO	UHC	VOC	CO2	NOx	CO	UHC	VOC	CO2
Total Emissions per Start (lbs)	8	321	54	54	1206	9	320	53	53	2189

Total Emissions per Shutdown (lbs)	7	239	39	39	1444	8	215	34	34	2076
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Assumes ISO conditions: 59F, 60% RH, sea level, no losses.

Assumes unit is operating at >50% load prior to shutdown.

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