PUBLIC
DRAFT ENGINEERING EVALUATION
Mainspring Energy, Inc.
Plant No. 25153
Application No. 31569
400 Polar Way, San Leandro, CA 94577

BACKGROUND

Mainspring Energy, Inc. has applied for an Authority to Construct and Permit to Operate for two linear generators, fueled by natural gas:

S-1 Prime Natural Gas Linear Generator.
Make: Mainspring Energy; Model: MSE-230-NG; Max Rated Output: 321.84 bhp; Max Fuel Input: [redacted] MMBtu/hr;
Abated by two integral Oxidation Catalysts in parallel Johnson Matthey Model MC6T-6F-2

S-2 Prime Natural Gas Linear Generator.
Make: Mainspring Energy; Model: MSE-230-NG; Max Rated Output 321.84 bhp; Max Fuel Input: [redacted] MMBtu/hr;
Abated by two integral Oxidation Catalysts in parallel Johnson Matthey Model MC6T-6F-2

Mainspring is proposing to operate a manufacturing facility to be located at 400 Polar Way, San Leandro, CA 94577. The manufacturing process include assembly and testing 240kW linear generators. Mainspring will construct and operate up to two 240kW generators at any one time.

SOURCE DESCRIPTION

This section describes linear generators that will be assembled and tested at the proposed facility. Each set of two 120kW linear generator cores will be tested at one of the five test bays for a period of up to two weeks before shipment to customer sites.

Linear generator uses a low-temperature reaction of air and fuel to drive magnets through copper coils to efficiently produce electricity with near-zero NOx emissions. Figure 1 illustrates the components of a linear generator technology. The linear generator has a center reaction cylinder with two opposed oscillators and two outer air springs. The reaction section has intake and exhaust ports for gas exchange. Each oscillator has magnets attached to them for electricity production via the surrounding copper coils.

An operating cycle of the linear generator begins with compression of a fuel/air mixture that is driven by energy stored in the air springs from a previous cycle. Compression continues until a low-temperature, uniform reaction occurs, without burning and without a flame. This low-temperature reaction achieves high thermodynamic efficiency and near-zero NOx emissions. The reaction causes the oscillators to move outward, during which a portion of the kinetic energy is directly converted into electricity through the copper coils and the remaining kinetic energy is stored in the air springs for use during the next cycle. Following expansion, gas exchange replaces the exhaust products with a fresh fuel/air mixture. The electricity produced is rectified to direct current (DC) through power electronics and the DC power is then converted to 3-phase alternating current (AC) power via a UL 1741 SA-listed grid-tie inverter (these two are not shown in Figure 1).

[redacted]

Linear generator[1] is a new category of power generation technology. Unlike gas turbines and internal combustion engines, which both utilize a flame and burning from combustion (resulting in high temperatures and NOx emissions), linear generator technology uses a low-temperature reaction that results in ultra-low NOx emissions. Gas turbines and internal combustion engines generate rotary motion of their shafts which are coupled to generators to convert mechanical energy to electricity. Linear generators, however, create linear motion which is directly converted to electricity (engine and generator are combined).

The primary pollutants from linear generators are the products of combustion, including nitrogen oxides (NO_X), carbon monoxide (CO), hydrocarbon and other organic compounds (precursor organic compounds, POCs), sulfur dioxide (SO_2), and particulate matter (PM_{10} and $PM_{2.5}$). Various toxic air contaminants (TACs) are also emitted during the combustion of Natural Gas. Each source, S-1 and S-2 will be abated by two parallel oxidation catalysts that will reduce CO, POC, organic TACs, and Formaldehyde.

The generator is comprised of two linear generator cores packaged inside a single enclosure. The two linear generator cores are mechanically and electrically independent, with each having their own intake and exhaust systems. A simple emissions flow diagram is presented in Figure 2.

[redacted]

EMISSION CALCULATIONS

Basis:

- Maximum output rating 240 kWe, 321.84 bhp.
- Maximum Annual Operation: [redacted] hours
- Maximum Daily Operation: [redacted]ours

[1] https://www.youtube.com/watch?v=_pBPw33ceoQ
https://www.youtube.com/watch?v=gUgv2_v2TPc

- Maximum NG Consumption Rate [redacted] Btu/scf)
- The Generators will be equipped with the commercially available catalysts (Johnson Matthey, Model No. MC6T-6F-2) that will reduce emissions of CO, POCs, organic TACs, and formaldehyde.

Linear generator is a natural gas fired (not an EPA certified) engine with a compression ignition architecture, which is different from the traditional CI diesel engines.

For permitting a previous application (#29327) submitted by EtaGen, emission rates for NO_x, CO, and POC emissions from the engine were derived from the BACT Guideline for a spark ignition, natural gas fired, lean burn engine. However, emissions measured from the EtaGen linear generators tests averaged at 5.07 ppmv (1.91E-02 lb/MMBtu) and 8.33 ppmv (1.10E-02 lb/MMBtu) at 15% O_2 concentration, for NO_X and CO concentration, respectively.

NO_X and CO concentration of 6 ppmv (0.0225 lbs/MMBtu) and 12 ppmv (0.0273 lbs/MMBtu) will be used here, respectively, to provide compliance margin for the linear generators. POC emission factor was taken from source test data for linear generators at Calton Facility (South Coast Air Quality Management District).

No emission factors for PM, and SO_2 emissions are available for the linear generators testing. The Air District used the most stringent PM emission factor, based on requirements for CI engines, in reviewing the permit application #29327. Sources S-1 and S-2 of the current application are expected to meet the same standards. A summary of the emission factors used in this application are given in Table 1.

Table 1. Emission Factors for sources S-1 and S-2			
Pollutant	**Emission Factor**	**Units**	**Sources of Information**
NO_X	2.25E-02	lb/MMBtu	Based on NO_X concentration 6 ppmv at O_2% of 15%[2]
CO	2.73E-02	lb/MMBtu	Based on CO concentration limit of 12 ppmv at O_2% of 15%[2]
POC	1.10E-02	lb/MMBtu	Based on test data from linear generators at Colton Facility (SCAQMD).
PM_{10} [1]	1.00E-02	g/hp-hr	Based on Tier 4 Final Emission Standards set forth in 40 CFR Section 1039.101 for CI Engines (Subpart IIII) [2]
$PM_{2.5}$ [1]	1.00E-02	g/hp-hr	
SO_2	2.80E-03	lb/MMBtu	PG&E natural gas sulfur standard of 1 grain of sulfur per 100 SCF.

[1] All emissions emitted from the linear generators are assumed to be less than 2.5 micrometer in diameter for most conservative estimate of $PM_{2.5}$ emissions.
[2] https://www.ecfr.gov/cgi-bin/text-idx?node=pt40.36.1039&rgn=div5#se40.36.1039_1101

The annual and daily maximum emissions from each of the sources S-1 and S-2 are summarized below in Table 2.

Table 2 – Abated Emissions per Source S-1/S-2						
Pollutant	**Emission Factors**	**E.F. Unit**	**Maximum Firing Rate (MMBtu/hr)**	**Abated Emissions**		
				Daily (lbs/day)	**Annual (lbs/yr)**	**Annual (TPY)**
NO_x	2.25E-02	lb/MMBtu	[redacted]	1.172	[redacted]	
CO	2.73E-02	lb/MMBtu		1.422		
POC	1.10E-02	lb/MMBtu		0.573		
PM_{10}	1.00E-02	g/hp-hr		0.170		
$PM_{2.5}$	1.00E-02	g/hp-hr		0.170		
SO_2	2.80E-03	lb/MMBtu		0.146		

PLANT CUMMULATIVE INCREASE

Table 3 summarizes the cumulative increase in criteria pollutant emissions resulting from the operation of all five sources, S-1 and S-2.

Table 3 - Plant Cumulative Emissions			
Pollutant	**Existing Emissions (TPY)**	**New Emissions (TPY)**	**Total Emissions (TPY)**
NOx	0.000	0.428	0.428
CO	0.000	0.519	0.519
POC	0.000	0.209	0.209
PM_{10}	0.000	0.062	0.062
$PM_{2.5}$	0.000	0.062	0.062
SO_2	0.000	0.053	0.053

TOXIC HEALTH RISK ASSESSMENT

Mainspring Energy Inc. provided source test results conducted at the Haven facility TAC emissions were estimated from measured concentrations of pollutants. The source test used EPA Method T.O. 15, except for formaldehyde, which was measured by FTIR (Fourier Transform Infrared Spectroscopy).

For the linear generators that indicated presence of the following toxic air contaminants (TAC) at the exhaust of the linear generator: toluene, benzene, and formaldehyde. The TAC emission factors are calculated based on maximum post-catalyst concentration available from the source test results.

Based on the calculations in Table 4 below, Formaldehyde exceeds the District's Risk Screening trigger levels set forth in Table 1 of Reg. 2-5 (New Source Review for Toxic Air Contaminants). Therefore, a Health Risk Assessment (HRA) was required and performed for this permit application.

Table 4 - TAC Emission based on Source Test from AN28032							
Compound	**E.F. [lb/MMBtu]**	**Hourly Abated Emissions (lb/hr)**	**Acute Trigger Level (lb/hr)**	**HRA Triggered?**	**Annual Abated Emissions (lb/yr)**	**Chronic Trigger Level (lb/yr)**	**HRA Triggered?**
Benzene	1.56E-05	6.8E-05	6.0E-02	No	[redacted]	[redacted]	No
Toluene	1.56E-04	6.8E-04	8.2E+01	No	[redacted]	[redacted]	No
Formaldehyde	4.62E-03	2.0E-02	1.2E-01	No	[redacted]	[redacted]	Yes

[1] Total Input Heat for two generators.

This analysis estimates the incremental health risk resulting from toxic air contaminant (TAC) emissions from operation of five (5) new prime engines-natural gas generators at this facility. Results from this HRA indicate that the project cancer risk is estimated at 0.69 **in a million**, the project chronic hazard index is estimated at **0.0049**, and the project acute hazard index is estimated at **0.033**. In accordance with the District's Regulation 2-5-301, these sources do not require TBACT because each estimated source cancer risk is less than 1.0 in a million. Since the estimated project cancer risk does not exceed 10 in a million and hazard indices do not exceed 1.0, this project complies with the District's Regulation 2-5-302 project risk requirements.

BEST AVAILABLE CONTROL TECHNOLOGY (BACT)

Sources S-1 and S-2 do not trigger Best Available Control Technology (BACT), since the maximum daily emissions for POC, NO_X, CO, SO_2, PM_{10}, or $PM_{2.5}$ do not exceed 10 pounds per highest day per Regulation 2, Rule 2, Section 301 ("Best Available Control Technology Requirement").

OFFSETS

Offsets must be provided for any new or modified source at a facility that emits more than 10 tons per year of POC or NOx or emit more than 100 tons per year of PM_{10}. Since the permitted emissions from the facility are less than 10 tons per year of POC or NOx and less than 100 ton per year of PM_{10}, offsets are not required.

STATEMENT OF COMPLIANCE

Regulation 2, Rule 1 – General Requirements

This application is ministerial under California Environmental Quality Act (CEQA) guidelines (Regulation 2, Rule 1, Section 311), since the review of proposed new source is based on the criteria set forth in Regulation 2, Rule 1, Section 428 ("Criteria for Approval of Ministerial Permit Applications") and based on procedures, fixed standards, and objective measurements outlined in District's Permit Handbook and BACT workbook. Thus, this application is not subject to CEQA review. The engineering review for this project requires only the application of standard permit conditions and standard emission factors in the Permit Handbook Chapters (Chapter 2.3.2 Stationary Natural Gas Engines).

Regulation 2, Rule 1, Section 412 – Public/School Notification

The project is not within 1,000 feet from any K-12 school, however, it is located within an Overburdened Community as defined in Regulation 2-1-243 and triggered a refined Health Risk Assessment, therefore is subject to the public notification requirements of Reg. 2-1-412.

Regulation 6, Rule 1– Particulate Matter and Visible Emissions

Sources S-1 and S-2 are subject to and expected to comply with standards set forth in sections 301 (Ringelmann No. 1 Limitation), 305 (Visible Particles), and 310 (Total Suspended Particulate Concentrations Limits), because sources S-1 thru S-5 will exclusively consume natural gas.

Regulation 9, Rule 8 – NO_X and CO Emissions from Stationary Internal Combustion Engines

Per Section 9-8-101, the rule applies to "stationary internal combustion engines with an output rated by the manufacturer at more than 50 brake horsepower". Per Section 9-8-203, "rated brake horsepower" is defined as "the maximum brake horsepower rating at maximum revolutions per minute (RPM) specified for the engine by the manufacturer or indicated on the engine nameplate".

Sources S-1 and S-2 do not have rotating shafts, linear generators, create linear motion which is directly converted to electricity then, brake horsepower as defined in Section 9-8-203, does not apply. Thus, S-1 and S-2 are not subject to the requirements of Regulation 9, Rule 8.

However, even if sources S-1 and S-2 were subject to the requirements of the rule, the maximum permitted and expected emissions rate are well below the emission limits of Section 9-8-304.

New Source Performance Standards (NSPS)

40 CFR 60, Subpart IIII, Standards of Performance for Stationary CI Internal Combustion Engines (ICEs)
40 CFR 60, Subpart JJJJ, Standards of Performance for Stationary SI Internal Combustion Engines (ICEs)

40 CFR 60, Subpart IIII and Subpart JJJJ, in their Section 60.4219 and 60.4248 respectively, define "Stationary Internal Combustion Engine", as follows:

Stationary internal combustion engine means any internal combustion engine, except combustion turbines, that converts heat energy into mechanical work and is not mobile. Stationary ICE differs from mobile ICE in that a stationary internal combustion engine is not a nonroad engine as defined at 40 CFR 1068.30 (excluding paragraph (2)(ii) of that definition), and is not used to propel a motor vehicle, aircraft, or a vehicle used solely for competition. Stationary ICE includes reciprocating ICE, rotary ICE, and other ICE, except combustion turbine.

Neither NSPS Subpart IIII nor Subpart JJJJ have definitions for "mechanical work". Therefore, a common dictionary definition is used. Per the Second Edition of "Dictionary of Engineering" by McGraw-Hill, mechanical work is defined as:

"The transference of energy that occurs when a force is applied to a body that is moving in such a way that the force has a component in the direction of the body's motion; it is equal to the line integral of the force over the path taken by the body."

As explained in the Background Section, linear generators convert heat energy (from autoigniting compressed fuel) into linear motion, which is then converted into electric energy. After combusting the compressed fuel, work is done by the expanding gas on the pistons.

In a traditional internal combustion engine, pistons are connected to a crankshaft that is rotated by the movement of the pistons. In this case, mechanical work is clearly being done by the pistons on the crankshaft.

For Sources 1 and 2, it is not clear whether the work done by the expanding gas on the pistons may be considered "mechanical work". A force (the expanding gas) is applied to a body (the pistons) in the direction of the body's motion. The facility has submitted an argument and request to the U.S. EPA stating that the technology does not meet the definition of mechanical work. The company has not reached any conclusion with EPA, yet.

Nevertheless, regardless of the sources being subject to the NSPS or not, sources 1 and 2 are expected to comply with the emissions requirement set forth in CFR 60, Subpart IIII and Subpart JJJJ.

Linear generators, being used for non-emergency purposes, will be tested at one of the five test bays for a period of up to two weeks after assembly and before shipment to the customer sites. Therefore, the emission limits for sources 1 and 2 were compared to the most stringent emission limits available for non-emergency engines in these two subparts.

The NOx and CO emissions from these sources will be limited to 0.0225 and 0.0273 lbs/MMBtu and thus, will comply with NOx and CO standard set forth in the two subparts as shown in Table 5. PM and POC emissions from these sources are expected to be low and will comply with the PM and POC emission standards in the two subparts, since these sources will be using natural gas instead of diesel fuel.

National Emission Standards for Hazardous Air Pollutants (NESHAP)

40 CFR 63, Subpart ZZZZ ("National Emission Standards for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engines") applies to stationary reciprocating internal combustion engines (RICE) at both major and area sources. The facility is not a major source and is therefore, considered an area source.

Per Section 63.6585(a), a stationary reciprocating internal combustion engine is "any internal combustion engine which uses reciprocating motion to convert heat energy into mechanical work and which is not mobile."

As described in the Background Section and within the discussion of the applicability of New Source Performance Standards, sources 1 through 5 convert heat energy into linear motion that is repeated or reciprocated through use of the air springs.

Per Section 63.6590(c)(1), a new stationary RICE at an area source is subject to the requirements of 40 CFR 60 Subpart IIII (if a compression ignition engine) or 40 CFR 60 Subpart JJJJ (if a spark ignition engine). As discussed above, Sources 1 through 5 are expected to meet the emission limits of both subparts. However, the facility has submitted a request to the U.S. EPA regarding the applicability of the subparts. As such, it is not known whether the sources will be required to comply with the non-emission requirements (e.g. certification, recordkeeping).

PERMIT CONDITIONS

Permit Condition # 27751 for S-1 and S-2

1. The owner/operator of S-1 and S-2 shall operate these sources on natural gas fuel exclusively. The fuel usage shall not exceed 19,009.2 MMBtu per source during any consecutive 12-month period. [Basis: Cumulative Increase]

2. The owner/operator of sources S-1 and S-2 shall abate each source with two oxidation catalysts in parallel. The catalysts shall be maintained and operated in accordance with manufacturer's recommendations.
   [Basis: Cumulative Increase]

3. The owner/operator shall ensure that sources S-1 and S-2 shall not exceed [redacted] pounds of NO_X emissions per source, [redacted] pounds of CO emissions per source, and [redacted] pounds of formaldehyde emissions per source, during any consecutive 12-month period. Emission limits shall be based on the following emission factors:
   a. NOx: 2.25E-02 lb/MMBtu
   b. CO: 2.73E-02 lb/MMBtu
   c. Formaldehyde: 4.62E-03 lb/MMBtu

   [Basis: Cumulative Increase]

4. When determining compliance with the formaldehyde emission limit of Part 3, a higher heating value for natural gas of 1,040 Btu per standard cubic feet shall be used.
   [Basis: Cumulative Increase]

5. The owner/operator of sources S-1 and S-2 shall retain the following records on-site at least for 24 months, from the date of entry, and make them available for inspection by District staff upon request.
   a. Monthly fuel usage for sources S-1 and S-2.
   b. Any maintenance records for sources S-1 and S-2 and oxidation catalysts

   [Basis: Cumulative Increase]

RECOMMENDATION

The District has reviewed the material contained in the permit application for the proposed project and has made a preliminary determination that the project is expected to comply with all applicable requirements of District, state, and federal air quality-related regulations. The preliminary recommendation is to issue an Authority to Construct/Permit to Operate for the equipment listed below. However, the proposed source will be located within 1,000 feet of at least one school, and required a Health Risk Assessment within an Overburdened Community which triggers the public notification requirements of District Regulation 2-1-412. After the comments are received and reviewed, the District will make a final determination on the permit.

I recommend that the District initiate a public notice and consider any comments received prior to taking any final action on issuance of an Authority to Construct/Permit to Operate for the following source:

S-1 Prime Natural Gas Linear Generator.
Make: Mainspring Energy; Model: MSE-230-NG; Max Rated Output: 321.84 bhp; Max Fuel Input: [redacted] MMBtu/hr;
Abated by two integral Oxidation Catalysts in parallel Johnson Matthey Model MC6T-6F-2

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