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May 6, 2016

Todd Anthony Bianco
Coordinator
Rhode Island Energy Facility Siting Board
89 Jefferson Boulevard
Warwick, RI 02888

Re: Invenergy Thermal Development LLC – Clear River Energy Center
Docket No. SB-2015-06

Dear Mr. Bianco:

Enclosed for filing in this matter are an original and 10 copies of the Town of Burrillville's 9th Set of Data Requests to Invenergy Thermal Development LLC. Electronic copies have been sent to the service list.

If you have any questions, please feel free to call.

Very truly yours,

Michael R. McElroy

MRMc:tmg

cc: Service List

Burrillville/Invenergy/EFSB/Data Requests Set 9

SB-2015-06 Invenergy CREC Service List as of 05/02/2016

Name/Address	E-mail	Phone/FAX
File an original and 10 copies with EFSB: Todd Bianco, Coordinator Energy Facility Siting Board 89 Jefferson Boulevard Warwick, RI 02888 Margaret Curran, Chairperson Janet Coit, Board Member Assoc. Dir., Div. of Planning Parag Agrawal Patti Lucarelli Esq., Board Counsel Susan Forcier Esq., Counsel Rayna Maguire, Asst. to the Director DEM	Todd.Bianco@puc.ri.gov; Patricia.lucarelli@puc.ri.gov; Margaret.Curran@puc.ri.gov; janet.coit@dem.ri.gov; kimberly.Crabill@doa.ri.gov; susan.forcier@dem.ri.gov; rayna.maguire@dem.ri.gov; Parag.Agrawal@doa.ri.gov;	401-780-2106
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Fighting Against Natural Gas and Burrillville Against Spectra Expansion Jillian Dubois, Esq. The Law Office of Jillian Dubois 91 Friendship Street, 4th Floor Providence, RI 02903	jillian.dubois.esq@gmail.com;	401-274-4591
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STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS
ENERGY FACILITY SITING BOARD

IN RE: INVENERGY THERMAL DEVELOPMENT LLC's	:	
APPLICATION TO CONSTRUCTION THE	:	DOCKET No. SB-2015-06
CLEAR RIVER ENERGY CENTER IN	:	
BURRILLVILLE, RHODE ISLAND	:	

THE TOWN OF BURRILLVILLE'S 9th SET OF DATA REQUESTS TO INVENERGY THERMAL DEVELOPMENT LLC

Please reference page 14 of the EFSB application where it states: "Hydrogen tube trailer – the unit generators will use gaseous hydrogen for cooling and heat rejection. Truck trailer mounted hydrogen tube racks will be used for on-site hydrogen storage and make up to the generators. Alternately, a hydrogen generator may be used for this purpose."

9-1 Please see the article attached hereto, especially the highlighted sections, and provide more information regarding the proposed hydrogen tube trailer/generation, and all related safety issues, including responses to the claims set forth in the attached article and whether Invenergy has considered any alternatives in addition to utilizing truck trailer mounted hydrogen tube racks or a hydrogen generator.

9-2 In particular, please provide all safety plans and designs concerning possible problems that could arise with the hydrogen. For example, the attached article claims:

a. A typical tube trailer has the equivalent of 5,585 pounds of TNT;
b. Hydrogen is especially dangerous because the explosive range of hydrogen in the air is from 4% to 74%;
c. Hydrogen has a wide flammability range;
d. Ignition of the hydrogen takes little energy;
e. All hydrogen cooled generators leak;
f. There is no shortage of ways to cause a hydrogen fire; and
g. It is estimated that perhaps five hydrogen fires a year occur at power plants with hydrogen cooled generators.

9-3 Please explain whether and how you intend to use monitors to make this safer, and which monitors you propose to use.

9-4 Please explain the safety measures that will be put in place for the hydrogen being transported by Town roads to the plant.

9-5 Please confirm whether in this power plant it would be necessary to replace a tube trailer every one or two weeks, and if not, how often the replacements will be required.

9-6 Please confirm that you are proposing to comply with the supply and siting requirements of the National Fire Protection Association, and provide specifics.

9-7 Please explain how you will have the installation site become a classified area limited in use pursuant to the National Fire Protection Association.

Respectfully submitted,
Town of Burrillville
By its attorneys

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Date: May 6, 2016

CERTIFICATE OF SERVICE

I hereby certify that on the 6th day of May, 2016, I sent a copy of the foregoing to the attached service list.

Theresa Gallo

Burrillville/Invenergy/EFSB/Data Requests Set 9

POWER Engineering®

Hydrogen Cools Well, but Safety is Crucial

06/01/2009

In its pure state, hydrogen is fine, but a mixture of air and hydrogen can be explosive. Then, why hydrogen?

By Nancy Spring, Senior Editor

Operating an electric power generator produces large amounts of heat that must be removed to maintain efficiency. Air, water and oil have all been used for cooling. But hydrogen's low density, high specific heat and thermal conductivity make it a superior coolant for this application. Plus, it's abundant and therefore relatively inexpensive.

The problem is, hydrogen can be dangerous. In its pure state, hydrogen is fine, but a mixture of air and hydrogen can be explosive. So why hydrogen?

Steve Kilmartin, director of products and markets for Environment One Corp.'s utility systems business, has asked himself the same question. The author of numerous papers on generator monitoring and maintenance, including co-authoring the Electric Power Research Institute's "Turbine-Generator Auxiliary Systems, Volume 3: Generator Hydrogen System Maintenance Guide," Kilmartin said one of the questions he asked when he first got into the business was "who came up with this idea? He had to be a madman."

But hydrogen is an effective way to cool the generator and allows power plant operators to get a lot more megawatts out of a smaller generator.

According to John Speranza, vice president, hydrogen product sales, Proton Energy Systems, almost 70 percent of all electric power generators over 60 MW worldwide use hydrogen cooling. And there are two ways to fill the generator's hydrogen demand: have it delivered in cylinders or make it on site.

"Hydrogen gas inventory becomes the chief safety concern because of the potential energy in hydrogen," said Speranza.

For example, Speranza said a standard portable cylinder filled with hydrogen at 2,400 psig is equivalent to 35 pounds of TNT in terms of explosion potential. A 12-pack of cylinders represents 420 pounds of TNT and a typical tube trailer, 5,585 pounds of TNT.

"Hydrogen is a critical plant resource and its supply and use should be treated with care," said Speranza. "Hydrogen gas safety continues to be a concern at power plants since the gas was first used more than 70 years ago, despite a generally good safety record."

Power plants using hydrogen-cooled generators must maintain recommended hydrogen purity and pressure in the generator casing for efficiency, safety and equipment reliability. Constant monitoring and use of certified equipment for hazardous areas are important first steps.

Playing It Safe

Hydrogen in a pure state is fine, but when mixed with air, it becomes combustible. What makes it especially dangerous is that the explosive range of hydrogen in air is broad, from concentrations that range from 4 percent to 74 percent. "Any mixture in that range is explosive," said Kilmartin.

Not only does hydrogen have a wide flammability range, ignition takes little energy, said Stephen Phelps, fixed systems product line manager for Sensidyne LP. Hydrogen burns with a pale blue, almost invisible flame that can seriously injure personnel, as well as cause severe equipment damage. A common method of detecting a hydrogen fire is to use a broom to "sweep" the suspected area.

Making hydrogen stay put is almost impossible, too, because it's light and its molecules are small.

"It's difficult to seal hydrogen, so there's a high probability you'll have leaks," said Kilmartin. All hydrogen-cooled generators leak and have an acceptable leakage rate, he said.

Luckily, when hydrogen does leak, it's so light that it dissipates quickly, unlike natural gas, for instance, which is heavy and will sink to the floor and stay there.

"In most cases, if hydrogen leaks out of a generator, it rises and would have to have some place to

accumulate," he said.

One dangerous area to watch out for is under the generator's floor. Hydrogen may form there because generators are often built right onto the turbine deck, said Kilmartin. "Half of the generator is above the floor and half is below so at the floor level the hydrogen can build up and accumulate."

Hydrogen can also build up in the oil used to seal it in the generator. The oil/hydrogen mixture then becomes explosive.

Monitoring hydrogen purity is important for two reasons, said Kilmartin. The first is efficiency: The purer the hydrogen the more efficient the generator, because hydrogen has less windage loss than air does. "It takes more horsepower to turn a fan in air than hydrogen," he said.

The second reason is the explosive mixture ratio-the purer, the safer.

Unfortunately, there's no shortage of ways to cause a hydrogen fire. Kilmartin estimated that perhaps five hydrogen fires a year occur at power plants with hydrogen-cooled generators.

"You may have an exciter that's attached to the generator and it could have arcing and sparking devices in it," said Kilmartin. Because hydrogen is so dry, static buildup can develop and discharge, causing its own internal arc.

"You may have a filter on a system that you need to blow down and if it's not properly grounded you can build up a static charge that can ignite the hydrogen."

Certified Safety Sandards

Thirty or 40 years ago, auxiliary equipment did not have to meet certification for use in a hazardous area. Today, however, Kilmartin said equipment has to be certified by North American Electric Code. He estimated he likely would find equipment that should not be used in an area with hydrogen in 75 percent of today's power plants. Even fluorescent lights, for instance, shouldn't be used in the area as they don't satisfy code.

Designs have changed, too.

"One of the things they used to do in the old days was put the electronics in one enclosure and hydrogen in another enclosure," he said. Although that helps, designers did not take into consideration that if hydrogen starts to leak it could end up in the other enclosure. And although the practice of separating electronics from hydrogen was safer than having the two together, it still did not satisfy code.

Kilmartin recommends inspecting all of the equipment in an area with hydrogen to verify that systems are either certified to be used in a hazardous area or are designed to meet the intent of the code for that area. He also recommends using monitors, called low explosive limit detectors, in confined spaces. "Put them in the cabinet and they'll tell you when hydrogen gets above that 4 percent range," he said.

Ambient gas detection is used to detect hydrogen leaks, said Sensidyne's Phelps. Hydrogen leaks occur at the generator bearings and shaft seals, in the seal oil supply system and from the hydrogen supply piping, mechanicals and purity/purging cabinet. Many plants monitor the seal oil system area and hydrogen purity cabinet. Older generating units may require bearing journal monitoring where access is available, he said.

Battery rooms can be notorious hydrogen generators, according to Phelps. Monitoring the rooms to turn on a ventilation fan is a good practice, often required by fire code. A single hydrogen sensor high inside the battery room, with annunciation outside the door and supervisory notification, is a commonly accepted solution, he said.

A condition monitor tracks insulating materials' thermal breakdown in the generator, said Kilmartin. When thermal breakdown occurs, it gives off millions of submicron particles. Under normal conditions in the generator, no submicron particles are present. Plant personnel should look for them as an indicator the generator will fail. "It's not a safety issue, it's a reliability issue," he said.

Equipment Detection Options

Sensidyne manufacturers and supplies gas detection and air monitoring systems. Based in Clearwater, Fla., the company also offers repair and calibration services.

Older detector types consisted of a non-specific catalytic detector sensitive to all combustibles, said Phelps. By using a hydrogen-specific gas detector no confusion exists about whether or not the detected leak is tramp methane, so corrective measures can be taken quickly. The detector is combined with the company's 2-Wire Universal Transmitter.

Phelps said gas sensors have reached a new technology level in the last 15 years. Percent remaining sensor life, extended calibration intervals, fully configurable electronics, real-time clocks with time-stamped data, large illuminated displays, multiple communication modes and "calibrate sensors in the shop-hot swap in the plant," have all contributed reliability and added value for the end user.

Ambient gas sensors can be installed above the equipment where leaks are most likely, such as generator bearing assemblies, valves, fittings and the carbon dioxide purging system. Other gas sensor mounting options include placing the sensor remote from the transmitter or drawing a sample from a remote or inaccessible location. In the latter case, a calibration adapter is supplied.

Sensidyne trains personnel to handle the routine maintenance associated with intelligent plug-in gas sensors. Training usually takes two or three hours and is done during the gas detection equipment's start-up and commissioning.

Environment One's general condition monitor (GMC) uses real-time detection to give early warnings of generator overheating and potential failure. The explosion-proof monitor's ion chamber detects pyrolytic products-submicron particles produced whenever materials in the generator are heated sufficiently to produce thermal decomposition-if they are present in the hydrogen. The GCM-X warns of impending failure. An alarm verification sequence is performed and if the alarm is confirmed, a fixed amount of the hydrogen flow automatically passes through the sampling system. Particles are collected for laboratory analysis to determine their source.

E/One's generator gas analyzer (GGA) for hydrogen-cooled generators is a triple-range sensor/analyzer that provides continuous monitoring of gas purity during all phases of generator operation. E/One says the system eliminates the issues of drift and need for frequent recalibration seen in some thermal conductivity systems.

Yokogawa Corp. is an industrial automation-and-control, test-and-measurement company with facilities in 40 countries. The company has applied a vibrating element (VBE) gas measurement technology used in a variety of process control environments to power generator hydrogen purity measurement.

A vibrating element device works on the principle that the resonant frequency of a thin-wall cylinder will change as the density of the surrounding gas varies-the "tuning fork method." The lighter the gas, the faster the cylinder vibrates. Yokogawa says VBE is well-suited for field measurement conditions because it does not require reference gas, an isothermal environment, warm-up or temperature stabilization time.

Generator hydrogen purity had historically been measured with thermal conductivity analyzers or mechanical fan differential devices, Yokogawa says. And while instances exist where traditional gas measurement cannot be replaced, vibrating element technology is viable and proven for gas properties measurement for density, specific gravity or gas percent concentration.

In the last few years, Yokogawa said GE Energy generators totaling almost 1,300 MW have been converted to VBE at Southern Co.'s Georgia Power Plant Yates. The Tennessee Valley Authority's Kingston Fossil Plant replaced nine thermal conductivity analyzers with VBEs on five GE 200 MW and four Westinghouse 150 MW generators.

MediVac Technologies' leak testing services can be applied to hydrogen-cooled generators, steam turbines, condensers, heat exchangers and buried pipelines. MediVac's technicians use the detector probe method of helium leak testing, which, according to the company, can locate leaks on hydrogen-cooled

generators that would go undetected by bubble solutions and other less sensitive methods. If a generator fails to hold pressure after maintenance or prior to start-up, MediVac says it is not necessary to pressurize or test the generator with hydrogen. Using two or three standard cylinders of helium mixed with air or carbon dioxide as a tracer gas, the generator can be tested, repaired and re-tested before being filled with hydrogen for operation.

MediVac also performs helium leak detection on the tubes and tube sheets of the hydrogen coolers to identify the exact location of the leakage.

Safety and Onsite Hydrogen Production

The traditional mode of hydrogen supply differs from plant to plant depending on several factors, such as distance from the central hydrogen supply and permit restrictions on the volume of stored hydrogen, said Proton's Speranza. Some plants use single cylinders or transportable cradles of six, 12 or 18 high-pressure (2,400 psi) hydrogen cylinders. Others use large bulk systems that are either stationary high- or low-pressure tanks or transportable high-pressure tube trailers. Some plants have a cryogenic liquid hydrogen supply.

The potential for accidents increases every time hydrogen is transported, transferred or a bulk hydrogen connection is handled, said Speranza. In power plants with a bulk hydrogen supply, it is common to replace a tube trailer every one or two weeks, while plants with cylinder packs may require replacement and reconnection every four to seven days. When a leak occurs, it potentially may involve the entire bulk inventory, releasing the entire inventory within seconds. Supply and siting requirements per National Fire Protection Association (NFPA) standards require systems greater than 15,000 scf to be located outdoors or in a "dedicated, ventilated, noncombustible and detached building." NFPA 55 also prescribes clearances of 50 feet from public assembly areas, electrical areas, air intakes and conventional construction. The installation site becomes a classified area, limited in use and complicated to permit.

In contrast to traditional bulk hydrogen systems, an on-site hydrogen generator solution, such as a Hogen Proton Exchange Membrane (PEM) water electrolyzer, has relatively insignificant (<1.5 scf) internal hydrogen inventory, permitting location within almost any ventilated structure that complies with NFPA standards, said Speranza.

In the event of an onsite generator leak, the rate will not exceed the hydrogen generator's maximum production capacity. This low volume, typically less than 4 scf/min, is diluted locally in ventilation air to a safe level.

An onsite hydrogen generator is typically sized to provide all of the daily hydrogen makeup requirements, leaving the re-gas requirement to be met by bulk delivery methods.

A Hogen onsite hydrogen generator requires minimal operator training due to its fully automatic operation and requires less than eight man-hours of annual maintenance.

Hydrogen's Benefits as a Cooling Medium for Generators

Hydrogen has one of the best heat transfer properties of any gas, with a specific heat of 3.4 Btu/lb-F at standard conditions. On a mass basis, hydrogen is 14 times more efficient than dry air for removing heat and hydrogen's superior cooling properties increase as the hydrogen pressure increases.

Cooling Medium	Heat Removal Ability	Specific Heat Capacity	Density
Air	1.00	1.00	1.00
Hydrogen	-	14.30	0.07
Hydrogen at 30 psig	3.00	14.30	0.21
Hydrogen at 45 psig	4.00	14.30	0.26
Water	50.00	4.18	1000.00
	Cooling Medium Comparison		Source: EPRI

Click here to enlarge image

Hydrogen, as the lightest gas, has the lowest density of any stable gas. Wind resistance losses are kept to a minimum because the rotor's wind resistance in a hydrogen-cooled generator is far less than in a similarly sized air-cooled generator. And unlike air, hydrogen is not an oxidizing agent.

While hydrogen can be an effective cooling medium for large turbo generators, it can also be hazardous and proper practices must be followed for safe operation.

Source: "Turbine-Generator Auxiliary Systems, Volume 3: Generator Hydrogen System Maintenance Guide," EPRI.