VERIFICATION STATEMENT

In accordance with ISO 14034:2016 – Environmental Technology Verification

Technology & Company Information	
Technology Name	Clean Combustion Thermal Oxidizer
Company	Questor Technology Inc. www.questortech.com
Technology Type & Application	High-Efficiency Enclosed Combustion System for Gaseous Emissions Control for Industrial processes
Technology Model(s)	Q50, Q100, Q250, Q500, Q1000, Q3000, Q5000

Verification Parameter	Verified Performance	Verification Testing Conditions[a]	
		Gas Input Rate (MCFD)	Feed Gas Characteristics
Combustion Efficiency	99.99 ± 0.01%	5.40 – 4,450	49.1 – 98.9 % total hydrocarbons
H2S Conversion Efficiency	99.99 ± 0.01%	62.2 – 4,450	0.28 – 15.2% H_2S
Greenhouse Gas Emission Reductions	9-1,657 Tonne CO_{2e}/d (100 yr GWP) 26-5,316 Tonne CO_{2e}/d (20 yr GWP)	62.2 – 4,450	25 – 77% Methane

[a] *Operational boundaries of data used for verification, not representative of full operational range of technology*

Verifier Information	
Verification Body	350Solutions, Inc. www.350solutions.com
Lead Verifier	Bill Chatterton
Verification Body Accreditation	ANAB Cert. AI-2618 for ISO:IEC 17020-2012 / ISO 14034-2016
Verification ID	VS-QU1901

*Disclaimer: 350Solutions Name and/or Logo does not imply approval or certification of this product, nor does it make any explicit or implied warrantees or guarantees as to product performance. Information on the performance characteristics of the **Questor Clean Combustion Device** can be found at https://350solutions.com or contact sales @questortech.com to obtain a copy of this ETV verification statement.*

Issue Date:

February 28, 2020

ENVIRONMENTAL TECHNOLOGY VERIFICATION STATEMENT

Technology Name:	**Clean Combustion Thermal Oxidizer**
Technology Type:	**High Efficiency Enclosed Combustion System**
Application:	**Gaseous Emissions Control – Industrial Processes**
Company:	**Questor Technology Inc., Calgary, AB, https://www.questortech.com/**
Verification Body:	**350Solutions, ISO/IEC 17020:2012 and ISO 14034 Environmental Technology Verification, Certificate Number AI-2619**
Lead Verifier:	**Bill Chatterton, 350Solutions**

VERIFIED PERFORMANCE CLAIMS

Performance data from the waste gas incinerators by Questor Technology was assessed by 350Solutions to verify specific technology performance claims including:

- Combustion efficiency (CE),
- H_2S conversion efficiency, and
- Greenhouse gas reductions.

Verified results for three technology performance claims are summarized in Table 1.

Table 1 - Questor Technology Verified Performance

Verification Parameters	Applicable Technology (Model(s))	Verification Testing Conditions[a]		Verified Performance
		Gas feed rate (MCFD)	Feed gas characterization	
Combustion efficiency	All currently offered (Q50, Q100, Q250, Q500, Q1000, Q3000, Q5000)	5.40 – 4,450	49.1 – 98.9 % THC	99.99 ±0.01%
H_2S conversion efficiency		62.2 – 4,450	0.28 – 15.2 % H_2S	99.99 ±0.01%
GHG emission reductions [b]		62.2 – 4,450	25 – 77 % CH_4	26 – 5,316 Tonne CO_{2e}/D (20-yr GWP)
				9 – 1,657 Tonne CO_{2e}/D (100-yr GWP)

[a] *Operational boundaries of data used for verification not representative of full operational range of technology.*

[b] *Compared to waste gas venting and range of flare efficiency baseline scenarios using IPCC 20-year and 100-yr global warming potential emission factors.*

TECHNOLOGY DESCRIPTION

Questor's Clean Combustion Thermal Oxidizers (commonly referred to as combustors or incinerators) are designed to combust hydrocarbon waste gas streams with efficiency greater than 99.99%. The combustors vary in size to accommodate a range of gas flow rates from nominally 50 (Q50 model) to 5,000 (Q5000 Model) thousand cubic feet per day (MCFD). Incinerators designed by Questor are used in multiple segments of the oil and gas industry including upstream, midstream and downstream processes, in addition to chemical plants and the general waste management industry. The system is particularly suitable for the industry owners and operators that are required to comply with the environmental regulations and guidelines for emissions reduction of hazardous air pollutants, greenhouse gases (i.e. methane) and VOCs. In addition, the system is useful for the industries that are interested in reducing greenhouse gas emissions to generate offset credits. As an example, Air Quality Control Commission, Regulation 7 in Colorado mandates the use of enclosed combustors, and more recently targets methane, resulting in a statewide focus on the responsible management of potentially fugitive hydrocarbons. North Dakota also has additional requirements that reflect some of the unique and specific needs that extend beyond the EPA's requirements.

Questor combustors have been designed to handle both low- and high-pressure gas streams through a selection of burners which result in the destruction of offensive odors, toxic gases and harmful vapors. The combustors can even draw gases at near-atmospheric pressure (such as dehydrator still columns and tank vapors) and still exceed 99.99% CE. Questor combustors perform within their design across a range of capacities (Table 2).

Table 2 – Questor Clean Combustion Thermal Oxidizer specifications

	Model			
Specifications [a]	**Q50**	**Q500**	**Q3000**	**Q5000**
Nominal Capacity (MCFD) [b]	5 - 50	50 - 500	300 - 3000	500 - 5000
Typical height (ft)	30	30	40	40
Exterior diameter (in)	20	48	96	144
Typical weight (lbs)	4,000	14,000	36,000	45,000

[a] *Specifications are illustrative and show approximate sizing. Actual capacity depends on the type of gas burned and available pressure. Questor custom designs combustors to meet multiple end use applications. Additional models/capacities are available including Q100, Q250 and Q1000 depending on application requirements.*

[b] *Nominal capacity is determined based on combustion of natural gas (0.6 kg/m^3)*

VERIFICATION DESCRIPTION

The primary objective of this assessment was to verify the performance claims made by Questor with respect to operation of the combustor technology in relevant applications. Verification parameters were assessed quantitively using data generated in appropriate field applications of the technology. Verifiers reviewed technology performance data to determine whether the data met the objectives of the verification process. The result of the verification represents a confirmation of the performance of the technology achieved under the same conditions, constraints and limitations as those specified for the generation of the data used for verification.

For Performance Claims 1 and 2, the verification addressed technology performance with respect to combustion efficiency (conversion of hydrocarbons to CO_2) and H_2S conversion efficiency (oxidation of

hazardous sulfur species). Performance Claim 3 examined GHG emission reductions by calculating the GHG intensity of the inlet (waste) gases and comparing those values to the GHG intensity of corresponding technology exhaust gases. Reductions in GHG intensity were analyzed using two baseline scenarios: 1) no emission controls employed where feed gases to the technology would otherwise be vented as GHG emissions, and 2) emissions controlled using a device typical to the applications analyzed here (i.e. a flare with typical GHG conversion efficiencies ranging from 20 to 95%) and by examining reductions using both 20- and 100-year IPCC GHG global warming potential (GWP) intensity factors.

In its application for verification, Questor provided significant test data relevant to assess the performance claims. This existing data was the basis for verification and were reviewed in detail following procedures specified in the plan. Verification of the existing performance data indicated that:

- Verified data was generated by third party emissions testing contractors outside of Questor management;
- Testing was conducted following standardized reference methods published by EPA or Canadian regulatory bodies;
- Testing was conducted at a variety of oil and gas facilities and other processing plants; and
- Tests were generally conducted to demonstrate regulatory compliance under stable and representative process operations.

VERIFICATION OF PERFORMANCE

The Questor system design is reported to be consistent across the range of model capacities and, therefore, the performance claims span the operational range and technology models offered by Questor. The verification assessed consistency across this capacity range to the extent that existing testing data provided in the verification application supported the claims.

Verified results for three technology performance claims are summarized in Table 3. The results are presented as a function of verification boundaries (process operations, unit capacity), verified test results and key verification findings. For CE and H_2S conversion, efficiencies were at or above 99.99% for all test examined and measured concentration of hydrocarbons and H_2S were at or near method detection limits.

Table 3 - Questor Technology - Verified Combustion and H_2S Conversion Efficiency

Verification Parameters	Applicable Technology (Model(s))	Verification Operating Range (gas feed MCFD)	Verified Performance
Combustion efficiency (CE)	Q50, Q100, Q250, Q500, Q1000, Q3000, Q5000	5.4 – 4,450	99.99 ±0.01%, (99% confidence level)
H_2S conversion efficiency		62.2 – 4,450	99.99 ±0.01%, (95% confidence level)

In evaluating the GHG reductions performance claim, a wide range of operational flare efficiency was selected for the analysis based on a review of relevant and recent literature on the subject. Although properly operated flares can achieve 95 % or higher combustion efficiency in the flare plume under stable conditions, many studies concluded that flares have highly variable efficiencies in field operations with variable feed gas, environmental and flame conditions (between 62 - 98 %). The demonstrated

efficiencies of the Questor units verified here were used to estimate GHG reductions achievable in both baseline scenarios and quantified as tonne CO_{2e}/day. Results of these analyses are summarized below for two operational scenarios verified here: 1) high waste gas flow rate and methane content (Table 4), and 2) low waste gas flow rate and methane content (Table 5).

Table 4 - GHG Reductions at high flow rate (4,450 MCFD) and high methane content (77%-molar)

			Treatment method						
			Venting (no treatment)	Flare (variable efficiency)					Questor Incinerator
Efficiency (%)			0	20	40	60	80	95	99.99
20 Y	Net GHG Emissions	Tonne CO_{2e}/D	5510	4441	3379	2317	1256	459	194
100 Y			1850	1514	1184	854	524	276	193
20 Y	GHG Reductions		0	1069	2131	3192	4254	5051	5316
100 Y			0	337	667	997	1327	1575	1657

Table 5- GHG Reductions at low flow rate (62.2 MCFD) and low methane content (25%-molar)

			Treatment method						
			Venting (no treatment)	Flare (variable efficiency)					Questor Incinerator
Efficiency (%)			0	20	40	60	80	95	99.99
20 Y	Net GHG Emissions	Tonne CO_{2e}/D	30.8	24.18	19.41	14.64	9.87	6.29	5.10
100 Y			14.37	11.03	9.55	8.07	6.58	5.47	5.10
20 Y	GHG Reductions		0	6.6	11.4	16.2	20.9	24.5	25.7
100 Y			0	3.3	4.8	6.3	7.8	8.9	9.3

Across the entire range of test data verified during this study, net GHG emissions through use of the Questor incinerators ranged from 5.1 to 193 Tonne CO_{2e}/D (100-yr GWP), compared to 14.3 – 1850 Tonne CO_{2e}/Day in a venting (no treatment) scenario and 5.47 – 276 Tonne CO_{2e}/Day in a 95% efficient flare. In a 20-yr GWP case, an incinerator has an approximate similar net GHG emissions due to the low hydrocarbon content in the outlet stream; whereas, the net emissions of venting is 30.8 to 5510 Tonne CO_{2e}/D, and a 95% efficient flare has an equivalent net emission range of 6.29 – 459 Tonne CO_{2e}/D.

DATA QUALITY

350Solutions, an ANAB accredited ISO/IEC 17020:2012 inspection body for ISO 14034 ETV, was contracted by Questor to provide independent verification of performance of their clean combustion thermal oxidizer (or incinerator) technology. The verification process applied was based on 350Solutions' Standard Operating Procedure QSP-350-223-01: "ISO 14034 Environmental Technology Verification", the ISO Technical Committee 207 draft guidance document "*Environmental technology verification — E.T.V — Guidance to implement ISO 14034*", and a technology specific Verification Plan. The objectives and approaches used for this verification were designed to apply these principles and processes to Questor's application for verification and performance claims. The verification was

approached without consideration to how the technology may apply to any specific regulatory requirements but rather to provide verified performance results based on a series of real world and relevant technology applications.

In broad terms, the existing data provided by Questor to verify performance with respect to the performance claims were found to be acceptable for verification with few findings of incompleteness or insufficiency that may present moderate or minimal impact on verification of results as detailed in the full verification report. Following ISO 14034 guidance, the data quality assessment included:

- Data quality assessment for the specified performance claims;
- Assessment of ancillary data quality (operations, relevance, representativeness);
- Performer competence (testing and analytical providers);
- Sampling and analytical procedures (repeatability, accuracy, measurement equipment calibration and quality checks); and
- Data management and processing.

All data reviewed for this verification was categorized as existing test data. In conformance with ISO 14034 requirements, test data provided by the applicant that were generated prior to verification were acceptable for the verification by meeting the following requirements:

- Relevance to the performance claims;
- Were produced and reported according to the requirements of ISO/IEC 17025; and
- Met the requirements specified in the verification plan.

Detailed results of the verification are presented in the Final Report titled *Environmental Technology Verification Report – Questor Technology Inc.* (350Solutions 2020). The report can be made available to the interested parties upon request to Questor Technology.

Bill Chatterton
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Bill Chatterton
Lead Verifier
350Solutions

Audrey Mascarenhas
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Audrey Mascarenhas
President and CEO
Questor Technology Inc.

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