

**EQUIPMENT AND PROCESS  
PRECERTIFICATION PROGRAM**

**EVALUATION OF THE AIR QUALITY  
PERFORMANCE CLAIMS  
FOR THE CATALYTICA ENERGY SYSTEMS, INC.  
XONON™ COOL COMBUSTION TECHNOLOGY**

**JUNE 2002**

California Air Resources Board  
Precertification Program

Equipment: **Xonon™ Cool Combustion  
Technology**

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## **ABSTRACT**

The purpose of this report is to document the California Air Resources Board's (ARB's) evaluation and verification of the air quality-related claims made by Catalytica Energy Systems, Inc. (Catalytica) concerning its Xonon™ Cool Combustion (Xonon) technology installed on a natural gas-fueled 1.5 megawatt (MW) Kawasaki M1A-13X turbine.

In an effort to make progress towards attaining healthy air quality in California, regulations are being implemented to restrict emissions of oxides of nitrogen (NOx) and carbon monoxide (CO) from a broad spectrum of activities. NOx and CO emissions are emitted directly from combustion-related sources such as turbines. The reduction of these pollutants is part of California's clean air strategy to achieve and maintain healthy air quality in California.

As part of its Equipment and Process Precertification (Equipment Precertification) Program application package, Catalytica requested that the ARB evaluate its proposed performance claims. The 1.5 MW Kawasaki M1A-13X gas turbine demonstrated emissions of NOx no greater than 2.5 parts per million by volume, measured on a dry basis (ppmvd), corrected to 15 percent oxygen on a one hour rolling average basis. This technology also demonstrated CO emissions no greater than 6 ppmvd, corrected to 15 percent oxygen on a one hour rolling average basis. NOx and CO emissions were measured when the turbine operated at 98 percent or greater of maximum design capacity.

Upon successful completion of the requirements associated with the ARB's Equipment Precertification Program, a report is issued with two companion documents— an Executive Order issued by the ARB and a certificate issued by the California Environmental Protection Agency. These documents serve as official records that the ARB has independently verified the applicant's performance claims. Executive Orders issued under the ARB's Equipment Precertification Program are valid for three years from the date of issuance, provided that the holder complies with: 1) the terms and conditions identified in this report; and 2) the general requirements discussed in the Equipment Precertification Program Guidelines and Criteria.

After review of the documents discussed throughout this report, the ARB staff recommends that an Executive Order and a Precertification certificate be issued to Catalytica for the Xonon technology installed on a natural gas-fueled 1.5 MW Kawasaki M1A-13X turbine.

**CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY  
AIR RESOURCES BOARD**

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## **I. INTRODUCTION**

This report discusses Catalytica Energy Systems, Inc. (Catalytica) Xonon™ Cool Combustion (Xonon) technology installed on a natural gas-fueled 1.5 Megawatt (MW) Kawasaki M1A-13X turbine. This report also discusses performance claims to be verified by the Air Resources Board (ARB), the emissions testing results, the findings, and recommendations of the ARB staff concerning this technology.

This report is organized into several sections. The General Information section provides background information on the ARB's Equipment and Process Precertification (Precertification) Program. The next three sections (Summary of Scope, Statement of Claims, and Description of Technology) discuss the breadth of our evaluation, performance claims, and a description of Xonon.

The Technical Evaluation and the Evaluation of Claims sections present detailed information on the ARB staff's technical review, and assessment of Xonon. The Quality Management and Environmental Benefits sections provide supporting information on Xonon, and a brief assessment of potential air quality impacts of the technology.

The Recommendations section discusses the ARB staff's determination of the performance of Xonon relative to the company's claims. The Suggested Operating Conditions and the Precertification Conditions sections provide

guidance with respect to the specific conditions that must be met for the certificate to remain valid for three years.

Appendix A contains a listing of the information that we relied upon to conduct our evaluation. The remaining appendices contain detailed information that supports the evaluation in this report.

## **II. GENERAL INFORMATION**

On June 14, 1996, the ARB adopted section 91400, California Code of Regulations, which included the criteria for the Equipment and Process Precertification Program. This regulation became effective on November 30, 1996.

Under this regulation, equipment or processes eligible for the Precertification Program must:

- 1) have an air quality benefit;
- 2) be commonly-used or have the potential to be commonly-used in the near future (market ready);
- 3) not pose a significant potential hazard to public health and safety or the environment.

Furthermore, applicants must demonstrate that they have sufficient control over the manufacturing of the equipment or process to ensure that they can consistently, and reliably produce equipment that performs at least as well as equipment used in this evaluation.

### **A. ARB's Equipment Precertification Program Background**

The Equipment Precertification Program is a voluntary statewide program for manufacturers of

commonly-used equipment or processes. A precondition for entry into the program is that the equipment has an air quality benefit.

Under the Precertification Program, manufacturers request that the ARB conduct an independent third-party verification of performance claims which focus on the air quality benefits of its equipment or process. If the claims are verified, the manufacturer is free to refer to the results of the ARB staff's evaluation in its marketing literature. Upon successful completion of the verification process, the ARB staff notifies air pollution control and air quality management districts (Districts) in California of its determination. As a result of the ARB's notification, the Districts have an advanced opportunity to become familiar with the performance of the equipment or process.

The ARB received a request from Catalytica that the ARB staff determine if Xonon was eligible for the Precertification program. After receiving confirmation from the ARB staff that Xonon was eligible for this program, Catalytica submitted a Precertification application package. As part of our review of the application package, we evaluated the results of emissions testing programs and other information concerning the performance of Xonon to determine whether the claims were verifiable.

## **B. Relationship to Air Quality**

### **1. Oxides of Nitrogen (NOx) Emissions**

NOx are by-products of combustion. NOx can cause adverse effects on the human respiratory system. Through a complex series of atmospheric reactions, NOx contributes to the formation of ground-level ozone, secondary particulate matter, and acid rain.

### **2. Carbon Monoxide (CO) Emissions**

CO is a by-product of incomplete combustion. CO can adversely affect the ability of blood to deliver adequate amounts of oxygen (O<sub>2</sub>) to the human body.

### **3. Control of NOx and CO Emissions from Turbines**

Standard turbine controls used to reduce NOx and CO emission include wet controls, dry controls, and post-combustion controls. Catalytica replaces the normal combustion zone in a turbine with Xonon preventing the formation of NOx and CO.

Local air districts rules, and regulations specify emission limits for NOx and CO using the best available control technology (BACT). For example, the South Coast Air Quality Management District's (SCAQMD) Rule 1134 (Emissions of Oxides of Nitrogen from Stationary Gas Turbines) applies to existing gas turbines that are greater than or equal to 0.3 MW, and less than or equal to 2.9 MW. The rule specifies NOx emissions limitations on these turbines of not greater than 25 parts per million by volume, measured on

a dry basis (ppmvd), corrected to 15 percent O<sub>2</sub>, and averaged over 15 consecutive minutes.

In addition, the current SCAQMD BACT limits for NO<sub>x</sub> and CO emissions for natural gas-fueled turbines are 9 ppmvd and 10 ppmvd, respectively.

The ARB's Guidance for the Permitting of Electrical Generation Technologies (2002) recommends BACT limits for stationary gas turbines less than 3 MW used for electrical generation. The emission limits for NO<sub>x</sub> and CO are 9 ppmvd and 10 ppmvd, respectively.

Districts in California require any equipment that may emit contaminants to operate under a permit, unless otherwise exempt. The reduction of NO<sub>x</sub> and CO emissions is part of California's clean air strategy to achieve and maintain healthy air quality in California.

### **C. Health and Environmental Impacts**

As part of our evaluation, the ARB staff conducted a cursory review of the potential health and environmental impacts associated with Xonon. Based on this review, we concluded that Xonon would not likely present health impacts significantly different from those associated with other similar technologies that are currently in wide use throughout California. Catalytica is required to meet all applicable health and safety standards with respect to the manufacture, installation, operation, and maintenance of Xonon.

### **D. Manufacture/Ownership Rights**

The recommendations in this report are contingent upon Catalytica having the legal rights to produce and/or market Xonon. Catalytica documented its ownership of these rights in its Precertification Eligibility Request on October 19, 1998.

### **III. SUMMARY OF SCOPE**

Catalytica claims using Xonon will minimize NO<sub>x</sub> and CO emissions associated with the operation of a natural gas-fired 1.5 MW Kawasaki M1A-13X turbine. Specifically, Catalytica claims that Xonon demonstrated NO<sub>x</sub> emissions no greater than 2.5 parts per million by volume, measured on a dry basis (ppmvd), corrected to 15 percent O<sub>2</sub> on a one hour rolling average. In addition, Catalytica claims that this technology demonstrated CO emissions no greater than 6 ppmvd, corrected to 15 percent O<sub>2</sub> on a one hour rolling average. Catalytica supports these claims with emissions data obtained with a continuous emissions monitoring system (CEMS), when the turbine operated at 98 percent or greater of maximum design capacity.

### **IV. STATEMENT OF CLAIMS**

The following are the claims verified by the ARB staff concerning the Catalytica's Xonon technology. The verification of these claims are predicated on the presumption that Xonon is tested, manufactured, installed, and maintained in accordance with the manufacturer's instructions contained in the Catalytica's Installation and Operation Manual.

1. **Catalytica Energy Systems' Xonon™ Cool Combustion technology incorporated in a natural gas-fueled 1.5 megawatt Kawasaki M1A-13X turbine demonstrated with a continuous emissions monitor, emissions of oxides of nitrogen no greater than 2.5 parts per million by volume, measured on a dry basis, corrected to 15 percent O<sub>2</sub>, on a one hour rolling average at 98 percent or greater operating load of design capacity.**
2. **Catalytica Energy Systems' Xonon™ Cool Combustion technology incorporated in a natural gas-fueled 1.5 megawatt Kawasaki M1A-13X turbine demonstrated carbon monoxide emissions of no greater than 6 parts per million by volume, corrected to 15 percent O<sub>2</sub>, on a one hour rolling average at 98 percent or greater operating load of design capacity.**

## **V. DESCRIPTION OF TECHNOLOGY**

The Xonon technology is a flameless catalytic combustion system integrated into a 1.5 MW Kawasaki M1A-13X turbine. The technology replaces the conventional combustor. It consists of a lean pre-mix preburner, fuel injectors, a fuel/air mixer, a Xonon catalyst module, and a burnout zone. (See Appendix B, Figure B-1)

The Xonon fuel-air mixture flow begins with the lean premix pre-burner preheating the air to about

880 degrees Fahrenheit. Fuel injectors inject fuel into the preheated air mixture. Then the fuel/air mixing system mixes the preheated air and fuel along with the main airflow. A homogeneous preheated fuel-air mixture now enters the catalyst. The two-stage Xonon catalyst module produces a gas about 1600 degrees Fahrenheit. The remaining fuel is combusted in the burnout zone. All of the combustion is completed without a flame.

The Kawasaki M1A-13X turbine with a Xonon module emits little NO<sub>x</sub> and CO because the fuel is combusted completely at a low temperature.

## **VI. TECHNICAL EVALUATION**

### **A. Description of Emissions Testing**

Catalytica conducted CEMS testing using a Monitor Labs model ML<sup>®</sup>661 that measured NO<sub>x</sub>, CO, and O<sub>2</sub> from the exhaust stack of the turbine. An automatic calibration system checked the CEMS accuracy every 24 hours, which meets the requirements of the U.S. Code of Federal Regulations (CFR) Title 40, Part 60, Appendix B and F. During the testing period, (June 15, 1999 through December 16, 1999) additional manual calibration was performed as necessary. The CEMS measured, and recorded NO<sub>x</sub>, CO, and O<sub>2</sub> from the turbine stack at one-second intervals. Catalytica converted the one-second readings into 15 minute averages throughout the test period. An hour average was calculated using four 15 minute average data records.

A gas audit was performed every three months to assess the accuracy of the CEMS analyzers. The Avogadro Group (AG) annually validated the accuracy of the CEMS by conducting a relative accuracy test audit (RATA). A separate calibrated probe and analyzer was used concurrently with the CEMS for the RATA. Also, the AG tested for district compliance.

The AG used the United States Environmental Protection Agency (U.S. EPA) Method 20 with a Chemiluminescent Analyzer and a Electrochemical Cell Analyzer to measure NO<sub>x</sub> and O<sub>2</sub>, respectively. CO emissions were tested with U.S. EPA Method 10 analyzed by Non-Dispersive Infrared (NDIR)/gas filter correlation analyzers.

#### **B. Description of Test Results**

After evaluating all the test data, the ARB staff concluded that Xonon incorporated in a natural gas-fueled 1.5 megawatt Kawasaki M1A-13X turbine achieved a NO<sub>x</sub> level of less than 2.5 ppmvd, and a CO level of less than 6.0 ppmvd measured on a dry basis, corrected to 15 percent O<sub>2</sub>, over a one hour rolling average at 98 percent or greater operating load of design capacity.

The ARB staff reviewed CEMS Event Criteria Analysis data including startups and shutdown. Also, the 15-minute, and one hour rolling average emission data were reviewed. Emissions of NO<sub>x</sub> and CO are illustrated in Appendix C, Figure C-1 and C-2

#### **C. Facility Visit**

As part of the evaluation, the ARB staff visited the Silicon Valley Power, a municipally owned electric utility in Santa Clara, California. Xonon was installed on a natural gas-fueled 1.5 MW Kawasaki M1A-13X gas turbine, operating as a simple-cycle unit. During the site visit, the ARB staff observed that Xonon performed satisfactorily. The facility operator claimed that he was satisfied with the performance of Xonon.

### **VII. EVALUATION OF CLAIMS**

The ARB staff verification of these claims are based on the evaluation of the information listed in Appendix A. As stated earlier, the ARB staff evaluation and recommendations presented in this report are predicated on the expectation that Xonon is tested, manufactured, and maintained in accordance with Catalytica's procedures, and installed in accordance with the turbine manufacturer. The claim language is precise because it directly correlates with the supporting documentation included in the application package. Below the claims are supporting comments, which may be used to interpret the significance of the claims verified in this report. To assist the reader, the claims are displayed in bold text.

#### **1. Catalytica Energy Systems' Xonon™ Cool Combustion technology incorporated in a natural gas-fueled 1.5 megawatt Kawasaki M1A-13X turbine demonstrated with a continuous emissions monitor, emissions of oxides of**

**nitrogen no greater than 2.5 parts per million by volume, measured on a dry basis, corrected to 15 percent O<sub>2</sub>, on a one hour rolling average at 98 percent or greater operating load of design capacity.**

- 2. Catalytica Energy Systems' Xonon™ Cool Combustion technology incorporated in a natural gas-fueled 1.5 megawatt Kawasaki M1A-13X turbine demonstrated carbon monoxide emissions of no greater than 6 parts per million by volume, corrected to 15 percent O<sub>2</sub>, on a one hour rolling average at 98 percent or greater operating load of design capacity.**

## **VIII. QUALITY MANAGEMENT**

### **A. Practices and Standards**

Catalytica's quality management practices and standards for Xonon are described in detail in the Catalytica's Quality Management Program Manual version I, August 7, 2000. Catalytica's quality system is registered to the International Organization of Standardization (ISO) 9001 standards. Catalytica's Quality Management Program Manual contains quality management practices for the following areas:

- Publication Information, Scope, and Field of Application
- Catalytica Combustion Systems, ISO Quality System Requirements
- Quality System, Contract Review, and Design Control

- Document, Data Control, and Purchasing Department
- Control of Customer Supplied Product
- Product Identification, Traceability, and Process Control
- Inspection, Test, Control of Inspection, Measuring, and Test Equipment
- Inspection, Test Status, and Control of Nonconforming Product
- Corrective and Preventive Action
- Handling, Storage, Packaging, Preservation, and Delivery
- Control of Quality Records and Internal Quality Audits
- Training, Servicing, Statistical Techniques, and Revision of History

The ARB staff reviewed Catalytica's quality management practices, and standards of Xonon. The ARB staff's review determined that the quality management program is sufficiently comprehensive to support Precertifying Catalytica's Xonon technology.

### **B. Operation and Maintenance Requirements**

Catalytica's Xonon is an integral component of a turbine application. The turbine manufacturer is responsible for incorporating any unique operating requirements into the operating and maintenance manual for the turbine generator system.

The Xonon module must be replaced periodically. According to Catalytica, the operator may elect one of several strategies for scheduling the replacement. It can be replaced on

a schedule based on Catalytica's recommendations. The replacement can be scheduled to coincide with the major maintenance inspection of the turbine. The tracking of certain turbine parameters can be used to determine remaining module life. Replacement can usually be done in conjunction with the normal maintenance shutdown when the turbine is disassembled for inspection.

#### **C. Other Certifications/Approvals**

The Xonon technology complies with standards for the ISO 9001 certification. Catalytica received its ISO 9001 certification (A8468) from Underwriters Laboratories Inc.® on December 1999, which is valid until December 2003.

#### **D. Warranties**

Catalytica warrants that Xonon is free from defects in design, workmanship, and material used in its manufacture. A copy of the warranty is provided in Appendix D.

### **IX. ENVIRONMENTAL BENEFITS**

As part of the ARB review, we evaluated the potential air quality impacts of Xonon. We have determined that the use of this technology, in accordance with manufacturer's instructions, likely will minimize NOx and CO emissions.

It should also be noted that under certain conditions, NOx, and CO emissions reductions resulting from the use of Xonon in a gas turbine may be eligible for emission reduction credits. However, individual Districts in California should be consulted to determine the

eligibility for emission reduction credits.

### **X. ARB's RECOMMENDATIONS**

After evaluating the information discussed in this report, we recommend that Xonon be precertified under the ARB's Precertification Program. Specifically, we have independently verified Catalytica's claims concerning Xonon, as presented in the claims section of the report.

By accepting Precertification under the ARB's program, Catalytica assumes, for the duration of the three years Precertification period, responsibility for maintaining the quality of the manufactured equipment, and materials at a level equal or better than was provided to obtain this Precertification. Precertification under the ARB's program is also contingent on the recipient agreeing to be subject to quality monitoring by the ARB, as provided by law.

The ARB makes no express or implied warranties as to the performance of the manufacturer's product or equipment. Nor, does the ARB warrant that the manufacturer's product or equipment is free from any defects in workmanship or material caused by negligence, misuse, accident, or other causes. The ARB staff believes, however, that Xonon will achieve the performance levels presented in the claims section of this report. Our determination is based on our evaluation of the data submitted by Catalytica, as well as other

information identified in this report. Our recommendations are predicated on the expectation that installation, and maintenance are performed in accordance with Catalytica's procedures.

## **XI. SUGGESTED OPERATING CONDITIONS**

In California, stationary sources are permitted at the local level by districts. Each of California's 35 districts has rules and regulations, which must be met to receive an air quality permit. The district rules and regulations reflect federal and state regulatory requirements, as well as, any additional requirements that the district boards determine to be appropriate for the region.

Technologies, which have been certified under the ARB's Precertification Program, are subject to the same federal, state, and local permitting requirements as sources which have not been certified. In short, receipt of a certificate under the ARB's Precertification Program does not limit the authority of local air districts. However, it is expected that local air districts will have an interest in considering the information presented in this report when making permitting decisions, including operating conditions, on Xonon.

## **XII. PRECERTIFICATION CONDITIONS**

The recommendations in this report are conditional upon Xonon being manufactured, installed, and maintained, in accordance with Catalytica's instructions. A copy of these instructions must be provided

to each installer, and user of Xonon prior to installation. In order for the Precertification to remain valid, Catalytica must retain the manufacturing rights for Xonon.

Precertification does not relieve the person constructing, installing or operating the equipment at each specific site from the requirement to obtain an authority to construct, and permit to operate. Precertification does not relieve the person from compliance with any local air district rules or regulations.

Any manufacturer's modification that affects the claimed performance or emissions of Xonon shall void this precertification. This precertification is valid only for the 1.5 MW Kawasaki M1A-13X gas turbine that was designed, and tested with Xonon for this evaluation.

**APPENDIX A**

**MATERIALS AVAILABLE FOR EVALUATION**

## MATERIALS AVAILABLE FOR EVALUATION

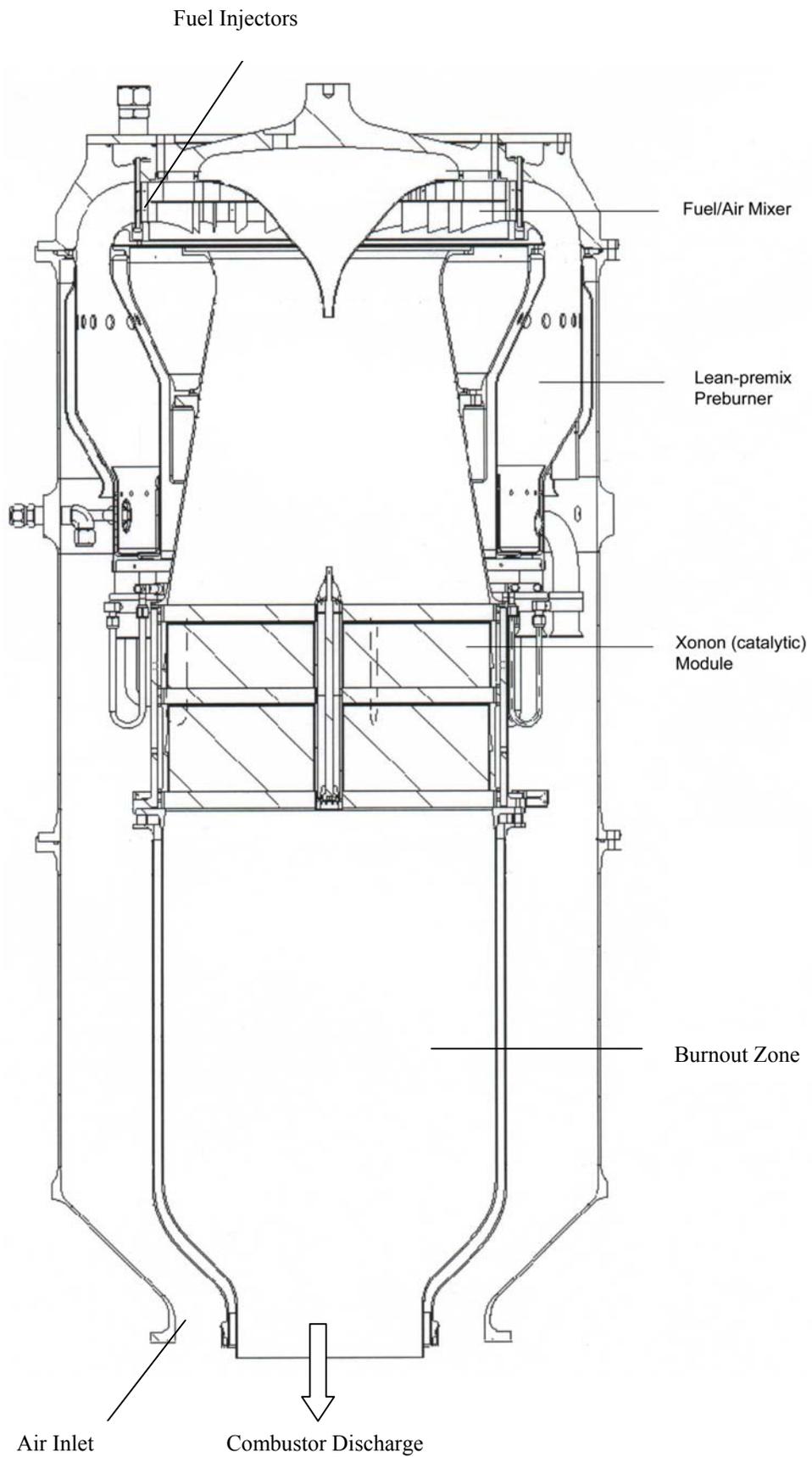
1. Request to determine eligibility for the ARB Equipment Precertification Program from Mr. Chuck Solt of Catalytica to Mr. Richard Corey of the ARB, October 19, 1998.
2. Letter from Mr. Richard Corey of the ARB to Mr. Chuck Solt of Catalytica, notifying Catalytica that Xonon technology was eligible for the ARB Equipment Precertification Program and transmitting an estimate of fee required for Precertification, October 27, 1998.
3. Letter from Mr. Richard Corey of the ARB to Mr. Chuck Solt of Catalytica, providing Catalytica, with guidance in preparing an application for the ARB Equipment Precertification Program for Xonon technology, January 19, 1999.
4. Letter from Mr. Chuck Solt of Catalytica, to Mr. Richard Corey of the ARB providing information about the operating schedule for the Silicon Valley Power Xonon Innovative Clean Air Technology (ICAT) project, October 21, 1999.
5. Memorandum from Ms. Tam Doduc of the ARB's Office of Environmental Technology to Mr. Richard Corey of the ARB notifying him of the need to discuss the eligibility of the Xonon technology for the ARB Equipment Precertification Program, July 13, 2000.
6. Letter from Mr. Richard Corey of the ARB to Mr. Chuck Solt of Catalytica, confirming receipt of the Silicon Valley Power Xonon Emissions Review, providing Catalytica with further guidance in preparing an application for the ARB Equipment Precertification Program, and expressing appreciation for a recent site visit, July 17, 2000.
7. Letter from Ms. Tam Doduc of the ARB's Office of Environmental Technology to Mr. Chuck Solt of Catalytica notifying him that the Xonon technology was eligible to participate in the California Environmental Technology Certification Program, August 10, 2000.
8. Letter from Mr. Chuck Solt of Catalytica to Mr. Richard Corey of the ARB transmitting an Application for Precertification, the Xonon technology test results (CD-ROM), and an application fee, September 6, 2000.
9. Letter from Mr. Richard Corey of the ARB to Mr. Chuck Solt of Catalytica, notifying Catalytica that the ARB had received its application package, and application fee and that the application was sufficiently complete, September 13, 2000.

10. Letter from Mr. Chuck Solt of Catalytica to Mr. Raymond E. Menebroker of the ARB providing information about the Control Technology for Power Plant Guidance Addendum, September 19, 2000.
11. United State Environmental Protection Agency Environmental Technology Verification Report: NOx Control Technologies for Xonon Flameless Combustion System by Mr. Douglas VanOsdell of Research Triangle Institute, Cary, NC, October 2000.
12. Letter from Mr. Craig N. Kitchen of Catalytica to the ARB staff notifying the ARB about the merging of Catalytica Combustion Systems and Advanced Technologies to a single public company, Catalytica Energy Systems, December 19, 2000.
13. Letter from Ms. Kitty Martin of the ARB to Mr. Chuck Solt of Catalytica, notifying Catalytica of the Status of their Precertification, September 21, 2001.
14. Letter from Mr. Chuck Solt of Catalytica to Ms. Kitty Martin of the ARB notifying the ARB of a revised claim, October 15, 2001.
15. Letter from Mr. Orris Anson of Catalytica to Mr. Hafizur Chowdhury of the ARB transmitting the Xonon Warranty; Operation and Maintenance of the Xonon technology; a copy of the Equipment Layout at Santa Clara Facility; and the American Society of Mechanical Engineers (ASME) paper titled: "Field Demonstration of a 1.5 MW Industrial Gas Turbine with a Low Emissions Catalytic Combustion System", October 22, 2001.
16. Letter from Ms. Kitty Martin of the ARB to Mr. Chuck Solt of Catalytica, confirming Catalytica's revised claim language for the Xonon Cool Combustion technology, October 30, 2001.
17. Letter from Mr. Chuck Solt of Catalytica to Ms. Kitty Martin of the ARB, notifying the ARB that Catalytica accepted the revised claim language of the Xonon Cool Combustion technology, December 20, 2002.
18. South Coast Air Quality Management District Rule 1134, "Emissions of Oxides of Nitrogen from Stationary Gas Turbines", Amended August 8, 1997.
19. California Air Resources Board, Stationary Source Division, "Guidance for Power Plant Siting and Best Available Control Technology," September 1999.
20. South Coast Air Quality Management District Best Available Control Technology Guidelines (BACT), Part D: BACT Guidelines for Non-Major Polluting Facilities, October 20, 2000.

21. California Air Resources Board, Stationary Sources Division, Guidance for the Permitting of Electrical Generation Technologies, September, 2001.
22. The Avogadro Group, Quality Assurance Quality Control Plan Continuous Emission Monitoring System Catalytica Combustions Systems, Inc., Mr. Kevin Crosby, August 18, 1999.
23. The Avogadro Group, Report for 1998, Emissions Compliance Test at the Catalytica Genxon Turbine Santa Clara, California, Mr. Kevin Crosby, February 9, 1999.
24. The Avogadro Group, Report for 1998, CEMS Certification Tests at the Catalytica Genxon Turbine Santa Clara, California, Mr. Kevin Crosby, February 9, 1999.
25. The Avogadro Group, Report for the 1999 CEMS Relative Accuracy Test Audit at the Catalytica Genxon Turbine, Santa Clara, California, Mr. Kevin Crosby, February 4, 2000.

**APPENDIX B**

**XONON COMBUSTION SYSTEM ILLUSTRATION**



**Figure B-1 Xonon Combustion System Illustration**

**APPENDIX C**

**EMISSION TEST RESULTS**  
**FOR**  
**THE XONON COMBUSTION SYSTEM**

Figure C-2

CO Emissions Performance 1.5 MW Kawasaki M1A-13X Gas Turbine  
(1-hour rolling average)

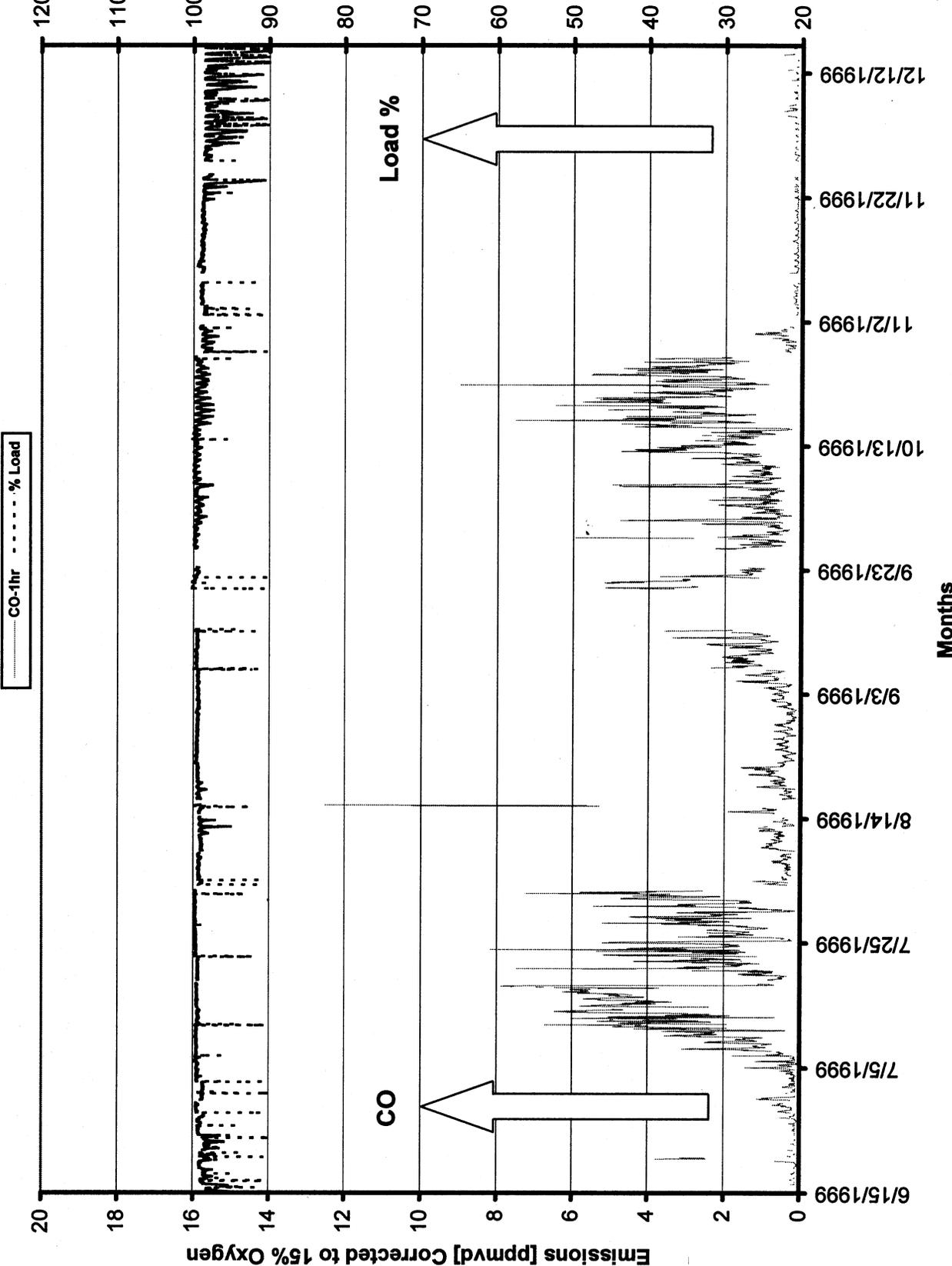
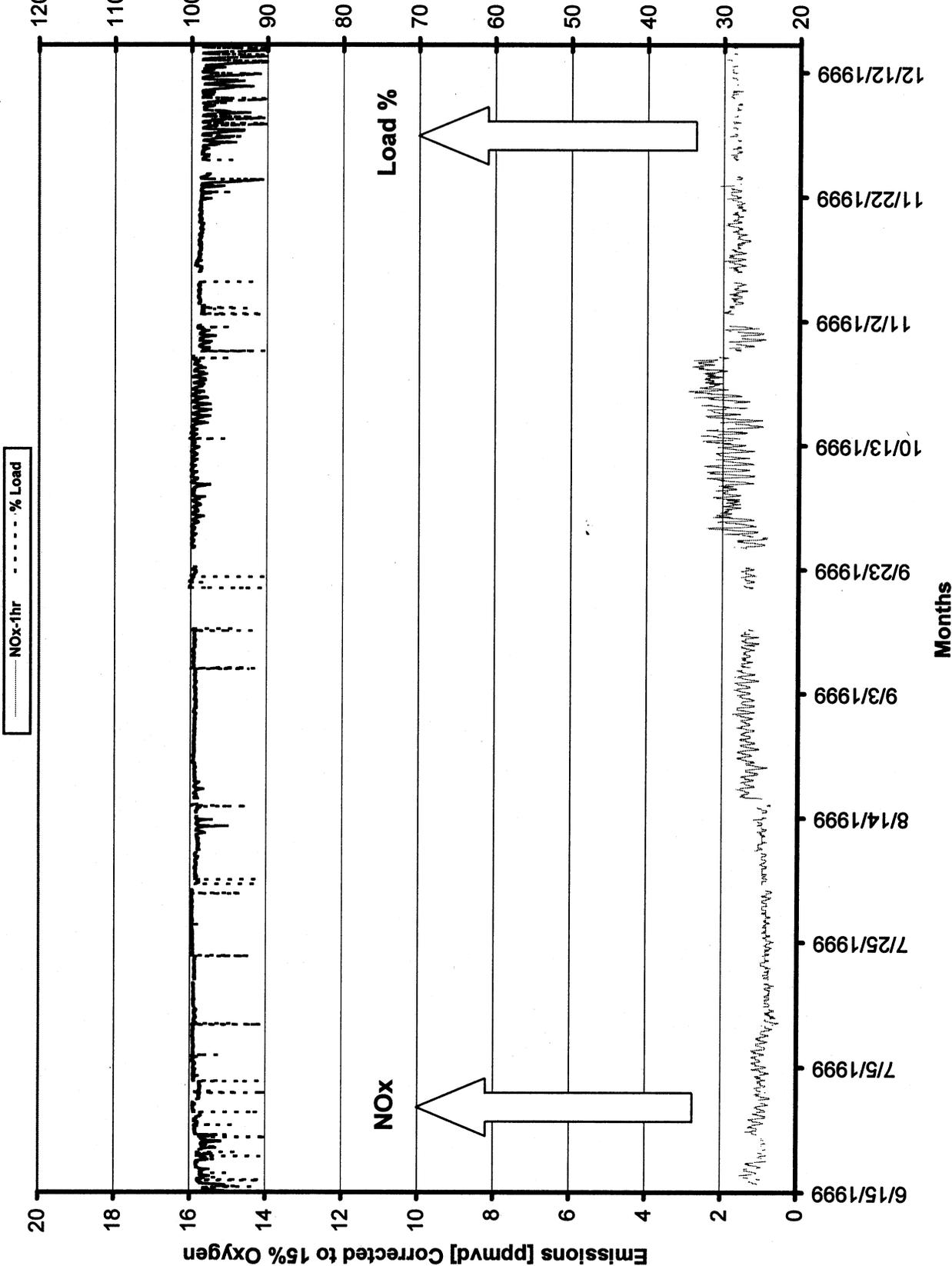


Figure C-1

NOx Emissions Performance for 1.5 MW Kawasaki M1A-13X Gas Turbine  
(1-hour rolling average)



**APPENDIX D**  
**XONON WARRANTY**

## Xonon™ Warranty

Catalytica Energy Systems, Inc. (CESI) warrants the XONON Module to be free from defects in design, workmanship and material used in their manufacture. This warranty will cover , each XONON Module on a unit-by-unit basis, only for claims for such defects made during the first expiration of that period (the "Warranty Period") (i) which begins upon the first firing of a gas turbine containing the XONON Module and ends after an aggregate 8,000 hours of fired operation of the gas turbine containing the XONON Module, or (ii) which begins on the date of the first firing of the gas turbine containing the XONON Module and ends five (5) years thereafter, whichever occurs first.

This warranty is conditioned on:

- a. The XONON Module being installed and used in accordance with CESI's recommended procedures and good industry practice, not altered, disassembled, misused, tampered with or otherwise subjected to conditions outside the environmental envelope specified; and,
- b. Any defective XONON Modules are returned to CESI's facility without undue delay within the Warranty Period in accordance with CESI's standard warranty claim instructions, transportation charges prepaid; and,
- c. Examination of such module(s) by CESI confirms the existence of such a defect.

CESI's obligations under this warranty are limited to repair or replacement including freight of such defective XONON Module(s) (as CESI elects ), free of charge at CESI's place of business. Should multiple removal and reinstallation during a single warranty period be required CESI will provide reimbursement for reasonable costs of the second and subsequent installations. All replacement XONON Modules and repaired XONON Modules are, warranted through, but not beyond, the original Warranty Period. CESI's sole liability and responsibility, and customer's sole and exclusive remedy, with respect to this warranty shall be limited to the remedies set forth above.

This warranty shall not apply to or include (i) Normal maintenance services or adjustments, or (ii) the removal or reinstallation of warranted modules except as stated above (iii) any XONON Module which have been repaired or altered by others, or (iv) the effects of corrosion, erosion or wear and tear or failure occasioned by operation or condition of service more severe than specified.

CESI warrants that the XONON Module will conform only to such national, federal, state or local laws, ordinances, regulations, codes and standards, as stated in the Purchase Order applicable to the XONON Module supplied by CESI hereunder.

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