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ENVIRONMENTAL QUALITY BOARD

December 20, 2002

State of Pennsylvania
Environmental Quality Board
Rachel Carson State Office Building
15th Floor
400 Market Street
Harrisburg, PA 17101-2301

Original: 2302

Re: Proposed Rulemaking – Small Sources of NOx, Cement Kilns and Large Internal Combustion Engines, dated September 17, 2002

To Reviewers of Proposed Amendments to PA Chapters 121, 129 and 145:

These comments are being submitted to the Proposed Rulemaking docket involving 25 PA Code Chapters 121, 129 and 145, "Small Sources of NOx, Cement Kilns and Large Internal Combustion Engines".

Digicon, Inc. is a Craley, Pennsylvania-based company that is engaged in the development of cost-effective NOx control equipment for large, stationary internal combustion engines such as those used at gas pipeline compressor stations. All of our development and manufacturing facilities are located within Pennsylvania.

Regarding the Proposed Pennsylvania Rule for IC Engines, we would like to draw your attention to the attached memorandum from EPA – Office of Air Quality Planning and Standards, dated 8/22/02, entitled "State Implementation Plan Call for Reducing Nitrogen Oxides (NOx) – Stationary Reciprocating Internal Combustion Engines". This was issued to assist States with a variety of issues concerning IC engines and SIP development, and is described as superceding prior EPA Federal Implementation Plan Requirements (dated 10/98) concerning IC engines.

The general thrust of the EPA memorandum is to encourage States to be flexible in their approach to IC engine NOx controls, as it is extremely difficult to shoehorn this very diverse source population into a common set of regulations. In particular, the document clearly states that EPA is indifferent (with regard to IC engines) as to how NOx tonnage reductions are achieved from this source category. Instead, EPA simply suggests that States look at the entirety of IC engine NOx tonnage, rather than controlling every single named unit to a specific emissions level, and establishes that it is acceptable to employ this source category control philosophy for IC engines in individual State Implementation Plans.

EPA's only concern is that the NOx tonnage reductions from the IC engine category be accounted for in SIP submittals. They are indifferent to the means by which these reductions are achieved. Thus, mathematically, reductions can be achieved in at least three ways:

1) Obtaining high-level (>85%) reductions from the specific engines identified in the inventory (which approximates the current Proposed Rule),

2598 Craley Road • P.O. Box 326 • Craley, PA 17312 Phone 717.252.1385 Fax 717.252.5345
www.DigiCon-Inc.com

2) Obtaining moderate (~40 to 50%) NOx reductions from whatever number of engines is required to achieve the overall NOx tonnage reduction target for the IC engine source category, or,

3) Ignoring IC engine controls altogether, as long as the overall State NOx inventory goal is met through reductions in other source categories.

Digicon respectfully submits that an emissions averaging approach that requires moderate NOx reductions to achieve the overall IC engine NOx tonnage reduction target is by far the most cost-effective solution for large IC engine operators. In addition, by diversifying the set of engines that install NOx controls, this approach would statistically increase the likelihood that target reductions are physically achieved – because some engine types and models are extremely difficult to control to high levels, and operators would realize large cost savings. This is a win/win proposition.

There are a variety of means that IC engine operators can employ to achieve these moderate NOx reductions, and this diversity of technology options provides a greater likelihood that compliance can be achieved at these levels, thus providing a much greater assurance of meeting overall NOx targets than simply pursuing very high-level controls. This allows pipelines the operational flexibility to better meet their statutory FERC and PUC service obligations, and should reassure the DEP that the NOx reductions are real and sustainable vis-à-vis overall NOx tonnage cap targets.

Moderate NOx reductions also greatly expands the number of vendors who can provide and guarantee such NOx emissions performance, which will assist engine operators to meet compliance schedules, and will provide a larger pool of support and service personnel to maintain and service the equipment over time. This diversification of NOx equipment supply sources is in the DEP and engine operators interests, and is best facilitated by a moderate-level NOx control requirement that allows averaging over affected sources to achieve the overall source category NOx tonnage reductions.

We feel the EPA guidance memorandum clearly provides the DEP with the ability to meet its SIP Call IC engine NOx tonnage goals through a program of moderate controls across the source category coupled with the ability to average between units. This will reduce the cost of compliance, allow greater margins of compliance on individual units promoting greater operating flexibility, efficiency and reliability, and possibly result in a greater level of NOx reductions than anticipated due to the additional diversity of controlled sources. All of these are in the DEP's, the operators and the public interest. We strongly urge the inclusion of this flexibility in the final Pennsylvania NOx control rule.

Respectfully submitted,

David Stickler
President

DEPARTMENT OF THE NAVY
NAVAL SURFACE WARFARE CENTER
CARDEROCK DIVISION

NAVAL SHIP SYSTEMS
ENGINEERING STATION
5001 S. BROAD STREET
PHILADELPHIA, PA 19112-1403

IN REPLY REFER TO

5090
Ser 027/051
29 JUL 2002

Mr. Thomas Barsley
City of Philadelphia
Air Management Services
321 University Avenue
Philadelphia, PA 19104-4543

Subj: NEW SOURCE PERFORMANCE STANDARD REQUEST FOR EXEMPTION

Dear Mr. Barsley:

The purpose of this letter is to request an exemption from the Subpart GG New Source Performance Standard (NSPS) for nitrogen oxides (NO_x) emissions from the proposed P-104 Marine Gas Turbine (MGT) Test Facility. This test facility will be constructed inside Building 633 at the Naval Surface Warfare Center, Carderock Division, Ship Systems Engineering Station (NSWCCD-SSES) located in Philadelphia Pennsylvania.

The P-104 MGT Test Facility will be used to support research and development (R&D) testing of a variety of gas turbines and hybrid gas turbine/fuel cell combinations for the next generation of naval propulsion and power generation systems. We also anticipate using the test facility for military crew training on next generation naval propulsion plants. The various No. 2 distillate oil fired gas turbine platforms to be installed in the P-104 MGT Test Facility will be designed to simulate shipboard conditions. Much of the proposed testing will be conducted for the purpose of researching techniques to increase turbine efficiency and/or reduce emissions. Because testing must simulate shipboard conditions, the implementation of emission controls would invalidate test results and is not feasible. A description of the anticipated tests and military training to be conducted in the P-104 MGT Test Facility is included as enclosure (1).

NSWCCD-SSES requests that the P-104 MGT Test Facility be considered exempt from the Subpart GG NSPS for NO_x emissions based on the proposed uses of the test facility and the following exemptions provided by the Standard:

- Manufacturer R&D Exemption [40 CFR §60.332(h)] - This exemption pertains to stationary gas turbines engaged by manufacturers in R&D testing of equipment for both gas turbine emission control techniques and efficiency improvements. Although we do not produce gas turbines, NSWCCD-SSES performs R&D testing on gas turbines which is similar to that typically conducted by turbine manufacturers and, in some cases, performs the testing on behalf of the turbine manufacturers. NSWCCD-SSES also modifies gas turbines to create prototypes for R&D testing.

Subj: NEW SOURCE PERFORMANCE STANDARD REQUEST FOR EXEMPTION

- Military Gas Turbine Training Facilities [40 CFR §60.332(g)] - This exemption pertains to military gas turbines for use as military training facilities. Although the primary function of the test facility is R&D testing, we anticipate using the test cell to train military personnel on the operation of future naval propulsion plants as other NSWCCD-SSES test facilities are already used for this purpose on existing U.S. Navy gas turbines.

The requested exemption is required to allow future R&D testing and military crew training on next generation naval propulsion and power generation systems at NSWCCD-SSES. We appreciate your timely response to this request so that we may move forward with the permitting process for the P-104 MGT Test Facility.

Please contact Mr. Patrick Schauble at (215) 897-7057 with your determination regarding this request or if you have any questions that require clarification.

Sincerely,

S.L. JOSEPH
Captain, U.S. Navy
Commanding Officer

Encl: (1) P-104 Marine Gas Turbine Testing Program Description

Copy to:
PADEP J. Slade

P-104 Marine Gas Turbine Testing Program Description

The Marine Gas Turbine (MGT) Program at NSWCCD-SSES Philadelphia currently utilizes the DDG-51 Land Based Engineering Site (LBES) located in Building 77H as a testing facility for the General Electric (GE) LM2500 marine gas turbine. However, due to LBES being fully committed to military crew training and other research programs, this facility has not been fully available to meet all the testing requirements of the MGT Testing Program. In order to accomplish propulsion gas turbine testing to better serve the U.S. Navy (Navy) the proposed MILCON P-104 MGT Test Facility has been designed to be constructed within Building 633. This new test facility will provide the Navy with a variety of testing capabilities for both current GE LM2500 propulsion systems and the research and development of ship propulsion and power plants for future surface combatants and auxiliary vessels. The proposed test facility will provide the capability to test gas turbines up to 50,000 hp.

The variety of MGT Program testing requirements to be conducted in the new MILCON P-104 MGT Test Facility includes the following:

- Prototype testing of both NSWCCD-SSES and Original Equipment Manufacturer (OEM) developed Engineering Change Proposals (ECPs), many of which address increasing turbine efficiency.

- Qualification testing of decommissioned LM2500 gas turbine assets for quality assurance prior to being installed on active duty naval vessels to ensure power rating and efficiency.

- Testing of next generation/upgrades to Full Authority Digital Engine Controllers (FADEC) to increase turbine efficiency.

- Research and development testing of Condition Based Maintenance (CBM) algorithms to increase turbine operating efficiency, reliability, and to reduce maintenance/shipboard manning.

- Research and development testing of new/additional engine sensors in support of CBM to increase turbine efficiency.

- Testing of hybrid turbine/fuel cell propulsion and power systems for development of next generation ship service power plants for Navy vessels. The current testing facility (LBES) is too small and does not have the utilities and support infrastructure to support such testing. Hybrid turbine fuel cell systems have the potential to be much more efficient and produce much lower emissions than today's Navy gas turbines.

- Test and evaluate OEM propulsion plant enhancements that improve turbine efficiency and/or reduce emissions to ensure system applicability to shipboard operational and environmental conditions.

- Qualification of next generation surface combatant ship propulsion plants (i.e. LHD 8, DD(X)) such as, but not limited to, the GE LM2500+ (35,000 hp) and LM6000 (50,000 hp). Testing to be conducted to ensure power rating, turbine efficiency, and reliability.

- Provide military crew training on next generation surface combatant ship propulsion plants (i.e. LM2500+ for the LHD 8).

ATTACHMENT 4

Analysis of Best Available Technology And Lowest Achievable Emission Rate

P-104 Marine Gas Turbine Test Cell Facility
Naval Surface Warfare Center, Carderock Division
Ship Systems Engineering Station
Philadelphia, Pennsylvania

October 31, 2002

I. INTRODUCTION

This report presents the Best Available Technology ("BAT") and Lowest Achievable Emission Rate ("LAER") determinations to support a Plan Approval Application for the construction of a Marine Gas Turbine Test Cell Facility located at the Naval Surface Warfare Center in Philadelphia, Pennsylvania.

The Naval Surface Warfare Center Carderock Division-Ship System Engineering Station ("NSWCCD-SSES") provides machinery engineering support for the current and future Navy. A major part of that mission is construction and operation of numerous full scale test sites which house a variety of propulsion and other marine engines used for the research, development, test and evaluation of ship propulsion and power generation systems. These test facilities are used to evaluate equipment of various kinds under shipboard conditions in an at-sea environment.

NSWCCD-SSES proposes the construction and operation of a new test cell (P-104 MGT Test Facility) located at the Philadelphia Naval Business Center ("PNBC") for testing a variety of large and small gas turbines and fuel cells for the Navy's next generation surface combatants. This test cell will be used to support research and development testing of a variety of gas turbines and hybrid gas turbine/fuel cell combinations for the next generation of naval propulsion and power generation systems. NSWCCD-SSES also anticipates using the test cell facility for military crew training on next generation naval propulsion plants. The various No. 2 distillate oil fired gas turbine platforms to be installed in the test cell will be designed to simulate shipboard conditions. Much of the proposed testing will be conducted for the purpose of researching techniques to increase turbine efficiency and reduce emissions. A description of the anticipated tests and military training to be conducted in the test cell facility is included as Exhibit A.

Milcon P-104 is a FY01 congressional mandate that comprises the construction of a 6,600 square foot facility within an existing building with a steel lined reinforced concrete test cell enclosure, a control room, supporting electrical, mechanical and weight handling equipment and space for a waterbrake and laydown. BRAC 95 consolidated NSWCCD-SSES facilities for heavy mechanical equipment evaluation/testing at the PNBC. Consequently, the Navy has no alternative facilities or sites for conducting research, development, testing and evaluation of ship propulsion and power generation systems as is contemplated for the Milcon P-104 test cell.

II. EVALUATION GUIDELINES

The Philadelphia region, including the proposed location of the test cell facility, is designated as severe non-attainment for ozone. Because estimated actual emissions from the proposed test cell facility indicate that it will emit greater than 25 tons per year of nitrogen oxides, it is subject to New Source Review requirements. Section 127.205 of Chapter 25 of the Pennsylvania Code, which has been adopted by Philadelphia Air Management Services ("AMS"), provides, in pertinent part, that a Plan Approval shall not be issued for a new major stationary source in a non-attainment area unless the applicant demonstrates that it will comply with Lowest Achievable Emission Rate ("LAER"). This phrase is defined as the rate of emissions achieved by application of the more restrictive of (a) the most stringent emission limitation in the state implementation plan or (b) the most stringent emission limitation achieved in practice by the class or category of source. In addition to the application of LAER to a new major stationary source, AMS has adopted Section 127.12(a)(5) of Chapter 25 of the Pennsylvania Code, which requires that an applicant for a Plan Approval show that the emissions from the new source will be the minimum attainable through the use of best available technology ("BAT"). This phrase is defined as equipment, devices, methods or techniques, which will prevent, reduce or control emissions to air contaminants to the maximum degree possible and which are or may be made available.

The purpose of this analysis is to identify LAER and BAT, for the proposed Marine Gas Turbine ("MGT") Test Cell Facility. Underlying this analysis is the general consensus that LAER is a "floor" below which there can be no more stringent control of emissions. Accordingly, the applicant submits that any conclusions from this analysis regarding LAER for the proposed test cell facility will also satisfy the requirements of BAT under the applicable regulations.

III. ANALYSIS OF LOWEST ACHIEVABLE EMISSION RATE

LAER has at the foundation of its definition and purpose the concept that air emissions from new stationary sources should be regulated and controlled on the basis of classes or categories of sources. Any LAER analysis thus begins with an evaluation and determination of whether the proposed new source of air emissions falls within an existing class or category of sources established by the U.S. Environmental Protection Agency ("EPA"), the state or the local implementing agency. It is against this backdrop that the applicant reviewed all federal, state and local regulations with an eye toward locating a source category or class of stationary sources identified as engine test cells. This research conclusively demonstrates that, while engine test cells have a number of gas stream characteristics in common with stationary gas turbines used for power generation, because of certain unique and distinctive operational considerations, engine test cells are appropriately considered as their own source category. One limited qualification to this conclusion is that the applicant's research uncovered a Maximum Achievable Control Technology("MACT") standard being proposed by the EPA for potential hazardous air pollutants from engine test cells. However, the proposed MACT standard does not establish an emission limit for any criteria pollutant, including nitrogen oxides, which is the most important pollutant in the context of the LAER analysis for the proposed test cell facility. In conclusion, engine test cells generally, and the proposed MGT Test Cell Facility in particular, are a class and source category by themselves and LAER must be determined on that basis. This conclusion is supported by the facts that (a) the Pennsylvania State Implementation Plan does not contain any emissions limitation whatsoever for any kind of engine test cell facility, whether turbine or otherwise and (b) the EPA's RACT/BACT/LAER Clearinghouse does not establish an emission limit for or contain any reference to engine test cells.

In light of this conclusion, LAER for purposes of the proposed MGT Test Cell Facility must be determined based on "the most stringent emission limitation achieved in practice by the class or category of source". It is against this backdrop that the applicant contacted every state environmental agency in the nation to identify the presence, if any, of existing and operating engine test cells and obtain air permits issued by the state environmental agency for such operations. A summary of the findings from this effort, specifically regarding how the state environmental agencies addressed the issues of (a) emissions limits for conventional pollutants, and (b) the use of add-on controls, are attached as Exhibits B and C.

A number of noteworthy items can be gleaned from the findings presented in Exhibit B regarding the issue of LAER. First, the overwhelming majority of engine test cell facilities in the United States are designed with the intent and purpose of evaluating the performance of aircraft engines, not marine propulsion systems. Second, the regulatory aspects of the various air permits revealed a wide spectrum of approaches by the state environmental agencies ranging from the most stringent emission limit of 0.37 pounds per hour and 1.59 tons per year of nitrogen oxides (Little Rock, Arkansas-Aircraft Engine Test Cells) to the most lenient of totally unregulated emissions (Oahu, Hawaii and Paxuxent River, Maryland-Aircraft Engine Test Cells). Third, a good number of the engine test cells in the United States are minor sources of air emissions, in many instances accepting federally enforceable limitations on such things as operating hours, type of fuel combusted, number of permissible test runs per year, and type of engine to be tested, in order to avoid being designated a "major stationary source". Finally, a number of the permits covered in Exhibit B applied to entire facilities containing various air emissions sources, not just engine test cells. Most or all of emissions limits in those permits could not be dissected to identify an emission limit specific to the engine test cell portion of the permitted facility.

All things considered, then, there is no one "most stringent emission limit that has been achieved in practice" as is required by the definition of LAER. To the contrary, air emissions from engine test cells across the United States are clearly regulated on a case-by-case basis without regard to the establishment or application of a most stringent emission limit for the test cells as a class or source category. This variability in emissions limits alone is a confirmation that LAER has not been established for engine test cells as a class. Accordingly, none of the emissions limits established in these air permits are a good measure of LAER for the MGT Test Cell Facility because those other permitted facilities do not reflect the kind of operating conditions that will be encountered at the MGT Test Cell Facility.

One other finding of particular and overriding importance here is the fact that no permitted engine test cell in the United States has add-on air pollution control. This finding is consistent with the fact that the unique operating constraints imposed upon engine test cells by the military make it extremely difficult to apply air pollution controls to these facilities. The EPA funded a national study of aircraft engine test cells in order to determine what, if any, emission reduction strategies can be applied to them. "Jet Engine Test Cells- Emissions and Control Measures" (EPA 340/1-78-001, April, 1978). The results of this study indicated that there is no air pollution control option currently available that will permit the jet engine development test program to operate within the requirements demanded by the military and the Federal Aviation Administration. Among the options considered for the control of emissions were fuel modifications, engine combustion modifications, Selective Non-Catalytic Reduction, Selective Catalytic Reduction, electrostatic precipitation, nucleation scrubbing, thermal conversion, and catalytic oxidation. These options were all found to be technically infeasible since they would cause unacceptable interference with engine performance requirements. In addition, the economic impacts were prohibitive in most circumstances.

Although this federal study dealt with aircraft engine test cells, it is equally applicable to the test cell facility proposed for the PNBC. Even though it will be testing marine turbine propulsion systems, the proposed test cell facility is subject to a number of unique performance criteria and operating constraints that, if upset in any fashion, will void the validity of the testing results. The EPA study appropriately noted that there are two key practical aspects that must be considered with regard to add-on controls for engine test cells. The first is the probable intermittent operation of the add-on control equipment and the varying load and exhaust rate of the test cell. The second is the impact of the add-on control device on the engine operation. In this case, testing will be performed for different purposes (performance, emissions controls, endurance, and operator training). Also, tests periods will vary dramatically during the course of the year, not to mention the fact that operating conditions during a particular test will vary as a particular turbine is ramped up and down. Additionally, downtime for the test cell between tests could last from a period of several hours to several days or more. Operation of an add-on control technology will therefore be awkward and not at optimum efficiency due to the irregular schedule of start-up and shut-down of the control equipment. The control equipment would also suffer from extended periods of non-operation.

Like the aircraft engine test cells, applying air pollution controls is a sure way to create conditions in the proposed test cell facility that will upset the performance criteria and operating constraints. Because testing must simulate shipboard conditions, the implementation of emission controls would invalidate test results and is thus not feasible.

IV. ANALYSIS OF BEST AVAILABLE TECHNOLOGY

The applicant's analysis of LAER concludes that implementation of emission controls is not feasible for the proposed turbine test cell facility. Because LAER is a "floor" for purposes of emission controls for new stationary sources, and is thus arguably more stringent than BAT, a separate analysis for BAT in this case is not necessary. However, the applicant wishes to demonstrate conclusively that the conclusion reached for LAER is the same as what the outcome will be with a full review of BAT. Accordingly, the following is a presentation of emissions controls for stationary gas turbines using a typical "top down" approach.

A. NITROGEN OXIDES

1. Characteristics of Turbine Nitrogen Oxides Emissions

Nitrogen oxides (NO_x) are generated by high temperature combustion processes, resulting primarily from the interaction of the nitrogen content of the fuel (fuel NO_x) and the dissociation of atmospheric nitrogen and oxygen which reform as NO_x during combustion (thermal NO_x). The net result is the near establishment of the nitrogen-oxygen-nitric oxide-nitrogen dioxide equilibria at the high temperatures achieved by the flame. NO_x formation is a complex process that involves several elementary chemical reactions representing both equilibrium and non-equilibrium states that take place in the pre-combustion, combustion, and post-combustion regions.

The principal nitrogen oxide formed in the combustion process is nitric oxide (NO). Nitrogen dioxide (NO_2) is also formed but to a lesser extent. NO_2 formation is more significant after the combustion process when the NO is oxidized through mixing with atmospheric oxygen. It is NO's role as a precursor to NO_2 formation that makes NO emissions an important consideration.

NO formation in a combustion system is essentially determined by the peak temperature achieved during combustion. The longer that the high temperatures are maintained, the larger the quantity of NO that can be expected to form. Conversely, since

NO formation continues well into the post flame region, rapid quenching the post-combustion gases by removing heat or diluting with cooler air will tend to reduce overall NO formation.

NO formation in combustion has been described by the Zeldovich mechanism which is comprised of two simple, reversible, interrelated reactions:

$NO_2\bullet + O\bullet <---> NO + N\bullet$
$N\bullet + O_2 <---> NO + O\bullet$

NO_2 is formed from NO through several reaction pathways. During the first few minutes that a nitric oxide rich exhaust is mixed with air, oxidation may significantly proceed through the simple reaction:

$2NO + O_2 ---> 2NO_2$

The rate of formation is dependent upon the square of the NO concentration. Therefore, at high NO concentrations characteristic to combustion process exhausts, the NO_2 formation rate will be relatively high. In general, about 25 percent of the NO will oxidize to NO_2 through the simple reaction shown above. Additional oxidation can occur in the exhaust plume and atmosphere through a myriad of reaction pathways including photochemical conversions.

Nitrogen oxides are generally agreed to be the most significant pollutant emitted by turbines. The high excess air operating principle of turbines tends to promote thermal NO_x formation.

2. Summary of NO_x Control Technologies

Several emission control technologies have been and are being developed to reduce NO_x emissions from stationary gas turbines. Most of these technologies are based upon combustion modifications alternatives fuels, or exhaust gas treatment (add-on controls). Two recent USEPA documents discuss these technologies:

- Alternative Control Techniques Document--NO_x Emissions from Stationary Gas Turbines, EPA-453/R-93-007, January 1993.
- Nitrogen Oxide Emissions and Their Control from Uninstalled Aircraft Engines in Enclosed Test Cells, EPA-453/R-94-068, October 1994.

Findings from these two reports were primarily used for this evaluation. Several technologies including alternative fuels, post-combustion reburn, and sorbent technology were not considered in detail by the evaluation. These technologies are clearly not feasible for a variety of reasons. For example, testing must be performed using the fuel types that will be used in the field installation; reburn is relatively inefficient, 10 to 30 percent NO_x reduction, and may actually generate additional NO_x; and, sorbent technology is in the early development stage.

Technologies which are considered and discussed in this report include selective catalytic reduction (SCR), selective non-catalytic reduction (SNCR) and water (or steam) injection.

a. Selective Catalytic Reduction

Selective catalytic reduction ("SCR") is capable of providing the highest NO_x control efficiency for gas turbines when combined with water or steam injection. SCR controls have demonstrated reductions of inlet NO_x concentrations from 40 to 60 ppmv to levels of 8 to 10 ppmv at the outlet.

The SCR process involves passing the NO_x –laden exhaust gas over a catalyst bed in the presence of ammonia. Ammonia is introduced upstream of the catalyst bed, and together with NO_x reacts to form elemental nitrogen (N_2) and water. The function of the catalyst is to control the chemical reaction rate. The catalyst is used to promote the following reactions:

$4NO + 4NH_3 = O_2$ ---catalyst--- > $4N_2 + 6H_2O$
$2NO_2 + 4NH_3 + O_2$ ---catalytic--- > $3NH_2$ to $6H_2O$

Both reactions occur readily without a catalyst present at temperatures of approximately 1300°F or higher. However, in the presence of a catalyst, these reactions can occur at much lower temperatures ranging from 500°F to 750°F.

The anhydrous ammonia supply can be stored either in tanks or cylinders in the form of liquid ammonia. The ammonia is mixed with water to yield a 25 percent by weight ammonia solution. The solution is typically fed to an indirectly heated evaporator, and the vapor is injected into the exhaust gases through nozzles upstream from the catalyst. Injection upstream allows the ammonia enough time to properly mix with the exhaust gas. Sometimes compressed air is used as the ammonia carrier gas. When this is the case, the ammonia concentration must be kept below the explosive limit.

Ammonia slip and proper NH_3/NO_x ratio levels are two areas that must be monitored closely in order to maintain efficient emission control. SCR systems generally operate with a molar NH_3/NO_x ratio of about 1.0. Values ranging from 0.7 to 1.5 are possible depending on the specific design requirements and catalyst condition. For a given system, increasing NH_3/NO_x over this range will reduce NO_x emissions. However, the amount of unreacted ammonia that passes through the SCR system, referred to as "ammonia slip", can also increase.

SCR catalysts are typically comprised of an active metal on a rigid inert support material which provides a large specific surface area. One such design uses a honeycomb configuration consisting of titanium dioxide – vanadium pentoxide (TiO_2-V_2O_5) arranged in a parallel fashion to the gas flow. The benefits of such a design include reduced pressure drops, lower risk of pluggage resulting from particulate matter, and high surface to volume ratio.

SCR catalysts deteriorate with use due to surface deposits, poisoning, or sintering (structural change to a monolithic solid without melting). As the catalyst activity decreases, the NH_3/NO_x ratio required to maintain a designed NO_x removal level increases. As a result, more NH_3 is unreacted, increasing slip, and NH_3 consumption becomes uneconomical. At this point, the catalyst modules typically have to be replaced.

Catalyst regeneration can be accomplished by periodically washing the modules with water in a reverse flushing method. Most manufacturers provide a one year guarantee for the catalyst life. However, the life span of a catalyst module can be approximately five years if maintained on a regular basis. Wastewater from rinsing is usually 10 times the catalyst volume and may contain up to 250 ppm V_2O_5. Spent catalyst may also contain various alkaline metals such as NaO_2. Some manufacturers will accept and regenerate spent catalyst modules when new modules are purchased. Others recommend crushing and mixing the catalyst with cement prior to disposal.

Recent technological advances have allowed several companies to apply new types of catalysts which are more resistant to deterioration and operate better when sulfur containing fuels are used. The Norton Company manufactures zeolite-based catalysts. Although not extensively applied, this new catalyst is said to be more resistant to poisoning; operates over a larger temperature window (600°F to 950°F); is not toxic and therefore easier to dispose; produces half the pressure drop of conventional catalysts, and acts as an "ammonia sponge". Zeolite catalysts are also claimed to not oxidize SO_2 and

SO_3 and therefore produce less sulfuric acid and ammonium sulfate/bisulfate when sulfur bearing fuels are burned.

Several design factors must be considered when implementing SCR controls. Operating temperature, sulfur content of the fuel, design of the ammonia injection system and catalyst maintenance. Inlet temperature optimization is critical when using SCR. Temperatures below 500°F inhibit the reaction while temperatures above 850°F promotes oxidation of NH_3 to NO_x.

As was referred to above, fuel sulfur content must be considered in a potential SCR system application. The SCR catalyst promotes oxidation of sulfur dioxide (SO_2) to sulfur trioxide (SO_3) which, in the presence of water, forms sulfuric acid (H_2SO_4). The typical conversion rate of SO_2 to SO_3 is approximately 2%.

Ammonia can react with sulfuric acid in the exhaust gas to produce particulate compounds: ammonium bisulfate and ammonium sulfate. These compounds are formed by the following reactions:

$NH_3 + H_2SO_4 \text{ --- > } NH_4HSO_4$
$2NH_3 + H_2SO_4 \text{ --- > } (NH_4)_2SO_4$

Ammonia bisulfate is a corrosive solid and can be produced when the exhaust gas temperature is below 699°F. Ammonium sulfate forms at lower temperatures and poses less material damage problems due to its non-corrosive properties. If formed in significant quantities, these sulfates can cause severe plugging and/or corrosion. Prevention of such build ups include the use of lower sulfur fuels and/or the control of ammonia slip to levels below 5 ppm. Small deposit rates can be managed through periodic in situ catalyst washing.

As mentioned earlier, a major concern with NO_x reduction using SCR catalyst is "ammonia slip". Strict control of the ammonia injection system must be kept in order to keep the NH_3/NO_x ratio at a level such that all of the ammonia is reacted. Ideal conditions are usually not realistic and thus most SCR catalyst manufacturers estimate approximately 10 ppmv of ammonia slip under normal operating conditions. Obviously, improper system operation would result in either a high NH_3 slip or conversely a lower NO_x removal efficiency.

Significant differences exist between the stack gas characteristics of conventional stationary gas turbines and exhaust gas characteristics of test cell operations. In fact, P-104 has its own unique differences in comparison with conventional stationary gas turbine installations. The major difference which will have a substantial effect on ammonia slip and NO_x reduction is the comparatively very rapid and frequent changes in engine speed and power output. The variations in temperature and NO_x emissions will place demands on the SCR controller not found in conventional SCR installations. If the controller is not able to react to the rapid changes, increased ammonia slip and increased NO_x emissions will result.

Another operation factor worth noting is the catalyst preheat time. Typically, the catalyst is preheated for 10 to 15 minutes before ammonia injection is initiated. The preheat source is the engine exhaust. During the preheat period, the SCR is providing little if any NO_x emission control. Some test cycles only have durations of 10 to 15 minutes. Therefore, a test run may be completed before the SCR system would be functional.

Installation of an SCR on an engine test facility will require development of advanced ammonia injection technology. A sophisticated controller will be necessary to regulate the amount of ammonia injected as the NO_x concentration changes in conjunction with engine power levels. If the controller is not able to respond to the rapid power changes, the potential for excessive ammonia slip increases and NO_x emissions will not be effectively controlled. SCR units serving simple and combined cycle (cogeneration) gas turbine installations require ammonia injection controllers which have to respond to small modulations in engine power output. Therefore, controllers which exist for field installations are not adequate to respond to the rapid power changes which typically occur within a minute or less during test cycles.

In addition to the NO_x concentration change, exhaust temperature and flowrate changes will impact SCR effectiveness. Exhaust temperatures in test cells will, for the most part, fall within the applicable range. However, some test cycles will be shorter than the required preheat time. Further, the long term effect of temperature cycling on the mechanical integrity of the catalyst is unknown. It is reasonable to assume that the catalyst life will be shortened. Exhaust flowrates will vary by a factor of approximately five, i.e., 40 pounds per second to 200 pounds per second. Although of lesser concern then the NO_x concentration and exhaust temperature changes, such flowrate variation is not typical to conventional stationary gas turbine installations.

In short, engine testing requires rapid and frequent changes in engine output, thus the variations in temperature, exhaust flowrate, and NO_x emissions from test facilities would place demands on the SCR controller not found in typical SCR installations. SCR systems cannot be considered reliable for application to the proposed project.

Finally, as is discussed in more detail in subsection 3 below, adding SCR onto a test cell will change the operating conditions of the facility. Changing these conditions would not allow testing to completely simulate Shipboard operations as required and would therefore invalidate the testing results.

b. Selective Non-Catalytic Reduction

Selective non-catalytic reduction ("SNCR") is a post-combustion technology that reduces NO_x using ammonia or urea injection. One of these chemicals is added to the combustion products where they react at elevated temperatures (1,600° to 2,200°F) with NO_x to form molecular nitrogen. The primary limiting factor restricting SNCR application is that it is only viable over a fairly narrow temperature range and there is potential for the production of by-product emissions. For both ammonia and urea injection, incomplete reactions will result in "ammonia slip". It is also possible to increase NO_x emissions if the upper temperature range is exceeded. Similar to SCR, adding SNCR will disrupt the operating conditions of the test cell and invalidate test results. Accordingly, this alternative is infeasible.

c. Water Injection

The principle behind this control technology is to reduce the peak combustion temperature and formation of thermal NO_x. This process involves injection of water or steam into the combustor. It may be used alone or in conjunction with an SCR system. The water acts as a coolant which reduces the peak combustion temperature in the combustion zone. As a result, the maximum temperature is lowered thereby reducing the formation of thermal NO_x. Water or steam injection typically reduces thermal NO_x emissions by 60-70 percent.

Technical considerations associated with water injection NO_x control include the water to fuel ratio and the potential for increasing levels of other combustion generated pollutants. The NO_x emission concentration is approximately inversely proportional to the water to fuel ratio. This relationship is true to the limit where inhibits the overall combustion process itself. As the injection rate increases, within the limit, the NO_x emission concentration decreases. However, increasing the injection ratio does reduce the combustion efficiency. From an environmental standpoint, as the combustion efficiency decreases, carbon monoxide and unburned hydrocarbon emissions generally increase. Therefore, control by water injection involves a pollutant trade-off, i.e., lower NO_x emissions in exchange for higher CO and hydrocarbon emissions.

For gas turbines at normal water to fuel injection ratios of 1:1, NO_x emission concentrations of approximately 42 ppmv are typically achieved with acceptable thermal efficiency, CO and unburned hydrocarbon emissions. It has been reported that gas turbines employing steam to fuel ratios as great as 1.5:1 have been developed and have been shown to be capable of reducing NO_x emissions to as low as 25 ppmv.

The use of water injection would significantly alter the performance characteristics of the turbine under test, and would also invalidate any emissions measurements. The operating characteristics of the turbine, and particularly the combustor segment, will be significantly different in all of the critical areas used to evaluate the performance of the turbine within the test facility. The test would be invalid or provide data for unrealistic or non-representative turbine operating conditions. For these reasons, water injection technology should not be considered as a technically viable option.

3. EPA Study of No_x Controls for Test Cells

Under Section 233 of the Clean Air Act, EPA and the Secretary of Transportation, in consultation with the Secretary of Defense, were directed by Congress to study and investigate the testing of uninstalled aircraft engines in enclosed test cells. As part of their investigation they were to address at a minimum the following issues:

- o whether technologies exist to control some or all emission of oxides of nitrogen from test cells;
- o the effectiveness of such technologies;
- o the cost of implementing;
- o whether such technology affect the safety, design, structure, operation, or performance of aircraft engines;
- o whether such technology impairs the effectiveness and accuracy of aircraft engine safety design and performance test conducted in test cells, and
- o the impact of not controlling such oxides of nitrogen in the applicable nonattainment areas and on other sources, stationary and mobile, on oxides of nitrogen in such areas.

In September of 1994 in response to the above Congressional mandate, a report (EPA-453/R-94-068, September 1994) was submitted to Congress to provide a characterization of aircraft engine test cells and their emissions. The report points out that although control technologies exist for the control of NO_x, none have been applied full scale to any of the 368 enclosed aircraft engine test cells in the United States. This EPA report investigates the various NO_x control technologies that have been applied to combustion sources other than test cells and examines in the report their applicability to test cells.

The following six points are made in the executive summary of the EPA report and can be summarized as follows:

"Although technologies exist for the control of NO_x, none have been applied (full scale) to aircraft engine test cells in the United States. The differences of engines, engine tests, test cell sizes and types complicate the design ..."

"The effectiveness of add-on control technologies applied to test cells...cannot be determined until after installation and testing on a full-scale test cell".

"Costs... will be high ranging from an estimated $167,000 to over $2.5 million per ton NO_x reduced".

"NO_x control technologies using water or steam injection and fuel/water emulsions would directly adversely affect the safety, design, structure, operation, or performance of aircraft engines"...water or stream injection and fuel/water emulsions should not be considered technically feasible"...

"...unwanted back pressure effects may result from add-on NO_x control technologies"...

"The impact of not controlling NO_x emission from test cells... The vast majority of test cells contribute less that 1 percent of the stationary source NO_x emissions and less than 0.07 percent of the combined stationary and mobile source NO_x emissions".

After reviewing the configuration of the proposed P-104 test cell many of the above mentioned roadblocks can be easily reaffirmed. The conditions of operations do not make control technologies viable or practical. Test cells are historically run on a very intermittent basis and tests are run for short periods of time.

Adjusting the fuel burning parameters is also not a viable alternative in light of the fact that test requirements are dictated by the need to replicate at-sea conditions. Fuel must be used in a manner that will allow the desired operational simulation.

In summary, since there are no facilities in the U.S. using control technologies on engine test facilities and in light of the definitive conclusion by EPA that add-on controls would have questionable effectiveness and be technically infeasible, no added controls are in order at this time for the proposed test cell.

B. SULFUR OXIDES

1. Characteristics of Turbine Sulfur Oxides Emissions

Sulfur oxides ("SO_x") are generated when sulfur-bearing fuels are burned. SO_x are stoichiometrically generated with one pound of sulfur yielding two pounds of sulfur dioxide (SO_2). Sulfur Trioxide (SO_3) is also formed, typically in small amounts. Sulfuric acid is formed by hydration of the SO_3. SO_x emission factors, and therefore emissions, for gas turbines are the same as for any other combustion process using sulfur-bearing fuels.

2. Summary of SO_x Control Technologies

There are two general types of SO_x emission control technologies applied to combustion sources. These technologies are "clean fuels" and add-on emission control equipment. Clean fuel in this case refers to those that have a low sulfur content. Natural gas and other true gaseous fuels are the cleanest, having essentially no inherent sulfur content other than mercaptan odorants added for safety purposes to aid in leak detection. Kerosene and No. 2 fuel oil are the "cleanest" of the liquid fuels, having the lowest inherent sulfur content. Jet fuel is a kerosene based fuel.

Add-on emission controls refer to equipment that is typically installed in the exhaust path following the emission generating process. A preliminary selection of suitable add-on sulfur oxides emission control equipment is generally based on knowledge of three items: fuel sulfur content, exhaust flowrate, and the allowable emission rate. Once the systems that are capable of providing the required emission reduction at the given flowrate have been chosen the ultimate selection is generally made on the basis of the total cost of construction and operation. The size of a collection device, and therefore its costs, is usually proportional to the volumetric exhaust flowrate. The operating factors which influence the cost of a device are the pressure drop through the collection device, the power required, and, in the case of wet scrubbers, the quantity of water, reagents, and sludge handling equipment needed. These factors are dependent upon the exhaust SO_x concentration.

The technologies that have traditionally been implemented to remove sulfur oxides and most other acid gases involved some form of liquid phase absorption. Both untreated and alkaline scrubbing solutions are used. The solubility of SO_x in plain water makes its use possible, but impractical for large systems or where high efficiency removal is required. Plain water saturates quickly, resulting in a low pH and reduced SO_x solubility. Therefore, plain water systems are typically "once-through". The fresh scrubbing water requirement and the relatively low removal efficiency achievable with plain water are typically prohibitive for implementation of this approach.

The techniques that have been more frequently used are wet scrubbing incorporating a caustic solution or lime-based liquor. More recently, dry technologies have been developed which include lime spray dryers, hydrated lime injection and sodium bicarbonate injection. Lime spray dryers have been applied to boiler sulfur dioxide (SO_2) emission control and are favored for acid gas control for municipal waste combustion (MWC) sources. Lime and sodium bicarbonate-based dry injection systems are also being considered for MWC acid gas emission control. However, these represent emerging rather than extensively demonstrated techniques.

Although available, add-on SO_x emission control technologies have not been demonstrated nor required for conventional gas turbine installations. The unique nature of the planned test facility, in comparison with conventional stationary gas turbine installations, would pose even greater operational limitations on an add-on control technology than would a conventional gas turbine installation.

Note that NSWCCD-SSES will control emission of SO_x by using low sulfur fuel 0.2% sulfur by weight maximum).

C. PARTICULATE MATTER AND PM_{10}

1. Characteristics of Gas Turbine Particulate Matter Emissions

Gas turbine particulate matter emissions and their control have received lesser attention. The lack of attention appears to be due to the fact that, in relative terms, the emissions are small by comparison with other fuel-burning sources. This condition is particularly true for natural gas operation. The only data that could be identified regarding gas turbine particulate emissions was found in a study of jet engine test cells (Jet Engine Test Cells – Emissions and Controls: Phase 1, EPA-340/1-78-001a, April 1978). It is important to remember that the study was conducted principally for military application jet engines.

The particles emitted by jet engines are approximately 95 percent carbon by weight and 5 percent oxygen and hydrogen. One of the difficulties in quantifying these emissions is that they may be comprised of condensed unburned hydrocarbons (fuel) and solid particulate. The unburned fuel particles, which grow into soot in the tailpipe section, oxidize completely at the high temperatures downstream from the tailpipe unless quenching occurs. In turbine systems, the formation of very large soot particles is prevented by the vigorous backmixing that occurs. Quenching occurs because combustor walls, turbine blades, and other internals are cooled by excess air. Any soot particles that come into contact with these surfaces are quenched rapidly.

The size of particles emitted by jet engines has not been fully established. Collecting and characterizing these particles under the extreme conditions in the engine exhaust is a difficult task. Testing reported by the study indicated that the particles were submicron with average particle diameters of 0.02 to 0.06 microns on a number basis and 0.2 to 0.4 microns on a mass basis. Further away from the engine at low power settings, soot particles grow slowly by agglomeration. Particles composed of condensable hydrocarbons grow rapidly by agglomeration in particles on the order of 10 microns in diameter. However, there is very little information about the size distribution of the condensed hydrocarbon vapor aerosol. At high power settings, the exhaust remains hot enough so that condensable hydrocarbon aerosols do not form at the engine exhaust.

2. Summary of Particulate Control Technologies

There are two general types of PM emission control technologies applied to combustion sources. These technologies are "clean fuels" and add-on emission control equipment. Clean fuels refers to those that have a low ash content and are characterized by complete combustibility under normal use conditions. Natural gas and other true gas fuels are the cleanest, having essentially no inherent ash content and exhibiting complete combustion to carbon dioxide and water vapor under proper combustion conditions. Kerosene and No. 2 fuel oil are the "cleanest" of the liquid fuels, having the lowest inherent ash content and excellent combustion characteristics. Jet fuel is a kerosene based fuel.

Add-on emission controls refer to equipment that is typically installed in the exhaust path following the emission generating process. A preliminary selection of suitable add-on particulate emission control equipment is generally based on knowledge of four items: particulate concentration in the exhaust stream, particle size distribution, exhaust flowrate, and the allowable emission rate. Once the systems that are capable of providing the required emission reductions at the given flowrates have been chosen, the ultimate selection is generally made on the basis of the total cost of construction and operation. The size of a collection device, and therefore its cost, is usually proportional to the volumetric exhaust flowrate. The operating factors which influence the cost of a device are the pressure drop through the collection device, the power required, and, in the case of wet scrubbers, the quantity of liquid needed.

Although conceivably available, add-on particulate matter control technologies have not been demonstrated nor required for conventional turbine installations. The unique nature of the planned test facility, in comparison with conventional turbine installations would pose even greater operational limitations on add-on control technology than would a conventional gas turbine installation.

D. CARBON MONOXIDE

1. Characteristics of Turbine Carbon Monoxide Emissions

Carbon monoxide is generated by the incomplete combustion of any carbon-based fuel. Even in the most closely controlled combustion process, some carbon monoxide will be generated. Unfortunately, the complex nature of combustion processes and the desire to reduce all combustion generated emissions requires a level of compromise. The process conditions required to reduce one pollutant may lead to an emission increase of another pollutant. Unburned hydrocarbon and CO emissions are reduced by maintaining high combustion zone temperatures and excess air conditions. However, high combustion zone temperatures and excess air levels lead to increased NO_x emissions. In the case of turbines, lean combustion and/or water or steam injection are used to control combustion zone temperatures to reduce the formation of thermal NO_x. The result is an increase of CO and unburned hydrocarbon emissions above "normal" levels.

2. Summary of CO Control Technologies

CO emissions are generally reduced by equipment design to promote high efficiency combustion, control of the combustion process, or exhaust gas treatment (add-on controls). The only add-on control typically used for CO emission control is oxidation (incineration). The selected approach is dependent upon the specific combustion process or equipment requiring a CO emission reduction.

a. Equipment Design and Combustion Control

Equipment design measures usually focus upon achieving complete mixing of the fuel and combustion air. The measures incorporated promote turbulence to affect the mixing. Burner design is a highly specialized technology and is typically considered proprietary by the burner manufacturers.

Combustion control measures are external to the combustion process. As an example, these might include equipment to provide fine control of the air to fuel ratio based on feed back from combustion process monitors.

Reduction of CO emissions by operation of the test cell is limited because of the constraints of the test program. The major purpose of the testing is to determine the durability and performance of the engine, and to measure the emissions at discrete intervals and at base load. As we discussed previously, this will necessitate different operating conditions, including power setting, length of operation at a power setting, etc. Therefore, the emissions from the engine can be expected to be the lowest achievable by combustor design.

b. Incineration

Incineration is the only form of add-on control applied to CO emissions from combustion processes. Simply stated, incineration is the thermal process by which CO is converted to carbon dioxide. The incineration controls the combustion process that was started in the combustion device. There are two types of incineration: catalytic and thermal.

(i) Catalytic Oxidation

Catalytic oxidation is often advantageous because it requires less auxiliary fuel to achieve oxidation temperatures than does the thermal type. In some cases, adequate heat energy may exist in the exhaust gases so that additional fuel is not required. The conversion is affected by passing the exhaust stream over a metallic catalyst. Where applicable, catalytic oxidation usually yields operating cost savings in comparison to thermal incineration.

Catalysis occurs at a molecular level. If particulate materials contact the catalyst as either discrete or partially combusted aerosols, they can ash on the catalyst surface. The catalyst surface eventually becomes coated with the ashed material. This coating reduces the amount of active catalyst surface and the oxidation efficiency is greatly reduced. This type of problem is generally evidenced by a secondary pollution problem, i.e., odorous emissions attributable to partially oxidized species.

Another concern with catalytic oxidizers is catalyst poisoning. Poisoning is the process by which specific contaminants in the gas stream chemically combine with or alloy with the active catalyst material. The list of metal poisons frequently cited includes phosphorous, bismuth, arsenic, antimony, mercury, lead, tin, and zinc. The first five metals are considered fast acting poisons. Such materials, including phosphate residues from metal cleaning detergents, should be excluded from the process exhaust stream. Even trace quantities of these fast acting poisons in the exhaust stream can lead to rapid catalyst deactivation. The last three metals are referred to as slow acting poisons. Experience indicates that catalysts are somewhat more tolerant of these metals, particularly at temperatures below 1,000°F. However, these materials should also be excluded from the gas stream, thereby excluding the use of galvanized ductwork in the exhaust and incinerator systems.

Sulfur and halogens are also regarded as catalyst poisons. But in most cases, their chemical interaction with the catalyst is reversible. That is, catalyst activity is restored when the halogen or sulfur-containing compound is not present in the gas stream.

(ii) Thermal Oxidation

Thermal oxidation is a widely used add-on control alternative, particularly for volatile organic compound emissions. The simplest thermal oxidizer consists of an auxiliary burner mounted in the exhaust stream along with baffle or profile plates to induce mixing between the exhaust gas and the auxiliary burner combustion zone. Temperatures are 1,400 to 1,500°F in the high temperature zone with residence times of 0.1 to 0.3 seconds usually sufficient to complete conversion of most substances. Some VOC can be effectively converted at temperatures in the range of 1,100 to 1,200°F. CO requires both higher temperatures and longer residence times.

Thermal incineration imposes a pollutant trade-off. Although CO and unburned hydrocarbon emissions can be reduced, NO_x emissions increase due to the high temperature supplemental fuel combustion.

V. <u>CONCLUSION</u>

In conclusion, a review of both LAER and BAT conclusively demonstrates that, for a variety of reasons, neither modification of the combustion process nor add-on air pollution control technology are appropriate in the context of turbine test cell facilities. Perhaps most compelling in reaching this conclusion is EPA's study of the control of nitrogen oxide emissions from aircraft engine test cells wherein the EPA concluded that, although control technologies exist for the control of nitrogen oxides, none have been applied full scale to any of the enclosed aircraft engine test cells in the United States. This finding has been confirmed by the applicant's recent research into air permits issued nationwide all forms of engine test cells, which confirmed that combustion process modifications and add-on controls were infeasible principally because of the disturbance to operating parameters for the test cells. In light of these findings, the applicant submits that Philadelphia Air Management Services should not require any form of air pollution control for the proposed MGT Test Cell.

EXHIBIT A

MARINE GAS TURBINE PROGRAM TESTING REQUIREMENTS

- Prototype testing of organic and Original Equipment Manufacturer (OEM) developed Engineering Change Proposals (ECPs), many of which address increasing turbine efficiency.
- Qualification testing of decommissioned LM2500 gas turbine assets for quality assurance prior to being installed on active duty naval vessels to ensure power rating and efficiency.
- Testing of next generation/upgrades to Full Authority Digital Engine controllers (FADEC) to increase turbine efficiency.
- Research and development testing of Condition Based Maintenance (CBM) algorithms to increase engine operating efficiency, reliability, and to reduce maintenance/shipboard manning.
- Research and development testing of new/additional engine sensors in support of CBM to increase turbine efficiency.
- Testing of hybrid turbine-fuel cell propulsion and power systems for development of next generation ship service power plants for US Navy vessels.
- Test and evaluate OEM propulsion plant enhancements that improve turbine efficiency and/or reduce emissions to ensure system applicability to shipboard operational and environmental conditions.
- Qualification of next generation surface combatant ship propulsion plants (i.e., LHD 8, DD(X)) such as, but not limited to, the GE LM2500+ (35,000 hp). Testing to be conducted to ensure power rating, turbine efficiency, and reliability.
- Provide military crew training on next generation surface combatant ship propulsion plants (i.e., LM2500+ for the LHD 8).

EXHIBIT B
LOWEST ACHIEVABLE EMISSION RATE
PROCEDURE FOR IDENTIFICATION OF EXISTING TEST CELLS

State	Contact	Results	Permit	Application
Alabama	Air Division (334) 271-7861	**No test facilities**	N/A	N/A
Alaska	Air and Water Quality - Bill Walker - (907) 465-5124	Test Facilities at Eilsonson AFB effectively unregulated, agency currently trying to figure out how to deal with them; agency has not performed BAT analysis; Jim Baumgardner (907) 465-5108 ; constructed hush house & other facility without permit; trying for PSD avoidance		
Arizona	Air Quality Division: (602) 207-2308	**No test facilities**	N/A	N/A
Arkansas	Thomas Rheaume (501)- 682-0762	No limit for test cells; BACT applied; cannot put SCR on test cell;3.5 ppm Ox from power plants; AR regulations require BACT; go on EPA website to get facilities in AR; regulates test cell, not aircraft or ships LOOK on EPA website for AR test cell facilities	Little Rock AFB minor source permit	
California	Michelle Marasigan , Public Records Air Management Bureau San Diego Air Pollution Control District (858) 650-4700	Submitted FOIA to San Diego Air District for permits, have fax describing permits.	received	
Colorado	Air Pollution Control Division - Mike Jensen – 303-692-3167	Sent sections of permits for facilities at Buckley AFB, and Fort Carson	Received partial permits	
Connecticut	Bureau of Air Management (860) 424-4152	Currently not enforcing regs on test cells, but thinks they should. If enforced, they would treat them like permanent facilities; e-mail sent to Carol Vanderlip, public information officer for permits	Awaiting e-mail response	
Delaware	Air Quality Management Ravi Rangan (302) 323-4542	**No test facilities**; if there were, they would require same standards as permanent facilities	N/A	N/A
Florida	Bureau of Air Regulation New Source Review Al Linero (850) 921-9523 and Jeff Koener Selva Selvendran (561) 355-3136, ext. 1143 Mallika Muthiah (305)372-6921 Frank Echaniquew (305) 372-6943	Test facilities subject to the same standards as permanent facilities; contact local agencies; Linero & Koerner in joint t/c referred me to Mallikah Muthiah at the county level; she is willing to e-mail me permits, but her assistant Frank Echanique and I continue to play telephone tag	Received	
Georgia	Jack Capp Manager of NOx Permitting Unit Department of Natural Resources 404-463-7143	Look at www.air.dnr.state.ga.us/sspp.	Delta permits from website	Application summaries from website

State	Contact	Results	Permit	Application
Hawaii	Mike Madsen Clean Air Branch, Environmental Management Division 808 586-4200	Kaneohe Marine Corps has test cell facility; but was not addressed in the application; Kaneohe submitted additional information to determine whether testing was exempt; it is exempt and thus the test cell facility Hickham Air Force Base has test cell	received	Received 3/18/02
Idaho	Mike Simon Air Quality Manager Department of Environmental Quality (208) 373-0212	Referred me to Jason Jedry Public Information Coordinator for permits/applications(208) 373-0165; Jedry advised that Mountain Home Air Force Base is only such permitted facility in state	**Received 3/26/02**	
Illinois	Illinois EPA, Air Quality Email to: Kim.Kuntzman@epa.state.il.us Chris Romaine NSR Manager Il. EPA, Dept. of Air Quality (217) 782-2113 Marilyn Cladry (217) 782-2113	Romaine replied to e-mail that a request for permits and applications need to be made to FOI Officer;	Follow-up needed; Scott AFB permit received 3/26/02; list of other sites sent; very expensive to copy permits and applications.	
Indiana	Mack Sims Permit Division Office of Air Quality Department of Environmental Management (317) 233-0867	Referred to www.in.gov/idem/oam/permits/powerplt; look at Merchant Plant also referred to BACT/RACT/LAER clearinghouse site of EPA;	Some docs printed off website	
Iowa	Gary Smith, Environmental , Engineer Air Quality Bureau	**No test facilities**	**N/A**	**N/A**
Kansas	John Ramsey, Environmental Engineer, Department of Health & Environment Division of Environment Bureau of Air & Radiation (785) 296-1992	**No test cells** for jet engines, nor for gas turbines that are not being installed in a power plant ; Boeing has plant in KS but does not perform tests there.	**N/A**	**N/A**
Kentucky	Tom Adams (502) 573-3382, Engineer Edd Frazier, Permit Review	**No jet engine cell testing is performed there.**	**N/A**	**N/A**
Louisiana	Jim Courville (225) 765-0197, Engineer Syed Quadri Air Permits Division ;Department of Environmental Quality (225) 765-0500,	**LA has never permitted a test cell;** only stationary gas turbines are tested	**N/A**	**N/A**
Maine	T/C Ed Cousins DEP Bureau of Air Quality; (207) 287-2437	Bangor Army National Guard had test cell 5 yrs. ago. Maine capped amount of time it could run and gave them a 1 Ton limit. Cousins e-mailed the "license". That's the only facility "licensed". Pratt & Whitney does not have a test facility on its property in Maine	**received 3/6/02**	

State	Contact	Results	Permit	Application
Maryland	T/C Russ Summers (410) 631-3251 (former Pratt & Whitney engineer; will retire in four months)	**No test cells in MD.**	Patuxnet River N..A.S.	
Massachusetts	Marc Altobelli Combustion Supervisor NE Regional Office MA Department of Environmental Protection Executive Office of Environmental Affairs	GE Aircraft has facility in Lynn MA.	Received permits 3/12/02	
Michigan	Lori Peacock Permit engineer Department of Environmental Quality (517) 373-7082 Lorraine Hickman FOIA Coordinator Dept. of Environmental Quality (517)241-9059	Submitted FOIA for Gas Turbine test facilities in general, and for Permit # 515-93A, Williams International Test Facility	Received partial list of permitted facilities; Permit #515-93A	
Minnesota	David Beil, Engineer Pollution Control Agency Department of Natural Resources (651)-296-7810	**No permits written yet for combustion turbines yet**	N/A	N/A
Mississippi	Dallas Baker (601) 961-5670 Department of Environmental Quality	NASA's Stennis Space Center has test cell; rocket engine testing is permitted stationary source	Received	
Missouri	Department of Natural Resources Omer Roberts Technical Assistance Program Outreach & Assistance Center Environmental Assistance Office Business Assistance Unit	**MO has nothing stricter than federal regulations**; Roberts will check locations of facilities, if any; directed to www.dnr.state.mo.us/alpd/apcp/maccagen.htm Found no reference to jet engine test cell therein	Awaiting follow-up call	
Montana	David Klemp Department of Environmental Quality (406) 444-0286	**No test facilities**	**N/A**	**N/A**

State	Contact	Results	Permit	Application
Nebraska	Clark Smith Supervisor of Permitting Department of Environmental Quality (402) 471-2189 William Lund, Environmental Engineer (402)471-2151 Todd Ellis Acting Compliance Supervisor Department of Natural Resources (402) 471-4561	Offutt Air Force Base has pending construction permit for test cell; restrictions: 15T per yr. PM 10; 40 T other pollutants, except 50 T CO_2; Nox 40 T per yr.; If they have construction permit, they wouldn't require RACT/BACT/LAER; **Lund says Offutt has *applied* to construct test cell, but it's not been issued**; Ellis says Offutt's permit is only pending one he knows of	Offutt construction permit	
Nevada	Bureau of Air Quality Mehrdad Moghimy (775) 687-4670	**No test facilities in the state**	N/A	N/A
New Hampshire	Parma Baru, Engineer	In 1994 a construction permit for jet engine test cell was issued, but test cell was never installed. Permit would have since expired. (maximum 14.7 Btu/hr.	**Received 3/18**	
New Jersey	NJ DEP Air Permit Program Kevin Greener (609) 292-0834 Bob Darrow - NSR - (609) 633-8249 who referred me to Bill Keuhne (609) 633-8247	Test facilities regulated the same as permanent facilities; no permits issued for test cells in NJ. However, Federal Aviation Authority in Pomona NJ and UNC, Inc. in Millville, NJ are considered **insignificant sources**; i.e. testing is performed there but those facilities have **de minimis emissions (less than 5 T per yr and less than 30 days per yr.)** Thus, no permits were issued.	**N/A**	**N/A**
New Mexico	Lawrence Alires(505) 955-8020 (referred by Ned Jerabek (505) 955-8013), Environmental Engineer Air Permitting Specialist Environment Department	Holloman Air Force Base is subject to construction permit with restrcition of 10lb. Per hour and 25 tons/yr of NOx emissions; New Mexico kept its state regulations but also adopted federal regulations in 1971; Emissions are calculated based on amount of time spent in each test mode (muffler built for noise protection, so stack was installed); subject to PSD; New Mexico writes Statement of basis before a Title V permit is written.	Received 3/7/02	
New York	NYDEC Mike Jennings, Environmental Engineer (518) 402-8403	GE Turbine Plant and Plattsburg AFB General Electric Turbine Plant DCID: 4421500054 Wood Group Gas Turbines, Permit ID# 5-0942-00239/00002	Received	

State	Contact	Results	Permit	Application
North Carolina	Tom Allen Rules Development Branch (919)733-1489 Robert Fisher Division of Air Quality (252) 946-6481 J.P. Chauhan, Air Quality Engineer (252) 966-6481 x. 266 John C. Evans (PSD Air Quality Division) (919) 715-6252 Edward Childs at Cherry Point (252) 464-9658	Allen advised that Cherry Point Marine Corps Base has test cell; many test cells have been operating since 1950's'and are not formally permitted; the one at Cherry Point was permitted in 1997	Received e-mail version of Cherry Point permit on 3/27/02	
North Dakota	Lee Huber, Environmental Scientist, Department of Health Division of Air Quality (701) 328-5188	**No test cell facilities**	**N/A**	**N/A**
Ohio	Ohio Environmental Protection Agency Division of Air Pollution Control Field Ops and Permit Management Section email to mike.ahern@epa.state.oh.us loretta.crum@epa.state.oh.us (614) 644-3626 Cindy Charles, Permit Supervisor Portsmouth Local Air Agency Portsmouth, OH (740) 353-5156 Brad Miller, Area Hamilton County Environmental Services	GE facilities exist in southeast Ohio and Cincinnati area	Peeble, OH and Cincinnati OH GE facilities	Peeble, OH and Cincinnati OH GE facilities
Oklahoma	Jerry Goochey (pronounced Goo shay') Air Quality Division Department of Environmental Quality	There are a couple of Air Force Bases in OK; Goochey called to report that no final permits have been issued; Tinker AFB was "grandfathered in"	N/A	N/A
Oregon	DEQ - Air Quality - NSR Dave Kauth (503) 229-5655 referred DS to Greg Grunow (503) 229-5571 who referred PMV to Kathy Amidon, Natural Resource Specialist (503) 229-5568 Randy Bailey (503) 229-6736	There is one engine test cell facility in NE region of OR; Oregon Energy is required to submit application for Title V w/I one yr of start-up	Received 3/13	Received 3/13
Rhode Island	Doug McVay Department of Environmental Management Air Resources Division (401) 222-2808 ext.7011	**No test facilities**	N/A	N/A

State	Contact	Results	Permit	Application
South Carolina	Heather Preston Bureau of Air Qualityy Dept. of Health & Environment Control (DHEC) (803) 898-4287	Regulations received from Preston; FOI request sent to Jody Hamm at DHEC	Received 3/20/02	Received 3/20/02
South Dakota	Kyrik Rombough, Engineering Specialist Air Quality Program Dept. of Environment & Natural Resources (605) 773-5708	Minor permit issued to Air National Guard	Received 3/8/02	
Tennessee	Manir Ahmed (615) 532-0536 TN Air Pollution Control Division TN Department of Environment & Conservation	Arnold Air Force Base has test cell; P. S. Reddy, Chief of Middle TN Permit Program advised that DRAFT permit for Arnold AFB was issued on 3/7/02 and can be printed from web: www.state.tn.us/environment/apc/apcppo/ArnoldEng.pdf	Printed from web 3/14/02	
Texas	Erick Hendrikson (512) 239-1249 referred PMV to Jim Randall who referred PMV to Jim Linville Combustion Team (512) 239-1261	TX issues minor source permit by rule; cannot be issued permit by rule if facility is subject to federal permit; if facility is not subject to non-attainment, then it must be below 25 tons per yr.(per 30 TAC 106.23) Stuart & Stephens facility is permitted	Received GE federal operating permit from GE;	
Utah	John Jenks, Environmental Engineer New Source Review Section, Division of Air Quality Department of Environmental Quality (801) 536-4000	**No test facilities**	**N/A**	**N/A**
Vermont	Jennifer Bryan, Environmental Engineer, Engineering Services Air Pollution Control Division of Agency of Natural Resources (802) 241-3840	**No test cell facilities**	N/A	**N/A**
Virginia	Office of Air Permit Programs Yogeshi N.Doshi (804) 698-4017 Gary E. Graham Virginia Department of Environmental Quality (804) 698-4103		Received 4/1/02 (Langley Air Force Base)	
Washington	Tom Todd , Rule Unit Supervisor Air Quality Program Department of Ecology (360) 407-7528 Steve Van Slyke, Superisor Engineer for Permit Team of Puget Sound Clean Air Agency (206) 689-4052	**No test cell facilities**	N/A	N/A

State	Contact	Results	Permit	Application
West Virginia	Steve Pursley, Environmental Engineer Department of Environmental Protection Division of Air Quality (304)926-3727	Pratt & Whitney in Bridgeport WV was issued permit in September ,1999	received 3/14/02	
Wisconsin	Air Management Program, Public Information Officer - email - urbana@dnr.state.wi.us Jeff Hanson (608) 266-6876 Department of Natural Resources Air Permitting	**No test cell facilities**	N/A	
Wyoming	Bob Gill, Compliance Program Manager Air Quality Division Casper, WY office 307-473-3455	**No test facilities in State**	N/A	N/A

EXHI C

LOWEST ACHIEVEABLE ENGINE RATE
NATIONWIDE TEST CELL EMISSION LIMITS
RESEARCH FINDINGS

Location	Type of Facility	NOx Limit	SOx Limit	TSP	PM-10	CO	VOC	Add On Controls
Little Rock, AR	Aircraft Engine Test Cells	0.37 PPH[1]; 1.59 TPY	0.25 PPH; 1.06 TPY		.05 lbs/yr .16 TPY[2]	.66 lbs/yr	.4 PPH 1.65 TPY	none
Los Angeles, CA	Aircraft Engine Test Cells							
	Cell 1	51 PPD[3]	2 PPD		1 lb/day	27 PPD	9 PPD	none
	Cell 2	12 PPD	2 PPD		1 PPD	19 PPD	25 PPD	none
Buckley AFB, CO	Jet Engine Test Cells	380.62 PPH	12.46 PPH	8.82 PPH		1637.60 PPH	1137.35 PPH	
Fort Carson, CO	Aircraft Engine Test Cell	2 TPY	none			2 TPY		none
Kaman Aerospace Corporation Bloomfield, CT	Turbine engine mounted in K-MAX test rig	11.0 PPH 4.94 TPY	1.01 PPH .45 TPY		.78 PPH .35 TPY	2.51 PPH 1.12 TPY	.78 PPH .35 TPY	
Pratt & Whitney, div. of United Technologies Corp. Andrew. Willgoos Lab East Hartford, CT	GG-8 stationary gas turbine at X-234 test stand	75.3 TPY	4.08 TPY		1.43 PPH	29.3 PPH	10.38 PPH	
Pratt & Whitney div of United Technologies Andrew Willgoos Lab East Hartford, CT	GG-8 stationary gas turbine at X-237 test stand	461.5 PPH 392.3 TPY	22.63 PPH 19.2 TPY		5.49 PPH 4.7 TPY	39.66 PPH' 37.7 TPY	15.68 PPH 15.9 TPY	

[1] PPH = pounds per hour
[2] TPY = tons per year
[3] PPD = pounds per day

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LOWEST ACHIEVEABLE ENGINE RATE
NATIONWIDE TEST CELL EMISSION LIMITS
RESEARCH FINDINGS

Location	Type of Facility	NOx Limit	SOx Limit	TSP	PM-10	CO	VOC	Add On Controls
Pratt & Whitney div. off United Technologies Corp. Andrew Willgoos Lab East Hartford, CT	GG-8 gas turbine at X-218 test stand	461.5 PPH 34.6 TPY	22.63 PPH 1.7 TPY		5.49 PPH	39.66 PPH 3.3 TPY		
Pratt & Whitney Middletown, CT	Gas turbine engine	230 PPH 15.7 TPY	51.4 PPH 3.505 TPY		15.2 PPH 1.037 TPY	12 PPH .819 TPY		
Hamilton Sunstrand Corporation, Windsor Locks, CT	Test cell E for testing of propeller systems and controls on Allison T56A-427 and comparably sized turbo prop engines	12.57 PPH	13.70 PPH	3.84	3.84	106.3 PPH	14.95 PPH	
GE Engine Service-Miami, Inc., FL	Engine test cells	240 TPY	240 TPY			240 TPY	240 TPY	
Atlanta, GA	Aircraft Engine Test Cell	90 TPY	none					none
Oahu, HI	Aircraft Engine Test Cell	unregulated	unregulated	unregulated	unregulated	unregulated	unregulated	
AFB, ID	Hush House (jet engine test cell)	212 TPY	7.8 TPY.		8.9 TPY	42 TPY	180 TPY	none
Scott AFB, IL	Jet engine test cell	1852 lb/yr				696 lbs/yr		
Lynn, MA	Aircraft Engine Test Cells	150 tons/month; 637 TPY	none					none
Paxuxent River, MD	Aircraft Engine Test Cell	unregulated	unregulated	unregulated	unregulated	unregulated	unregulated	
Bangor, ME	Aircraft Engine Test Cell	29.1 TPY	15.4 TPY		4.4 TPY	6.5 TPY	20 TPY	none

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LOWEST ACHIEVEABLE ENGINE RATE
NATIONWIDE TEST CELL EMISSION LIMITS
RESEARCH FINDINGS

Location	Type of Facility	NOx Limit	SOx Limit	TSP	PM-10	CO	VOC	Add On Controls
Walled Lake, MI	Aircraft Engine Test Cell	38.4 TPY	24 TPY					none
Hancock, MS	NASA Rocket Engine Test Cell	2520 lbs/test; 39.4 TPY	2520 lbs/test; 39.4 TPY		6060 lbs/test 14.4 TPY	558,600 lbs/test 1300 TPY	50 lbs/test 39.4 TPY	none
Cherry Point Marine Base, NC	Jet engine test cell	1.54 lb/hr						
	Building 133 TC-1,2,3,4							
	Building 137 D 154, TC 5, 102,105,106,109,110,113,121							
	Building 4188 F402							
	Building 3402 T407							
	Building 4172 GB1A							
Offutt AFB, NE	Jet Engine Test Cell	80.7 lbs/test; 29.4 TPY	9.1 lbs/test; 3.3 TPY		100.6 lbs/test	63.5 lbs/test	48.2 lbs/test	none
Portsmouth, NH	Aircraft Engine Test Cell	7.73 PPH; 4.23 TPY	max of 0.4% by weight of S in fuel			3.73 PPH		none
AFB, NM	Aircraft Engine Test Cell	331.4 PPH; 121.5 TPY	188 PPH; 122 TPY		28.2 PPH 6.7 TPY	900.4 PPH 393.7 TPY	132.2 PPH 60.2 TPY	none

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LOWEST ACHIEVEABLE ENGINE RATE
NATIONWIDE TEST CELL EMISSION LIMITS
RESEARCH FINDINGS

Location	Type of Facility	NOx Limit	SOx Limit	TSP	PM-10	CO	VOC	Add On Controls
Wood Group Plattsburgh, NY	Gas Turbines Jet Engine test cell	100 tons per yr. for Part 227 NOx RACT & Title V						
Cincinnati, OH	Aircraft Engine Test Cell	951 PPH; 52.3 TPY	83.2 PPH; 21.2 TPY	9 PPH 10.2 TPY		200 PPH 58.4 TYP		none
Evendale, OH	Aircraft Engine Test Cell	5.0 lbs/MMBTU; 23.7 TPY	0.44 lbs/MMBTU; 2.44 TPY		8.4 TPY	16.23 TYP		none
Peebles, OH	Aircraft Engine Test Cells							
	F007	5900 PPH; 389 TPY	200 PPH; 16.6 TPY		25 PPH 6.1 TYP	350 PPH 300 TPY		none
	F010	5900 PPH; 389 TPY	200 PPH; 16.6 TPY		25 PPH 6.1 TPY	350 PPH 300 TPY		None
	F012	5900 PPH; 320 TPY	200 PPH; 13.7 TPY		25 PPH 5 TPY	350 PPH 246.8 TPY		none
	F013	5900 PPH; 350 TPY	200 PPH; 15 TPY		25 PPH 5.5 TPY	350 PPH 269.9 TPY		none
	Total Facility Emissions	1448 TPY	61.9 TPY		22.7 TPY	1116.7 TPY		
Portland, OR	Aircraft Engine Test Cell	298 PPH; 35 TPY	none			390 PPH 47 TPY	11 PPH .4 TYP	none
Charleston, SC	Aircraft Engine Test Cell	45.43 PPH; 5.11 TPY	55.79 PPH; 6.28 TPY		.88 PPH	24.37 PPH		none

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NATIONWIDE TEST CELL EMISSION LIMITS
RESEARCH FINDINGS

Location	Type of Facility	NOx Limit	SOx Limit	TSP	PM-10	CO	VOC	Add On Controls
Greenville, SC	Aircraft Engine Test Cells	885.3 PPH; 179.6 TPY	396.1 PPH; 71.1 TPY					none
Sioux Falls, SD	Aircraft Engine Test Cell	None	191 PPH	30 TPY				none
Arnold AFB, TN	Turbine engine test cells	483 lb/hr (air-breathing propulsion engine; 176 TPY	97 PPH 51.8 TPY.			320 PPH 83 TPY	9.9 PPH 7 TPY	Wet scrubber when conditions allow
Nashville, TN	Various Jet Engine Test Cells							
	APTU test facility	none	4 PPH; <5TPY		21.9 PPH			none
	ETF Test Cell	483 PPH; 176 TPY	97 PPH; 51.8 TPY			320 PPH 83 TPY	9.9 PPH 7.0 TPY	none
	ASTF Test Cell	none	97 PPH; 51.8 TPY		12 PPH			none
	PWT Engine Testing	none	1.4 TPY	1 TYP				none
	SL1 Test Cell	544 PPH; 37.9 TPY	109 PPH; 7.6 TPY	.9 TPY		17.9 TPY	1.6 TPY	none
	SL2/SL3 Test Cells	1038 TPY	114 TPY	91 TPY		1890 TPY	325 TPY	none
Langley AFB, VA	Jet engine test cell Buildings 888 & 889	38.9 TPY	19.5 TPY		.7 TPY	11.5 TPY	.9 TPY	

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NATIONWIDE TEST CELL EMISSION LIMITS
RESEARCH FINDINGS

Location	Type of Facility	NOx Limit	SOx Limit	TSP	PM-10	CO	VOC	Add On Controls
Bridgeport WV	Aircraft Engine Test Cell	46.90 PPH; 41.48 TPY	0.16 PPH; 0.14 TPY		.03	18.30 PPH 16.19 TYP	17.41 PPH 15.40 TPY	none