Concerning the International Workshop on NO_x Control for Offshore Operations February 22-23, 1989

Summary of Proceedings

Arthur D. Little, Inc.

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APPENDIX

1.0 INTRODUCTION

The International Workshop on NO_x Control for Offshore Operations was held in Santa Barbara, California on February 22-23, 1989. This event was jointly sponsored by the Minerals Management Service of the U.S. Department of the Interior and the Santa Barbara County Air Pollution Control District. Each organization has a strong interest in reducing the environmental impact of outer continental shelf petroleum exploration and production operations. The workshop brought together a vital mix of NO_x control technology developers, regulatory agency officials, petroleum company staff, suppliers of services to offshore operations, and interested public. Its objectives were: (1) to identify promising NO_x control technologies; (2) to define technical, economic or institutional hurdles preventing their use; and (3) to further the process of developing and applying the technologies for OCS operations.

The workshop opened with a general session which defined the magnitude and sources of NO_x emissions, discussed regulatory issues, and identified operational constraints. Next, four technology-oriented panel sessions were held in the areas of gas turbines, diesel engines, exhaust gas treatment, and alternate fuels. The workshop concluded with the overview sessions on gas turbines and diesel engines, pulling together the conclusions for the previous sessions. In each session, technical presentations were made by leading experts in their respective fields. Ample time was provided for workshop attendees and panel members to discuss and prioritize relevant issues.

This workshop summary document supplements the speaker presentation materials by highlighting the content of panel sessions and by summarizing the consensus views from the technical presentations and subsequent discussions. The balance of this document contains the following sections:

- *Section 2.0* provides background regarding NO_x emissions from OCS operations and addresses the need for control of these emissions;
- *Section 3.0* highlights key conclusions drawn from the workshop presentations and discussions;
- *Section 4.0* summarizes each panel session;
- The *Appendix* provides the workshop agenda and a listing of attendees.

2.0 BACKGROUND

2.1 Environmental Issues

Oxides of nitrogen (NO_x) emitted from combustion sources are precursors to the photochemical formation of near ground level ozone and contribute to acid deposition. The former effect has posed an obstacle to the development of outer continental shelf (OCS) reserves offshore California. Many areas in the vicinity of OCS developments are in non-attainment with federal and state standards for ambient ozone concentrations. These regions include the areas around Los Angeles, Ventura, and Santa Barbara.

Various involved parties disagree as to the extent to which NO_x emissions generated offshore impact onshore air quality, despite extensive dispersion and photochemical modeling. However, reductions in these emissions are viewed by many parties as a necessary element in attaining acceptable air quality.

2.2 Sources of NO_x Emissions in OCS Operations

NO_x emissions associated with OCS operations result from the combustion of fossil fuels in engines that produce mechanical or electrical power. The most significant sources are:

- Platform Gas Turbines,
- Crew and Supply Boat Diesel Engines,
- Platform Construction/Installation Equipment, and
- Exploratory Drilling Rig Engines.

The workshop focused on effective technologies for control of NO_x emissions from gas turbines and diesel engines.

3.0 SUMMARY OF WORKSHOP CONCLUSIONS

The varying backgrounds of workshop partcipants resulted in a wide range of opinions on offshore NO_x control. Consensus opinions were reached for some areas; whereas for others, a divergence of opinion continues to exist.

The results of the four working sessions were summarized in two sessions: gas turbines and diesel engines. These two concluding sessions attempted to bring together information on combustion modifications, exhaust gas treatment and alternative fuels. Both the consensus and the divergent opinions of workshop participants are presented in the following two sections.

3.1 Gas Turbines

Not all workshop participants agreed that gas turbine emissions need to be reduced from today's level of 30 to 40 ppm. The participants generally did agree, however, that if technology is to be developed for offshore gas turbines, then 10 ppm NOx would be a reasonable target level. These emission levels are measured at standard conditions of dry exhaust gas, corrected to 15% O_2.

NO_x emissions of 10 ppm or less have been achieved onshore for turbines in cogeneration applications which employ both water injection and selective catalytic reduction. Offshore turbines, however, have a very different duty cycle. Since there are no other sources of power offshore, the turbines' power output must fluctuate to match the power demands of the platform. The workshop participants concluded that technologies which are demonstrated onshore are not necessarily proven for offshore applications. Furthermore, the space and weight limitations of production platforms place considerable limitations on installing some technologies.

In the individual panel sessions, workshop participants considered potential combustion modification technologies, exhaust gas NO_x removal processes, and alternate fuels for application to offshore gas turbines. Of these, the participants generally concluded that the following three technologies would be the most likely to achieve the NO_x target in the near term (demonstration within three to five years):

- Lean Premixed Combustor,
- Rich-Quench-Lean Combustor, and
- Water Injection Plus SCR.

Although the workshop participants generally agreed on these three being the most promising, they disagreed on which of the three is the most appropriate.

The most rapid solution may be the combination of water injection (which is currently used for offshore turbines) along with SCR. Based on information provided by SCR suppliers, the zeolite (or ceramic molecular sieve) type catalysts appear to be best suited since they have the wider operating temperature range to cover most offshore turbine exhaust levels. Furthermore, the manufacturers claim that the zeolite catalysts are less prone to deterioration in performance when burning liquid fuels. However, many workshop participants explained how SCR systems would be difficult to retrofit on platforms because of their size and weight; this combination would be significantly more expensive than the proposed advanced combustors.

Regarding the two advanced combustion techniques, lean-premix and rich-quench-lean, there was considerable discussion and disagreement over which approach is preferred. The gas turbine manufacturers participating on the panel, Allison (which is developing rich-quench-lean) and Solar (lean-premix) indicated strong belief that their respective technologies could be successfully demonstrated in about three years. Each has the potential to reach the target NO_x level while having inherently unique advantages and development challenges (see Section 4.1).

Catalytic combustion was also felt to be promising, but would require a significant materials' breakthrough and presumably would not be demonstrated within the timeframe of interest.

The most critical issues in applying these technologies were identified to be: (1) the ability to perform successfully during load transients; and (2) maintaining reliable turbine operations. Significant development effort are foreseen to meet these challenges. Other important issues included minimizing space and weight requirements and providing cost effective NO_x control.

3.2 Diesel Engines

Workshop participants discussed the technology requirements and feasibility of three possible levels of diesel engine NO_x emissions:

- 6 grams NO_x per horsepower hour - considered achievable and feasible in the near term with a combination of injection retard, separate circuit aftercooling, and "tuned" injection system design;
- 3-5 grams per horsepower hour - generally associated with more extensive engine modifications and/or replacements; and
- 1-2 grams per horsepower hour - this level would require switching to alternative fuels system R&D using exhaust gas treatment or very extensive (and long term) combustion.

There was no general consensus among workshop participants as to which of these three levels should represent either the next step or the ultimate step.

The engine manufacturers which were represented at the workshop generally supported the 6 gram NO_x target for the next development demonstration programs, suggesting that sufficient technical and operational uncertainties exist to justify this as the next step. Some engine manufacturers stated that they have --- or soon will have --- the technology for supply boat engines or other engines which would achieve this goal. Specific engine modifications toward this goal might include injector redesign, injection timing retard and control, separate circuit aftercooling, and cam shaft timing adjustments.

Other engine developers claimed that a 3 to 5 gram NO_x target, if not coupled with a highly stringent particulate target, would be readily achievable and feasible. Some regulators also supported this target level, since it involves technology which is comparable to that being developed for highway engines. It was generally agreed that this path would require more development time for most engine modifications than that to achieve the 6 gram target. Engine components and systems which would require development for this level include charge air temperature, injection schedule and control, fuel system and combustion chamber geometry.

The 1 to 2 gram target level was the subject of considerable controversy. Some workshop participants, such as SCR system suppliers, claimed that this level could be achieved in the very near future. Other participants, such as vessel owners and operators, expressed many severe misgivings about alternative fuels and exhaust gas treatment. Engine manufacturers expressed concerns over this level, but offered that they would likely participate in a program that is coordinated by others. There was considerable disagreement over the timetable required to achieve this level in a demonstration program. Some workshop participants suggested that SCR could be demonstrated within a year or two. Other participants expressed belief that technical and regulatory hurdles could prevent adoption of alternative fuels for ten years or more.

4.0 PANEL DISCUSSIONS

The workshop panel presentations and discussions focused on four key areas: gas turbine NO_x control techniques, diesel engine NO_x control techniques, exhaust gas treatment NO_x reduction technologies, and the use of alternate fuels. Promising technologies and development issues originating from these panel sessions are highlighted below. Each session is characterized in the following format: a brief description of technologies considered; key developments required for leading candidates; and critical issues.

4.1 Gas Turbines

4.1.1 Technologies Considered

Lean Premixed Combustion

Fuel and air are premixed at a very lean equivalence ratio (about 0.6) prior to ignition. The resulting lower flame temperatures produce less thermal NO_x. This technology is being developed by Solar, who indicated that turbine NO_x emissions below 10 ppm (dry, 15 percent O_2) could be achieved and that a full scale demonstration within three years is feasible.

Rich-Quench-Lean Combustion

Combustion is carried out in two stages, the first is fuel rich, while the second is lean (equivalence ratio is about 0.8). Between stages, water is injected to lower the flame temperatures under lean conditions. This technology is being developed by Allison, who also indicated that NO_x emissions below 10 ppm could be achieved and demonstrated within three years.

Water Injection and Selective Catalytic Reduction

Water injection directly into conventional gas turbine combustors to lower flame temperature is currently a commercial technology and can reduce NO_x emissions by about 70 percent. To reduce emissions further, an exhaust gas treatment system is needed. SCR has been commercially applied to onshore gas turbines but has not yet been demonstrated offshore. With further development, this combination would have a high probability of achieving NO_x emissions below 10 ppm.

Catalytic Combustion

Fuel and air are premixed to achieve very lean conditions. This mixture then passes through a catalyst bed that promotes combustion at relatively low temperatures. This technology has the potential for achieving NO_x emissions well below 10 ppm. However, materials-related technical hurdles will likely prevent its commercialization for at least five to ten years.

Alternate Fuels

Fuels that have lower adiabatic flame temperatures, such as methanol, produce less thermal NO_x. Combustion of methanol in gas turbines has been successfully demonstrated. However, the economic penalty for operators due to higher fuel cost has prohibited the use of methanol.

4.1.2 Leading Technologies and Required Development Areas

Of these technologies, the following were considered to be viable candidates for development and demonstration over the next four years.

- Lean Premixed Combustion,
- Rich-Quench-Lean Combustion, and
- Water Injection plus SCR.

These required development areas were cited by Workshop participants:

Lean Premixed Combustion

- Variable geometry for load following,
- Control systems for load following, and
- Prevention of flashback.

Rich-Quench-Lean

- Optimization of stoichiometry for each stage,
- Control systems for load following, and
- Optimization of quenching process.

Water Injection and SCR

- Achieving effective performance during transients;

- Maintaining the proper temperature windows for effective SCR performance;

- Increasing SCR catalyst life;

- Reducing fouling due to ammonia salts;

- Minimizing ammonia slip. On-line techniques to measure ammonia would be beneficial;
- Reducing corrosion of downstream equipment; and
- Reducing emissions of particulate matter, especially PM_{10}.

4.1.3 Critical Issues for Gas Turbine NO_x Control

- Attaining performance goals given the transient load cycle of platform gas turbines;
- Minimizing size and weight of equipment to be added to production platform turbines;
- Avoiding increases in other emissions, such as formaldehyde when burning methanol, or Co and hydrocarbons when modifying the combustion process;
- Providing water quality necessary for injection into turbine combustors;
- Avoiding increased maintenance that can result from NO_x control technologies;
- Reducing the cost to install and operate NO_x control technologies;
- Maintaining a safe working environment; and
- Ability to readily retrofit the NO_x control technologies.

4.2 Diesel Engines

4.2.1 Technologies Considered

Retarded Timing

In a diesel engine, fuel injection begins near the end of the compression stroke before the piston reaches top dead center to allow for ignition delay, after which combustion begins at about top dead center. Retarding the timing consists of mechanically shifting the start of fuel injection by several degrees so that combustion begins later and occurs at slightly lower temperatures. This modification, while easy to accomplish, provides only moderate NO_x reduction (15 to 30 percent) and is accompanied by increased BSFC.

Modified Fuel Injection and Modified Combustion Chamber Shape

In this technique, the injection system and combustion chamber are modified to produce a fuel spray and a mixing pattern which generates lower NO_x. For example, NO_x formation can be reduced in the early stage of combustion by minimizing the amount of prevaporized fuel available when ignition occurs. Also, since NO_x is produced in burned gases when when combustion-driven compression elevates the temperature, this process can be suppressed by "quenching" such with cooler fresh air. As a result, heat loss occurs prior to second stage combustion, flame temperatures are lowered, and NO_x formation is limited. Modified fuel injection techniques are currently under development by many engine manufacturers.

Reduced Air Temperature

Lower air temperature decreases NO_x emissions by two mechanisms: first, the mixture can be leaned out because the engine can be charged with denser air; and second, after compression the mixture will be cooler and combustion will proceed at lower temperatures. The degree of NO_x reduction with this technique is rather moderate (15 to 30 percent); however, it can readily be combined with other NO_x control technologies. In one method of air temperature reduction, a refrigeration unit run either from the exhaust or power takeoff or sea water exchanger can be used to pre-cool engine inlet air.

1991 Truck Engine Technology

Engine manufacturers and developers are utilizing many techniques to achieve the 1991 and 1994 highway diesel engine standards. These techniques include some of those described above.

- Modified injection and retarded timing;
- Modified combustion chamber;
- Increased turbocharger boost;
- Air-to-Air aftercooling; and
- Electronic engine control.

Most of these techniques are described individually in other sections of this report. Although each technique offers a unique contribution to emission reduction, engine manufacturers believe that a combination of technologies will produce highly reliable and efficient engines with low emissions (NO_x in the 4.5 to 6 g/hphr range).

Exhaust Gas Recirculation

In this method, a portion of exhaust gas is cooled and recirculated to the engine, lowering flame temperatures and thereby reducing NO_x emissions. The exhaust gas would be removed downstream of a turbocharger and cooled to manifold temperature, introduced by displacing part of the air flow ahead of the compressor. NO_x reduction of about 50 percent is achievable; however, there can be a modest BSFC penalty. EGR has been widely applied on automotive spark ignition engines, but is not yet commercially proven for diesel engines.

Valve overlap can also bring about exhaust gas recirculation. This technique is known as internal EGR. The timings of opening the intake valves and closing the exhaust valves are adjusted so that a portion of the exhaust gases are mixed with the fresh charge air and remain in the cylinder.

Fuel Additives

Alterations to the formulation of diesel fuel, such as removing certain compound categories or blending in a fuel additive, have shown to provide small but real emission benefits. One engine manufacturer reported a 5% NO_x reduction from limiting the aromatic content of diesel fuel to under 10%. Other manufacturers and developers reported similar results with additive and alternative diesel fuel formulations.

Water-Fuel Emulsions

Due to the addition of water, fuel oil emulsions burn at lower flame temperatures and thereby generate less NO_x. For example, emulsions containing about 40 volume percent water can reduce NO_x emissions by over 40 percent. (Reductions up to 75 percent have been reported.) Emulsifying systems placed close to injector are desirable to avoid the possible formation of slugs of water which can severely damage fuel system components. In addition, if over 20 percent water is utilized, nozzle tips and plungers must be resized to handle the increased fuel volume. After several years of experimentation, the diesel engine industry is beginning to take a serious look at water fuel emulsion technology.

Selective Catalytic Reduction

SCR is an exhaust gas NO_x reduction process that is described in Section 4.3.1.

Alternate Fuels

Methanol and compressed natural gas are the leading alternate fuel candidates. See Section 4.4.1.

4.2.2 Leading Technologies and Required Development Areas

To demonstrate 6 g/bhp-hr on offshore diesels

- Apply 1988 "Low-NO_x" truck engine technology,
- Demonstration on supply boat is needed,
- Modified injection and timing,
- Engine power for emergency operations, and
- Acceptance by vessel classification agencies.

To demonstrate 3-5 g/bhp-hr on offshore diesels

- Exhaust gas recirculation plus further development of engine combustion modifications (electronic tailored injection, air cooling, chamber shape).
- Exhaust gas recirculation development,
- Electronic tailored injection,
- Combustion chamber modifications, and
- Charge air cooling with seawater.

To demonstrate 1-2 g/bhp-hr on offshore diesels

- Application of SCR,
- Demonstration on supply boat is needed,
- Selective catalytic reduction for vessels,
- Application to diesel engines,
- Marine vessel safety and operability,
- Methanol, and
- Compressed natural gas.

4.2.3 Critical Issues for Diesel Engine NO_x Control

- Trade-off between NO_x and particulate emissions;
- Impact of NO_x control technologies on BSFC, reliability, and engine life;
- Market for offshore engines is relatively small which limits incentives for major company-funded development programs; and
- Boat safety must be maintained.

4.3 Exhaust Gas Treatment

4.3.1 Technologies Considered

Selective Catalytic Reduction (SCR)

Ammonia injected into the exhaust gas reacts with NO_x in a catalyst bed to produce molecular nitrogen and water vapor. The catalyst allows this reaction to proceed at moderately low temperatures (400-950°F). Most beds are in the form of a honeycomb to minimize pressure drop while providing adequate surface area.

The categories of catalysts that were considered are as follows:

- Noble metals,
- Metal oxides; and
- Zeolites or ceramic molecular sieve.

NO_x reduction up to 90-95 percent have been achieved in onshore applications for gas turbines and diesel engines operating under relatively steady loads. In practical field situations, reductions of about 80 percent are more commonly reported.

Selective Non-Catalytic Reduction (SNR)

A reagent is injected into the exhaust gas and homogeneous reactions proceed to reduce NO_x to molecular nitrogen. Work to date indicates that exhaust gas temperature must be fairly high (over 1400°F) for known reagents to be effective. Consequently, reheating of exhaust gas (which is typically 600-900°F) will be required.

Specific reagents that have been utilized are as follows:

- Ammonia,
- Urea, and
- Cyanuric acid.

The SNR process has been applied to boilers, furnaces and incinerators whose flue gas temperatures are between 1300-1900°F. NO_x reductions of 50-80 percent have been attained.

Electrochemical Cell

The exhaust gas is passed through a solid state, porous foam, ceramic electrolyte (zirconia, ceria, or bismuth oxide) containing silver electrodes. NO_x is selectively reduced by electrochemical reactions. This technology is in an embryoptic state of development.

4.3.2 Leading Technologies and Required Development Areas

Currently, the leading technology is SCR, including all categories of catalysts. SNR will also be a leading technology but only if an advanced process effective at lower temperatures is identified. Development areas cited here are listed below.

SCR

- Improving performance over wide temperature range;
- Reducing susceptibility to performance degradation when firing liquid fuels;
- Lowering catalyst volume and weight;
- Use of aqueous ammonia to minimize safety concerns; and
- Control systems to handle load swings and minimize ammonia slip.

SNR

- Identification of reagents that are effective at engine exhaust temperatures (380°C to 500°C);
- Lower cost chemical agents and lower dosages;

- Minimizing reagent slip and undesirable byproducts; and
- Control system to handle load swings.

4.3.3 Critical Issues for NO_x Control Through Exhaust Gas Treatment

- Safety in handling toxic reagent,
- Minimizing undesirable byproduct emissions,
- Reducing space and weight,
- Ability to handle load swings,
- Maintaining performance over the entire range of exhaust temperatures,
- Increasing catalyst life,
- Ease of retrofitting technology, and
- Disposal of spent catalyst which may be classified as a hazardous waste.

4.4 Alternate Fuels

4.4.1 Technologies Considered

Methanol

Methanol has an adiabatic flame temperature that is lower than either natural gas or diesel fuel. Consequently, under similar combustion conditions, this fuel will produce lower thermal NO_X emissions. Experience with methanol in high-speed reciprocating engines is extensive; however, for the medium-speed reciprocating engines and gas turbines of interest for offshore operations, limited experience is available. Generally, reductions in NO_X emissions of about 40-70 percent are possible. A NO_X target of 2 g/bhp-hr for reciprocating engines is believed to be achievable, even for retrofits without optimization.

Compressed Natural Gas (CNG)

Compressed natural gas can be stored in steel tanks at pressure up to about 3600 psi. Use of this fuel in reciprocating engines can lead to reductions in NO_X emissions through operation at leaner air/fuel ratios. Significant experience exists for low NO_X combustion of natural gas in medium-speed engines. A retrofit NO_X target of 5 g/bhp-hr is believed to be achievable with CNG. With optimization, 2 g/bhp-hr may be achievable.

Liquified Hydrocarbons

Liquified Petroleum Gas (LPG) and Natural Gas Liquids (NGL) may be employed for NO_x control similarly to CNG, except that storage would be in liquid form at significantly lower pressures.

Water-Fuel Emulsions

Emulsion of diesel fuel and water can reduce NO_x emissions because of the decrease in adiabatic flame temperature which results from the added water. However, experience to date has indicated that the NO_x reduction achieved is in the 20 to 50 percent range, which presumably is insufficient to meet the offshore needs.

4.4.2 Leading Technologies and Required Development Areas

Of the alternate fuels technologies discussed, workshop participants agreed that the two most promising fuels were methanol and CNG. Required development areas are as noted below, according to workshop participants.

Methanol

- Availability of methanol, development of infra-structure;
- Reduction in cost of methanol production;
- Minimization of aldehyde emissions;
- Optimization of ignition process (cetane improvers, glow plugs, diesel pilot); and
- Demonstration of high-speed, truck and bus engine technology on medium-speed engines.

CNG

- Improved retrofitting capability (lean burn technology is required to achieve low NO_x emissions);
- Demonstration of medium-speed technology on high-speed engines;

- High pressure injection process optimization; and
- Minimization of possible engine de-rating.

4.4.3 Critical Issues For Alternate Fuels

- Alternate fuel infrastructure;
- Definition of duty cycles and test procedures;
- Safety issues in retrofitting alternate fuels technologies. Coast Guard involvement is required for boat applications.
- Special fuel storage requirements (safety and size/weight are issues). May require a custom-built boat for marine application.
- Approach to conversion: retrofit kit or new engine.

APPENDIX

Workshop Agenda and Attendees

INTERNATIONAL WORKSHOP ON NO_x CONTROL FOR OFFSHORE OPERATIONS

FEBRUARY 22, 1989

GENERAL SESSION

8:00	Registration	
9:00	Introductory Remarks	Larry Philp, Workshop Coordinator, Arthur D. Little
9:05	Welcoming Remarks	Robert Kallman, Director, MMS James Ryerson, Director SBCAPCD
9:40	Offshore Air Pollution Control Regulations	Steve Wolfson, MMS (Pacific Region)
10:00	Offshore NO_x Control Programs	Peter Cantle, SBCAPCD
10:20	Break	
10:35	Sources of Offshore NO_x Emissions	John Peirson, Arthur D. Little
10:55	Design Constraints and Operating Experience in Offshore Operations	Herman Colligan, Chevron U.S.A.
11:15	Diesel Engine Operations on Work Boats and Drill Rigs	James Whitley, representing Zapata Gulf Marine
11:35	Logistics and Safety in Offshore Operations	Ralph Warrington, Shell Western E & P
11:55	Introduction to Panels	William Master, SBCAPCD
12:10	Lunch	

Gas Turbine Panel — Chair, Dr. James Peters, University of Illinois

1:15	Emission Control Technology Experience at Solar	Dr. Wilfred Hung, Solar Gas Turbines
1:40	Emission Control Developments for Allison Gas Turbines	Dr. Hukam Mongia, Allison Gas Turbines
2:05	Offshore Gas Turbine NO_x Control Development Program	Mahesh Talwar, SBCAPCD
2:30	Break	
2:45	Panel Discussions	

Diesel Engine Panel — Chair, Dr. Robert Wilson, Arthur D. Little

1:15	Emissions Reduction Techniques for Diesel Engines	Christopher Weaver, Sierra Research
1:40	NO_x Control Methods Derived from Truck/Bus Engines	Don Dowdall, Caterpillar Inc.
2:05	Panel Discussions	
2:30	Break	
2:40	Panel Discussions	

GENERAL SESSION

4:30	Gas Turbine Panel Summary	Chair, Gas Turbine Panel
4:45	Diesel Engine Panel Summary	Chair, Diesel Engine Panel
5:00	Close	

INTERNATIONAL WORKSHOP ON NO_X CONTROL FOR OFFSHORE OPERATIONS

FEBRUARY 23, 1989

Alternative Fuels Panel		Chair, Dr. William McLean, Sandia National Laboratories
9:00	Overview of Alternative Fuels Technology	Dr. Thomas Ryan, Southwest Research Institute
9:25	Natural Gas Fuel - Available Gas and Emerging Technologies	Tony Occhionero, Southern California
9:50	Methanol Fuel - Technology and Infrastructure	Carl Moyer, Acurex
10:15	Break	
10:35	Panel Discussion	

Exhaust Gas Treatment Panel		Chair, Dr. Jerry Caton, Texas A&M University
9:00	Current Status and Developments in Exhaust Gas Treatment	Richard Himes, Fosil Energy Research
9:20	Recent Developments in the $RAPRENO_X$ Process	Dr. Robert Perry, Technor
9:40	Commercial SCR Experience for Gas Turbines	Robert Kaupp, Johnson Matthey
10:00	Ceramic SCR NO_X Abatement Catalyst Systems	Manfred Grove, Steuler International
10:20	Break	
10:35	Panel Discussion	

GENERAL SESSION		
12:00	Lunch	
1:10	Alternative Fuels Summary	Chair, Alternative Fuel Panel
1:15	Exhaust Gas Treatment Summary	Chair, Exhaust Gas Treatment Panel

Gas Turbine Panel		Chair, Dr. James Peters, University of Illinois
1:30	Panel Discussions	
2:45	Break	
3:00	Conclusions and Recommendations	

Diesel Engine Panel		Chair, Dr. Robert Wilson, Arthur D. Little
1:30	Panel Discussion	
2:45	Break	
3:00	Conclusions and Recommendations	

GENERAL SESSION		
3:30	Gas Turbine Summary	Chair, Gas Turbine Panel
3:45	Diesel Engine Summary	Chair, Diesel Engine Panel
4:00	Concluding Remarks	Robert Kallman, Director, MMS
4:15	Offshore Air Pollution Control - Implications for the Future	William Master, SBCAPCD
4:30	Close	

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