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BUREAU OF AIR REGULATION

AIR PERMIT APPLICATION FOR LAKELAND ELECTRIC WINSTON PEAKING STATION PROJECT POLK COUNTY, FLORIDA

Prepared For:

Lakeland Electric – Power Supply
City of Lakeland
501 East Lemon Street
Lakeland, Florida 33801

Prepared By:

Golder Associates Inc.
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May 2001
0137552Y/F1

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PART I

AIR PERMIT APPLICATION

Department of Environmental Protection

Division of Air Resources Management

APPLICATION FOR AIR PERMIT - TITLE V SOURCE

See Instructions for Form No. 62-210.900(1)

I. APPLICATION INFORMATION

Identification of Facility

1. Facility Owner/Company Name: **Lakeland Electric**	
2. Site Name: **Winston Peaking Station**	
3. Facility Identification Number:	[X] Unknown
4. Facility Location: Street Address or Other Locator: **One mile southeast of the intersection of Airport Road and Old Tampa Highway** City: **Lakeland** County: **Polk** Zip Code: **33811**	
5. Relocatable Facility? [ ] Yes [X] No	6. Existing Permitted Facility? [ ] Yes [X] No

Application Contact

1. Name and Title of Application Contact: **Ms. Farzie Shelton, Manager of Environmental Affairs**
2. Application Contact Mailing Address: Organization/Firm: **Lakeland Electric** Street Address: **501 E. Lemon Street** City: **Lakeland** State: **FL** Zip Code: **33801-5079**
3. Application Contact Telephone Numbers: Telephone: (**863**) **834 - 6603** Fax: (**863**) **834 – 5670**

Application Processing Information (DEP Use)

1. Date of Receipt of Application:	5-14-01
2. Permit Number:	1050352-001-AC
3. PSD Number (if applicable):	
4. Siting Number (if applicable):	

Purpose of Application

Air Operation Permit Application

This Application for Air Permit is submitted to obtain: (Check one)

[ ] Initial Title V air operation permit for an existing facility which is classified as a Title V source.

[ ] Initial Title V air operation permit for a facility which, upon start up of one or more newly constructed or modified emissions units addressed in this application, would become classified as a Title V source.

Current construction permit number:________________________________

[ ] Title V air operation permit revision to address one or more newly constructed or modified emissions units addressed in this application.

Current construction permit number:________________________________

Operation permit number to be revised:______________________________

[ ] Title V air operation permit revision or administrative correction to address one or more proposed new or modified emissions units and to be processed concurrently with the air construction permit application. (Also check Air Construction Permit Application below.)

Operation permit number to be revised/corrected:________________________

[ ] Title V air operation permit revision for reasons other than construction or modification of an emissions unit. Give reason for the revision; e.g., to comply with a new applicable requirement or to request approval of an "Early Reductions" proposal.

Operation permit number to be revised:______________________________

Reason for revision:____

Air Construction Permit Application

This Application for Air Permit is submitted to obtain: (Check one)

[X] Air construction permit to construct or modify one or more emissions units.

[ ] Air construction permit to make federally enforceable an assumed restriction on the potential emissions of one or more existing, permitted emissions units.

[ ] Air construction permit for one or more existing, but unpermitted, emissions units.

Owner/Authorized Representative or Responsible Official

1.	Name and Title of Owner/Authorized Representative or Responsible Official: **Roger D. Harr, City Manager**
2.	Owner/Authorized Representative or Responsible Official Mailing Address: Organization/Firm: **Lakeland Electric** Street Address: **501 East Lemon Street** City: **Lakeland** State: **FL** Zip Code: **33801-5079**
3.	Owner/Authorized Representative or Responsible Official Telephone Numbers: Telephone: **(863) 834 - 6006** Fax: **(863) 834 - 8402**
4.	Owner/Authorized Representative or Responsible Official Statement: *I, the undersigned, am the owner or authorized representative*(check here [ ], if so) or the responsible official (check here [ ], if so) of the Title V source addressed in this application, whichever is applicable. I hereby certify, based on information and belief formed after reasonable inquiry, that the statements made in this application are true, accurate and complete and that, to the best of my knowledge, any estimates of emissions reported in this application are based upon reasonable techniques for calculating emissions. The air pollutant emissions units and air pollution control equipment described in this application will be operated and maintained so as to comply with all applicable standards for control of air pollutant emissions found in the statutes of the State of Florida and rules of the Department of Environmental Protection and revisions thereof. I understand that a permit, if granted by the Department, cannot be transferred without authorization from the Department, and I will promptly notify the Department upon sale or legal transfer of any permitted emissions unit.* Timothy C Bates for Roger Harr — 5-11-01 Signature Date

* Attach letter of authorization if not currently on file.

Professional Engineer Certification

1.	Professional Engineer Name: **Kennard F. Kosky** Registration Number: **14996**
2.	Professional Engineer Mailing Address: Organization/Firm: **Golder Associates Inc.** Street Address: **6241 NW 23rd Street, Suite 500** City: **Gainesville** State: **FL** Zip Code: **32653-1500**
3.	Professional Engineer Telephone Numbers: Telephone: **(352) 336 - 5600** Fax: **(352) 336 - 6603**

4. Professional Engineer Statement:

I, the undersigned, hereby certify, except as particularly noted herein, that:*

(1) To the best of my knowledge, there is reasonable assurance that the air pollutant emissions unit(s) and the air pollution control equipment described in this Application for Air Permit, when properly operated and maintained, will comply with all applicable standards for control of air pollutant emissions found in the Florida Statutes and rules of the Department of Environmental Protection; and

(2) To the best of my knowledge, any emission estimates reported or relied on in this application are true, accurate, and complete and are either based upon reasonable techniques available for calculating emissions or, for emission estimates of hazardous air pollutants not regulated for an emissions unit addressed in this application, based solely upon the materials, information and calculations submitted with this application.

If the purpose of this application is to obtain a Title V source air operation permit (check here [ ], if so), I further certify that each emissions unit described in this Application for Air Permit, when properly operated and maintained, will comply with the applicable requirements identified in this application to which the unit is subject, except those emissions units for which a compliance schedule is submitted with this application.

If the purpose of this application is to obtain an air construction permit for one or more proposed new or modified emissions units (check here [X], if so), I further certify that the engineering features of each such emissions unit described in this application have been designed or examined by me or individuals under my direct supervision and found to be in conformity with sound engineering principles applicable to the control of emissions of the air pollutants characterized in this application.

If the purpose of this application is to obtain an initial air operation permit or operation permit revision for one or more newly constructed or modified emissions units (check here [ ], if so), I further certify that, with the exception of any changes detailed as part of this application, each such emissions unit has been constructed or modified in substantial accordance with the information given in the corresponding application for air construction permit and with all provisions contained in such permit.

[signature] 5/10/2001

Signature Date

(seal)

* Attach any exception to certification statement.

Scope of Application

Emissions Unit ID	Description of Emissions Unit	Permit Type	Processing Fee
01	20 GM EMD 20/645/E4B Diesel Engines	AC1B	

Application Processing Fee

Check one: [X] Attached - Amount: $: 5,000 [ ] Not Applicable

Construction/Modification Information

1. Description of Proposed Project or Alterations: **Construction of twenty 2.5 MW General Motors: Electro-Motive Division 20/645/E4B diesel engines.** **See Attachment Part II.**
2. Projected or Actual Date of Commencement of Construction: **1 August 2001**
3. Projected Date of Completion of Construction: **30 Dec 2001**

Application Comment

See Attachment Part II.

II. FACILITY INFORMATION

A. GENERAL FACILITY INFORMATION

Facility Location and Type

1. Facility UTM Coordinates: Zone: **17**	East (km): **400.2**	North (km): **3100.6**	
2. Facility Latitude/Longitude: Latitude (DD/MM/SS): **28 / 01 / 45**		Longitude (DD/MM/SS): **82 / 00 / 53**	
3. Governmental Facility Code: **0**	4. Facility Status Code: **A**	5. Facility Major Group SIC Code: **49**	6. Facility SIC(s): **4911**
7. Facility Comment (limit to 500 characters): **See Attachment Part II.**			

Facility Contact

1. Name and Title of Facility Contact: **Ms. Farzie Shelton, Manager of Environmental Affairs**		
2. Facility Contact Mailing Address: Organization/Firm: **Lakeland Electric**		
Street Address: **501 E. Lemon Street**		
City: **Lakeland**	State: **FL**	Zip Code: **33801-5079**
3. Facility Contact Telephone Numbers: Telephone: **(863) 834 - 6603**	Fax: **(863) 834 - 5670**	

Facility Regulatory Classifications

Check all that apply:

1. [ ] Small Business Stationary Source?	[ ] Unknown
2. [ ] Major Source of Pollutants Other than Hazardous Air Pollutants (HAPs)?	
3. [X] Synthetic Minor Source of Pollutants Other than HAPs?	
4. [ ] Major Source of Hazardous Air Pollutants (HAPs)?	
5. [ ] Synthetic Minor Source of HAPs?	
6. [X] One or More Emissions Units Subject to NSPS?	
7. [ ] One or More Emission Units Subject to NESHAP?	
8. [ ] Title V Source by EPA Designation?	
9. Facility Regulatory Classifications Comment (limit to 200 characters): **Emissions for the twenty diesel engines will be less than 250 TPY per each primary pollutant. NSPS Subpart Kb applies to the fuel oil storage tank.**	

List of Applicable Regulations

Not Applicable	

B. FACILITY POLLUTANTS

List of Pollutants Emitted

1. Pollutant Emitted	2. Pollutant Classif.	3. Requested Emissions Cap lb/hour	tons/year	4. Basis for Emissions Cap	5. Pollutant Comment
PM_{10}	B				Particulate Matter-PM_{10}
VOC	B				Volatile Organic Compounds
SO_2	B				Sulfur Dioxide
NO_x	A				Nitrogen Oxides
CO	A				Carbon Monoxides

C. FACILITY SUPPLEMENTAL INFORMATION

Supplemental Requirements

1.	Area Map Showing Facility Location: [X] Attached, Document ID: **Part II** [ ] Not Applicable [ ] Waiver Requested
2.	Facility Plot Plan: [X] Attached, Document ID: **Part II** [ ] Not Applicable [ ] Waiver Requested
3.	Process Flow Diagram(s): [X] Attached, Document ID: **Part II** [ ] Not Applicable [ ] Waiver Requested
4.	Precautions to Prevent Emissions of Unconfined Particulate Matter: [ ] Attached, Document ID: ______ [X] Not Applicable [ ] Waiver Requested
5.	Fugitive Emissions Identification: [ ] Attached, Document ID: ______ [X] Not Applicable [ ] Waiver Requested
6.	Supplemental Information for Construction Permit Application: [X] Attached, Document ID: **Part II** [ ] Not Applicable
7.	Supplemental Requirements Comment:

Additional Supplemental Requirements for Title V Air Operation Permit Applications

8. List of Proposed Insignificant Activities: [ ] Attached, Document ID:________ [X] Not Applicable
9. List of Equipment/Activities Regulated under Title VI: [ ] Attached, Document ID:________ [ ] Equipment/Activities On site but Not Required to be Individually Listed [X] Not Applicable
10. Alternative Methods of Operation: [ ] Attached, Document ID:________ [X] Not Applicable
11. Alternative Modes of Operation (Emissions Trading): [ ] Attached, Document ID:________ [X] Not Applicable
12. Identification of Additional Applicable Requirements: [ ] Attached, Document ID:________ [X] Not Applicable
13. Risk Management Plan Verification: [ ] Plan previously submitted to Chemical Emergency Preparedness and Prevention Office (CEPPO). Verification of submittal attached (Document ID:________) or previously submitted to DEP (Date and DEP Office:________________________) [ ] Plan to be submitted to CEPPO (Date required:________________________) [X] Not Applicable
14. Compliance Report and Plan: [ ] Attached, Document ID:________ [X] Not Applicable
15. Compliance Certification (Hard-copy Required): [ ] Attached, Document ID:________ [X] Not Applicable

III. EMISSIONS UNIT INFORMATION

A separate Emissions Unit Information Section (including subsections A through J as required) must be completed for each emissions unit addressed in this Application for Air Permit. If submitting the application form in hard copy, indicate, in the space provided at the top of each page, the number of this Emissions Unit Information Section and the total number of Emissions Unit Information Sections submitted as part of this application.

A. GENERAL EMISSIONS UNIT INFORMATION
(All Emissions Units)

Emissions Unit Description and Status

1. Type of Emissions Unit Addressed in This Section: (Check one)

[ ] This Emissions Unit Information Section addresses, as a single emissions unit, a single process or production unit, or activity, which produces one or more air pollutants and which has at least one definable emission point (stack or vent).

[X] This Emissions Unit Information Section addresses, as a single emissions unit, a group of process or production units and activities which has at least one definable emission point (stack or vent) but may also produce fugitive emissions.

[ ] This Emissions Unit Information Section addresses, as a single emissions unit, one or more process or production units and activities which produce fugitive emissions only.

2. Regulated or Unregulated Emissions Unit? (Check one)

[X] The emissions unit addressed in this Emissions Unit Information Section is a regulated emissions unit.

[ ] The emissions unit addressed in this Emissions Unit Information Section is an unregulated emissions unit.

3. Description of Emissions Unit Addressed in This Section (limit to 60 characters):

20 GM EMD 20/645/E4B Diesel Engines

4. Emissions Unit Identification Number: [ ] No ID
ID: [X] ID Unknown

5. Emissions Unit Status Code:	6. Initial Startup Date:	7. Emissions Unit Major Group SIC Code:	8. Acid Rain Unit?
C	**DECEMBER – 01**	**49**	[ ]

9. Emissions Unit Comment: (Limit to 500 Characters)

This emission unit consists of 20 GM EMD 20/645/E4B diesel engines operating in simple cycle mode. See Attachment Part II.

Emissions Unit Control Equipment

1. Control Equipment/Method Description (Limit to 200 characters per device or method): **Selective Catalytic Reduction (SCR) and an Air/Fuel Ratio control.**	
2. Control Device or Method Code(s):	**31, 65**

Emissions Unit Details

1. Package Unit: Manufacturer:	**Genertek**	Model Number:	**20 GM EMD 20/645/E4B**
2. Generator Nameplate Rating:	**2.5**	MW	
3. Incinerator Information:			
Dwell Temperature:		°F	
Dwell Time:		seconds	
Incinerator Afterburner Temperature:		°F	

B. EMISSIONS UNIT CAPACITY INFORMATION
(Regulated Emissions Units Only)

Emissions Unit Operating Capacity and Schedule

1. Maximum Heat Input Rate:		26.2	mmBtu/hr
2. Maximum Incineration Rate:	lb/hr		tons/day
3. Maximum Process or Throughput Rate:			
4. Maximum Production Rate:			
5. Requested Maximum Operating Schedule:			
	hours/day		days/week
	weeks/year	4,460	hours/year

6. Operating Capacity/Schedule Comment (limit to 200 characters):

Dual fuel is requested for this emission unit and will operate 20 engines simultaneously. Maximum heat input rate for 20 engines is 523.0 MMBtu/hr with natural gas and 523.4 MMBtu/hr with fuel oil. (See Part II)

C. EMISSIONS UNIT REGULATIONS
(Regulated Emissions Units Only)

List of Applicable Regulations

See Attachment Part II for operational requirements	
See Attachment Part II for permitting requirements	

D. EMISSION POINT (STACK/VENT) INFORMATION
(Regulated Emissions Units Only)

Emission Point Description and Type

1. Identification of Point on Plot Plan or Flow Diagram? **See Att. Part II**	2. Emission Point Type Code: **1**	
3. Descriptions of Emission Points Comprising this Emissions Unit for VE Tracking (limit to 100 characters per point): **Each 2.5 MW unit exhausts through a single stack.**		
4. ID Numbers or Descriptions of Emission Units with this Emission Point in Common:		
5. Discharge Type Code: **V**	6. Stack Height: **30** feet	7. Exit Diameter: **1.83** feet
8. Exit Temperature: Natural Gas **740** °F Fuel Oil **635** °F	9. Actual Volumetric Flow Rate: **21,350** acfm	10. Water Vapor:
11. Maximum Dry Standard Flow Rate: dscfm	12. Nonstack Emission Point Height: feet	
13. Emission Point UTM Coordinates: Zone: **17** East (km): **400.2** North (km): **3100.6**		
14. Emission Point Comment (limit to 200 characters): **Single stacks for each engine unit.**		

E. SEGMENT (PROCESS/FUEL) INFORMATION
(All Emissions Units)

Segment Description and Rate: Segment 1 of 2

1. Segment Description (Process/Fuel Type) (limit to 500 characters): **Natural Gas**		
2. Source Classification Code (SCC): **20100201**	3. SCC Units: **Million Cubic Feet Burned**	
4. Maximum Hourly Rate: **0.50**	5. Maximum Annual Rate: **2,240**	6. Estimated Annual Activity Factor:
7. Maximum % Sulfur:	8. Maximum % Ash:	9. Million Btu per SCC Unit: **1,050**
10. Segment Comment (limit to 200 characters): **Natural gas firing requires 6% diesel fuel for ignition. Maximum hourly based on 59°F condition and 1,050 Btu/cf (HHV). Maximum annual based on 4,460 hr/yr. For diesel, maximum hourly fuel usage is 228 gal/hr and 1,018,700 gal/year.**		

Segment Description and Rate: Segment 2 of 2

1. Segment Description (Process/Fuel Type) (limit to 500 characters): **Distillate (No. 2) Fuel Oil**		
2. Source Classification Code (SCC): **20100101**	3. SCC Units: **1,000 Gallons Burned**	
4. Maximum Hourly Rate: **3.95**	5. Maximum Annual Rate: **8,184**	6. Estimated Annual Activity Factor:
7. Maximum % Sulfur: **0.05**	8. Maximum % Ash:	9. Million Btu per SCC Unit: **132.5**
10. Segment Comment (limit to 200 characters): **Million BTU per SCC unit = 132.5; based on 6.83 lb/gal; 19,400 Btu/lb (HHV), ISO conditions, maximum hourly rate based on 59°F conditions at peak load and annual rate based on an equivalent of 2,150 hours of oil firing per year at baseload.**		

F. EMISSIONS UNIT POLLUTANTS
(All Emissions Units)

1. Pollutant Emitted	2. Primary Control Device Code	3. Secondary Control Device Code	4. Pollutant Regulatory Code
PM_{10}			EL
SO_2			EL
NO_x	065	031	EL
CO	065	031	EL
VOC			EL

G. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION
(Regulated Emissions Units -
Emissions-Limited and Preconstruction Review Pollutants Only)

Potential/Fugitive Emissions

1. Pollutant Emitted: **PM_{10}**

2. Total Percent Efficiency of Control:

3. Potential Emissions: **19.0** lb/hour **17.0** tons/year

4. Synthetically Limited? [X]

5. Range of Estimated Fugitive Emissions:
[ ] 1 [ ] 2 [ ] 3 ______ to ______ tons/year

6. Emission Factor:
Reference: **Genertek, 2001**

7. Emissions Method Code: **2**

8. Calculation of Emissions (limit to 600 characters):

See Attachment Part II.

9. Pollutant Potential/Fugitive Emissions Comment (limit to 200 characters):

Lb/hr based on 59°F peaking operation and TPY based on oil firing 2,150 hr/yr baseload operation.

Allowable Emissions Allowable Emissions 1 of 2

1. Basis for Allowable Emissions Code: **OTHER**

2. Future Effective Date of Allowable Emissions:

3. Requested Allowable Emissions and Units: **VE ≤20% operation**

4. Equivalent Allowable Emissions: **19.0** lb/hour **17.0** tons/year

5. Method of Compliance (limit to 60 characters):

Annual VE test; EPA Method 9

6. Allowable Emissions Comment (Desc. of Operating Method) (limit to 200 characters):

Oil firing. See Attachment Part II.

G. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION
**(Regulated Emissions Units -
Emissions-Limited and Preconstruction Review Pollutants Only)**

Potential/Fugitive Emissions

1. Pollutant Emitted: **PM_{10}**	2. Total Percent Efficiency of Control:
3. Potential Emissions: **5.3** lb/hour **11.8** tons/year	4. Synthetically Limited? [ ]
5. Range of Estimated Fugitive Emissions: [ ] 1 [ ] 2 [ ] 3 ______ to ______ tons/year	
6. Emission Factor: Reference: **Genertek, 2001**	7. Emissions Method Code:
8. Calculation of Emissions (limit to 600 characters): **See Attachment Part II.**	
9. Pollutant Potential/Fugitive Emissions Comment (limit to 200 characters): **Lb/hr based on 59°F and TPY based on natural gas firing 4,460 hr/yr.**	

Allowable Emissions Allowable Emissions **2** of **2**

1. Basis for Allowable Emissions Code: **OTHER**	2. Future Effective Date of Allowable Emissions:
3. Requested Allowable Emissions and Units: **VE ≤20% operation**	4. Equivalent Allowable Emissions: **5.3** lb/hour **11.8** tons/year
5. Method of Compliance (limit to 60 characters): **EPA Method 9**	
6. Allowable Emissions Comment (Desc. of Operating Method) (limit to 200 characters): **Gas firing. See Attachment Part II.**	

G. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION
(Regulated Emissions Units - Emissions-Limited and Preconstruction Review Pollutants Only)

Potential/Fugitive Emissions

1. Pollutant Emitted: SO_2	2. Total Percent Efficiency of Control:
3. Potential Emissions: 34.3 lb/hour 27.9 tons/year	4. Synthetically Limited? [X]
5. Range of Estimated Fugitive Emissions: [ ] 1 [ ] 2 [ ] 3 ______ to ______ tons/year	
6. Emission Factor: Reference: Golder Associates Inc, 2001	7. Emissions Method Code: 2
8. Calculation of Emissions (limit to 600 characters): See Attachment Part II.	
9. Pollutant Potential/Fugitive Emissions Comment (limit to 200 characters): Lb/hr based on 59°F peaking operation and TPY based on oil firing 2,150 hr/yr baseload operation.	

Allowable Emissions Allowable Emissions 1 of 2

1. Basis for Allowable Emissions Code: OTHER	2. Future Effective Date of Allowable Emissions:
3. Requested Allowable Emissions and Units: 0.05% Sulfur Oil	4. Equivalent Allowable Emissions: 34.3 lb/hour 27.9 tons/year
5. Method of Compliance (limit to 60 characters): Fuel Sampling	
6. Allowable Emissions Comment (Desc. of Operating Method) (limit to 200 characters): Oil firing. See Attachment Part II.	

G. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION
(Regulated Emissions Units - Emissions-Limited and Preconstruction Review Pollutants Only)

Potential/Fugitive Emissions

1. Pollutant Emitted: **SO_2**	2. Total Percent Efficiency of Control:
3. Potential Emissions: **4.0** lb/hour **8.9** tons/year	4. Synthetically Limited? [ ]
5. Range of Estimated Fugitive Emissions: [ ] 1 [ ] 2 [ ] 3 ______ to ______ tons/year	
6. Emission Factor: Reference: **Genertek, 2001**	7. Emissions Method Code:
8. Calculation of Emissions (limit to 600 characters): **See Attachment Part II.**	
9. Pollutant Potential/Fugitive Emissions Comment (limit to 200 characters): **Lb/hr based on 59°F and TPY based on natural gas firing 4,460 hr/yr.**	

Allowable Emissions Allowable Emissions 2 of 2

1. Basis for Allowable Emissions Code: **OTHER**	2. Future Effective Date of Allowable Emissions:
3. Requested Allowable Emissions and Units: **See Comment**	4. Equivalent Allowable Emissions: **4.0** lb/hour **8.9** tons/year
5. Method of Compliance (limit to 60 characters): **Pipeline Natural Gas**	
6. Allowable Emissions Comment (Desc. of Operating Method) (limit to 200 characters): **Pipeline natural gas, 2 g/100 cf, See Attachment Part II.**	

G. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION
(Regulated Emissions Units - Emissions-Limited and Preconstruction Review Pollutants Only)

Potential/Fugitive Emissions

1. Pollutant Emitted: **NO_x**	2. Total Percent Efficiency of Control:
3. Potential Emissions: **278.0** lb/hour **249.1** tons/year	4. Synthetically Limited? [X]
5. Range of Estimated Fugitive Emissions: [ ] 1 [ ] 2 [ ] 3 ______ to ______ tons/year	
6. Emission Factor: Reference: **Genertek, 2001**	7. Emissions Method Code: **2**
8. Calculation of Emissions (limit to 600 characters): **See Attachment Part II.**	
9. Pollutant Potential/Fugitive Emissions Comment (limit to 200 characters): **Lb/hr based on 59°F peaking operation and TPY based on oil firing 2,150 hr/yr baseload operation.**	

Allowable Emissions Allowable Emissions 1 of 2

1. Basis for Allowable Emissions Code: **OTHER**	2. Future Effective Date of Allowable Emissions:
3. Requested Allowable Emissions and Units:	4. Equivalent Allowable Emissions: **278.0** lb/hour **249.1** tons/year
5. Method of Compliance (limit to 60 characters): **EPA Method 20 test on a representative engine.**	
6. Allowable Emissions Comment (Desc. of Operating Method) (limit to 200 characters): **See Attachment Part II.**	

G. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION
(Regulated Emissions Units - Emissions-Limited and Preconstruction Review Pollutants Only)

Potential/Fugitive Emissions

1. Pollutant Emitted: **NO_x**	2. Total Percent Efficiency of Control:
3. Potential Emissions: **111.6** lb/hour **248.8** tons/year	4. Synthetically Limited? [ ]
5. Range of Estimated Fugitive Emissions: [ ] 1 [ ] 2 [ ] 3 ______ to ______ tons/year	
6. Emission Factor: Reference: **Genertek, 2001**	7. Emissions Method Code:
8. Calculation of Emissions (limit to 600 characters): **See Attachment Part II.**	
9. Pollutant Potential/Fugitive Emissions Comment (limit to 200 characters): **Lb/hr based on 59°F and TPY based on natural gas firing 4,460 hr/yr.**	

Allowable Emissions Allowable Emissions 2 of 2

1. Basis for Allowable Emissions Code: **OTHER**	2. Future Effective Date of Allowable Emissions:
3. Requested Allowable Emissions and Units:	4. Equivalent Allowable Emissions: **111.6** lb/hour **248.8** tons/year
5. Method of Compliance (limit to 60 characters): **EPA Method 20 test on a representative engine.**	
6. Allowable Emissions Comment (Desc. of Operating Method) (limit to 200 characters): **See Attachment Part II.**	

G. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION
(Regulated Emissions Units - Emissions-Limited and Preconstruction Review Pollutants Only)

Potential/Fugitive Emissions

1. Pollutant Emitted: **CO**	2. Total Percent Efficiency of Control:
3. Potential Emissions: **19.0** lb/hour **17.0** tons/year	4. Synthetically Limited? [X]
5. Range of Estimated Fugitive Emissions: [ ] 1 [ ] 2 [ ] 3 ______ to ______ tons/year	
6. Emission Factor: Reference: **Genertek, 2001**	7. Emissions Method Code: **2**
8. Calculation of Emissions (limit to 600 characters): **See Attachment Part II.**	
9. Pollutant Potential/Fugitive Emissions Comment (limit to 200 characters): **Lb/hr based on 59°F peaking operation and TPY based on oil firing 2,150 hr/yr baseload operation.**	

Allowable Emissions Allowable Emissions 1 of 2

1. Basis for Allowable Emissions Code: **OTHER**	2. Future Effective Date of Allowable Emissions:
3. Requested Allowable Emissions and Units:	4. Equivalent Allowable Emissions: **19.0** lb/hour **17.0** tons/year
5. Method of Compliance (limit to 60 characters): **Manufacturer certification**	
6. Allowable Emissions Comment (Desc. of Operating Method) (limit to 200 characters): **Oil Firing. See Attachment Part II.**	

G. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION
(Regulated Emissions Units - Emissions-Limited and Preconstruction Review Pollutants Only)

Potential/Fugitive Emissions

1. Pollutant Emitted: **CO**	2. Total Percent Efficiency of Control:
3. Potential Emissions: **85.7** lb/hour **191.1** tons/year	4. Synthetically Limited? [ ]
5. Range of Estimated Fugitive Emissions: [ ] 1 [ ] 2 [ ] 3 ______ to ______ tons/year	
6. Emission Factor: Reference: **Genertek, 2001**	7. Emissions Method Code:
8. Calculation of Emissions (limit to 600 characters): **See Attachment Part II.**	
9. Pollutant Potential/Fugitive Emissions Comment (limit to 200 characters): **Lb/hr based on 59°F and TPY based on natural gas firing 4,460 hr/yr.**	

Allowable Emissions Allowable Emissions 2 of 2

1. Basis for Allowable Emissions Code: **OTHER**	2. Future Effective Date of Allowable Emissions:
3. Requested Allowable Emissions and Units:	4. Equivalent Allowable Emissions: **85.7** lb/hour **191.1** tons/year
5. Method of Compliance (limit to 60 characters): **Manufacturer certification**	
6. Allowable Emissions Comment (Desc. of Operating Method) (limit to 200 characters): **Natural gas firing. See Attachment Part II.**	

G. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION
(Regulated Emissions Units - Emissions-Limited and Preconstruction Review Pollutants Only)

Potential/Fugitive Emissions

1. Pollutant Emitted: **VOC**	2. Total Percent Efficiency of Control:
3. Potential Emissions: **20.6** lb/hour **16.8** tons/year	4. Synthetically Limited? [X]
5. Range of Estimated Fugitive Emissions: [ ] 1 [ ] 2 [ ] 3 ______ to ______ tons/year	
6. Emission Factor: Reference: **Golder Associates Inc., 2001**	7. Emissions Method Code: **2**
8. Calculation of Emissions (limit to 600 characters): **See Attachment Part II.**	
9. Pollutant Potential/Fugitive Emissions Comment (limit to 200 characters): **Lb/hr based on 59°F peaking operation and TPY based on oil firing 2,150 hr/yr baseload operation.**	

Allowable Emissions Allowable Emissions 1 of 2

1. Basis for Allowable Emissions Code: **OTHER**	2. Future Effective Date of Allowable Emissions:
3. Requested Allowable Emissions and Units:	4. Equivalent Allowable Emissions: **20.6** lb/hour **16.8** tons/year
5. Method of Compliance (limit to 60 characters): **Compliance with CO emission limit.**	
6. Allowable Emissions Comment (Desc. of Operating Method) (limit to 200 characters): **Oil firing. See Attachment Part II.**	

G. EMISSIONS UNIT POLLUTANT DETAIL INFORMATION
(Regulated Emissions Units - Emissions-Limited and Preconstruction Review Pollutants Only)

Potential/Fugitive Emissions

1. Pollutant Emitted: **VOC**	2. Total Percent Efficiency of Control:
3. Potential Emissions: **41.8** lb/hour **93.3** tons/year	4. Synthetically Limited? [ ]
5. Range of Estimated Fugitive Emissions: [ ] 1 [ ] 2 [ ] 3 ______ to ______ tons/year	
6. Emission Factor: Reference: **Golder Associates Inc., 2001**	7. Emissions Method Code: **2**
8. Calculation of Emissions (limit to 600 characters): **See Attachment Part II.**	
9. Pollutant Potential/Fugitive Emissions Comment (limit to 200 characters): **Lb/hr based on 59°F and TPY based on natural gas firing 4,460 hr/yr**	

Allowable Emissions Allowable Emissions 2 of 2

1. Basis for Allowable Emissions Code: **OTHER**	2. Future Effective Date of Allowable Emissions:
3. Requested Allowable Emissions and Units:	4. Equivalent Allowable Emissions: **41.8** lb/hour **93.3** tons/year
5. Method of Compliance (limit to 60 characters): **Compliance with CO emission limit.**	
6. Allowable Emissions Comment (Desc. of Operating Method) (limit to 200 characters): **Gas firing. See Attachment Part II.**	

H. VISIBLE EMISSIONS INFORMATION
(Only Regulated Emissions Units Subject to a VE Limitation)

Visible Emissions Limitation: Visible Emissions Limitation 1 of 2

1. Visible Emissions Subtype: **VE20**	2. Basis for Allowable Opacity: [X] Rule [ ] Other
3. Requested Allowable Opacity: Normal Conditions: 20 % Exceptional Conditions: % Maximum Period of Excess Opacity Allowed: min/hour	
4. Method of Compliance: **Annual VE Test EPA Method 9**	
5. Visible Emissions Comment (limit to 200 characters):	

I. CONTINUOUS MONITOR INFORMATION
(Only Regulated Emissions Units Subject to Continuous Monitoring)

Continuous Monitoring System: Continuous Monitor 1 of 2

1. Parameter Code:	2. Pollutant(s):
3. CMS Requirement:	[ ] Rule [ ] Other
4. Monitor Information: Manufacturer: Model Number:	Serial Number:
5. Installation Date:	6. Performance Specification Test Date:
7. Continuous Monitor Comment (limit to 200 characters):	

H. VISIBLE EMISSIONS INFORMATION
(Only Regulated Emissions Units Subject to a VE Limitation)

Visible Emissions Limitation: Visible Emissions Limitation 2 of 2

1. Visible Emissions Subtype: **VE99**	2. Basis for Allowable Opacity: [X] Rule [ ] Other
3. Requested Allowable Opacity: Normal Conditions: % Exceptional Conditions: **100** % Maximum Period of Excess Opacity Allowed: min/hour	
4. Method of Compliance: **None**	
5. Visible Emissions Comment (limit to 200 characters): **FDEP Rule 62-201.700(1), Allowed for 2 hours (120 minutes) per 24 hours for start up, shutdown and malfunction.**	

I. CONTINUOUS MONITOR INFORMATION
(Only Regulated Emissions Units Subject to Continuous Monitoring)

Continuous Monitoring System: Continuous Monitor 2 of 2

1. Parameter Code:	2. Pollutant(s):
3. CMS Requirement:	[ ] Rule [ ] Other
4. Monitor Information: Manufacturer: Model Number:	Serial Number:
5. Installation Date:	6. Performance Specification Test Date:
7. Continuous Monitor Comment (limit to 200 characters):	

J. EMISSIONS UNIT SUPPLEMENTAL INFORMATION
(Regulated Emissions Units Only)

Supplemental Requirements

1. Process Flow Diagram [X] Attached, Document ID: Part II [ ] Not Applicable [ ] Waiver Requested	
2. Fuel Analysis or Specification [ ] Attached, Document ID:______ [X] Not Applicable [ ] Waiver Requested	
3. Detailed Description of Control Equipment [ ] Attached, Document ID: ______ [X] Not Applicable [ ] Waiver Requested	
4. Description of Stack Sampling Facilities [ ] Attached, Document ID:______ [X] Not Applicable [ ] Waiver Requested	
5. Compliance Test Report [ ] Attached, Document ID:______ [ ] Previously submitted, Date:__________ [X] Not Applicable	
6. Procedures for Startup and Shutdown [ ] Attached, Document ID:______ [X] Not Applicable [ ] Waiver Requested	
7. Operation and Maintenance Plan [ ] Attached, Document ID:______ [X] Not Applicable [ ] Waiver Requested	
8. Supplemental Information for Construction Permit Application [X] Attached, Document ID: Part II [ ] Not Applicable	
9. Other Information Required by Rule or Statute [ ] Attached, Document ID: ______ [X] Not Applicable	
10. Supplemental Requirements Comment:	

Additional Supplemental Requirements for Title V Air Operation Permit Applications

11. Alternative Methods of Operation [ ] Attached, Document ID:________ [X] Not Applicable
12. Alternative Modes of Operation (Emissions Trading) [ ] Attached, Document ID:________ [X] Not Applicable
13. Identification of Additional Applicable Requirements [ ] Attached, Document ID:________ [X] Not Applicable
14. Compliance Assurance Monitoring Plan [ ] Attached, Document ID:________ [X] Not Applicable
15. Acid Rain Part Application (Hard-copy Required) [ ] Acid Rain Part - Phase II (Form No. 62-210.900(1)(a)) Attached, Document ID:________ [ ] Repowering Extension Plan (Form No. 62-210.900(1)(a)1.) Attached, Document ID:________ [ ] New Unit Exemption (Form No. 62-210.900(1)(a)2.) Attached, Document ID:________ [ ] Retired Unit Exemption (Form No. 62-210.900(1)(a)3.) Attached, Document ID:________ [ ] Phase II NOx Compliance Plan (Form No. 62-210.900(1)(a)4.) Attached, Document ID:________ [ ] Phase NOx Averaging Plan (Form No. 62-210.900(1)(a)5.) Attached, Document ID:________ [X] Not Applicable

PART II

REPORT

1.0 INTRODUCTION

Lakeland Electric proposes to construct, and operate a nominal 50-megawatt (MW) power production facility, referred to as the Winston Peaking Station Project (the "Project"), in Lakeland, Polk County, Florida (Figure 1-1). The site will be located on a 6-acre parcel. Lakeland Electric will own the property and own/control the operation of the facility. Lakeland Electric will own the equipment and dispatch the units to supply electric power. The Project consists of the construction and operation of twenty nominal 2.5-MW GM EMD 20/645/E4B diesel engines and one 294,000-gallon fuel oil storage tank. The engines will use selective catalytic reduction, oxidation catalyst, and an air/fuel ratio regulator for emission reduction control. The units are designed for peaking service. The fuel for the engines will be distillate fuel oil with natural gas. Fuel oil will contain a maximum sulfur content of 0.05 percent.

The permitting of the Project in Florida requires an air construction permit. To assist in performing the necessary permitting, Golder Associates Inc. (Golder) was contracted to prepare the necessary permit applications and determining the Project's applicability to any state and federal new source review (NSR) regulation, including prevention of significant deterioration (PSD) and nonattainment review requirements.

The requested operational conditions for the proposed Project will classify the facility as a "minor source" and therefore will not trigger PSD review.

The air permit application is divided into three major sections.

- Section 2.0 presents a description of the facility, including air emissions and stack parameters.
- Section 3.0 provides a review of the regulatory requirements applicable to the proposed Project.

2.0 PROJECT DESCRIPTION

2.1 SITE DESCRIPTION

The Project site, shown in Figure 2-1, is located approximately 1 mile southeast of the intersection of Airport Road and Old Tampa Highway. The legal description of the property is as follows:

> "A 6-acre parcel commencing at the Northeast corner of the SE ¼ of the SW ¼, of Section 21, Township 28 South, Range 23 East. Thence running West to the West line of cut off road, thence South 316.94 feet, thence West 1002.81 feet to the right-of-way line of Airport Road, thence South 20°32′ East along right-of-way 106.73 feet to the Point of Beginning; continue South 20°32′ East along the right-of-way to a point 320 feet North of the South line of Section 21, thence South 88°59′05″ East 338.63 feet, thence North 583.65 feet, thence West 554.77 feet to the Point of Beginning."

There are industrial, commercial, and residential developments within a 3-kilometer (km) radius of the site. The plant elevation will be approximately 130 feet above mean sea level (ft-msl). The terrain surrounding the site is flat.

2.2 SIMPLE-CYCLE DIESEL ENGINES

The proposed project will be the construction and operation of twenty nominal 2.5-MW GM EMD 20/645/E4B diesel engines operated in simple-cycle mode. The annual operation for these units is based on limiting the facility to less than 250 tons per year (TPY) for any air pollutant regulated under the Clean Air Act (CAA). Natural gas and fuel oil will be used. The maximum sulfur content of the distillate fuel oil will be 0.05 percent.

Plant performance with the GM EMD 20/645/E4B engines was developed for natural gas and distillate fuel oil firing; at 100-percent load and at an ambient temperature of 59°F. Additionally, the units were analyzed at a peaking capacity of 55 MW when firing fuel oil. Engine performance is based on a performance envelope developed from the manufacturer, Genertek.

The engines are capable of normal steady state operation from 50 to 100 percent of baseload. The efficiency of the engines decreases at part load. As a result, the economic incentive is to dispatch the plant to keep the units operating as near baseload as possible. Genertek has determined the maximum hours of operation at peaking capacity to be less than 50 percent of baseload operating hours. A mechanical description and supporting data for the diesel engines is presented in Appendix A.

The engines will be run strictly on fuel oil for the first two years of operation, after which, natural gas will be used at an equal ratio to the fuel oil. With natural gas firing, the engines require 6 percent fuel oil usage for ignition. Emission estimates have taken this into consideration.

Natural gas will be transported to the site via a planned pipeline and fuel oil will be stored at a planned, aboveground storage tank. The tank will be housed in a containment area with dimensions 50.5 feet by 23 feet. The tank will be 40.5 feet in diameter and 32 feet high and will have a capacity of 294,000 gallons.

Air emissions control, when firing natural gas or distillate fuel oil, will consist of an air/fuel regulator and selective catalytic reduction for NO_x and CO control. The sulfur dioxide (SO_2) emissions will be controlled by the use of low-sulfur fuels. Good combustion practices and clean fuels will also minimize potential emissions of particulate matter less than 10 microns (PM_{10}), carbon monoxide (CO), volatile organic compound (VOC), and other pollutants (e.g., trace metals). Supporting data for the emission control systems is presented in Appendix B.

2.3 PROPOSED SOURCE EMISSIONS AND STACK PARAMETERS

The estimated maximum hourly emissions and exhaust information for the engines operating at baseload and peaking conditions are presented in Tables 2-1 through 2-6. The data are presented for an ambient temperature of 59°F for both one engine and twenty engines. The performance calculations for the operating conditions are given in Appendix A.

The emission rates used to calculate maximum potential annual emissions for regulated air pollutants from the proposed engines are presented in Tables 2-2, 2-4, and 2-6. To limit emissions below the major PSD source threshold, a fuel use limitation equivalent to the engines operating at 100-percent load for 4,460 hours per year when using natural gas or 2,150 hours per year when using distillate fuel oil. At peaking capacity, the units are designed to run only 876 hours per year. For oil firing, the equivalent baseload heat input is 1,022,970 MMBtu/year-LHV (based on 2,150 hours x 475.8 MMBtu/hour) and 458,498 MMBtu/year-LHV (based on 876 hours x 523.4 MMBtu/hour) for peaking capacity. For natural gas firing, the equivalent heat input is 2,337,040 million British thermal units (MMBtu)/year-LHV (based on 4,460 hours x 524.0 MMBtu/hour). The limiting air pollutant for natural gas and oil firing is nitrogen oxides. Working and breathing losses for the fuel oil storage tank were calculated using the EPA Tanks 4.0 program. Potential VOC emissions from the tank will be less than 0.16 tons per year. Calculations and parameters for the tank are shown in Appendix C.

A process flow diagram of the engines operating at an ambient temperature of 59° at 100-percent load for gas and fuel oil firing is presented in Figure 2-2.

Table 2-7 contains estimated emission for hazardous air pollutants (HAPs). The HAP emissions are based on emission factors from the October 1996 revision of U. S. Environmental Protection Agency's (EPA's) AP-42 emission factor database.

The emission factors for many of the HAPs were developed with even less data and the use of the AP-42 emission factors for these pollutants provide an estimate of HAP emissions that are likely very conservative. An evaluation of the HAP emission from the Project indicates that emissions are less than 25 tons/year for all HAPs and less than 10 tons/year for a single HAP. Therefore, the requirements of 40 Code of Federal Regulations (CFR) 63.43 for maximum achievable control technology are not applicable to the Project.

2.4 PROPOSED SOURCE EMISSIONS AND STACK PARAMETERS

Operational limits are being proposed for both oil and gas firing to limit the total emissions from the project. These limits will be based on heat input and are as follows:

- Fuel Oil – 8.184 x 10^6 gal/yr x 132.5 MMBtu/1000 gal = 1,084,000 MMBtu/yr
- Natural Gas including 6% fuel oil– (2,352,000+135,000)MMBtu/yr = 2,487,000 MMBtu/yr; (2,240 MMcf/yr x 1,050 BTU/cf and 1,018700 gal x 132.5 MMBtu/1000 gal)

  See Segment (Process/Fuel) Information, Part E of the Application.

The City of Lakeland proposes that a ratio of 2.3 for gas versus oil firing be used to allow both gas and oil use. That is for each MMBtu fired as oil, the amount of gas fired would be reduced by a factor of 2.3

Table 2-1. Design Information and Stack Parameters for the Winston Peaking Station Project
20 GM EMD 20/645/E4B Diesel Engines, Distillate Oil, 100 % Load

Parameter	One Engine	Twenty Engines
Engine Performance		
Gross power output (MW)	2.5	50.0
Heat rate (Btu/kWh, LHV) - provided	9,516	9,516
(Btu/kWh, HHV) - calculated	10,087	10,087
Heat Input (MMBtu/hr, LHV) - calculated	23.79	475.8
(MMBtu/hr, HHV) - estimated	25.22	504.3
Fuel heating value (Btu/lb, LHV)- estimated	18,302	18,302
(Btu/lb, HHV)- provided	19,400	19,400
(HHV/LHV)	1.06	1.06
Engine Exhaust Flow		
Temperature (°F)	740	740
Volume flow (acfm)- provided	21,350	427,000
Fuel Usage		
Fuel usage (lb/hr) = Heat Input (MMBtu/hr) x 1,000,000 Btu/MMBtu (Fuel Heat Content, Btu/lb (LHV))		
Heat input (MMBtu/hr, LHV)	23.79	475.8
Heat content (Btu/lb, LHV)	18,302	18,302
Fuel usage (lb/hr)- calculated	1,300	25,997
Stack and Exit Gas Conditions		
Stack height (ft)	30	NA
Diameter (ft)	1.833	NA
Velocity (ft/sec) = Volume flow (acfm) / [((diameter)^2/4) x 3.14159] / 60 sec/min		
Volume flow (acfm)	21,350	NA
Diameter (ft)	1.8	NA
Velocity (ft/sec)- calculated	134.8	NA
Velocity (m/sec)- calculated	41.1	NA

Source: Genertek, 2001.
Note: Universal gas constant = 1,545 ft-lb(force)/°R; atmospheric pressure = 2,116.8 lb(force)/ft^2

Table 2-3. Design Information and Stack Parameters for the Winston Peaking Station Project
20 GM EMD 20/645/E4B Diesel Engines, Distillate Oil, Peak Load

Parameter	One Engine	Twenty Engines
Engine Performance		
Gross power output (MW)	2.75	55.0
Heat rate (Btu/kWh, LHV) - provided	9,516	9,516
(Btu/kWh, HHV) - calculated	10,087	10,087
Heat Input (MMBtu/hr, LHV) - calculated	26.17	523.4
(MMBtu/hr, HHV) - estimated	27.74	554.8
Fuel heating value (Btu/lb, LHV)- estimated	18,302	18,302
(Btu/lb, HHV)- provided	19,400	19,400
(HHV/LHV)	1.06	1.06
Engine Exhaust Flow		
Temperature (°F)	740	740
Volume flow (acfm)- provided	21,350	427,000
Fuel Usage		
Fuel usage (lb/hr)= Heat Input (MMBtu/hr) x 1,000,000 Btu/MMBtu (Fuel Heat Content, Btu/lb (LHV))		
Heat input (MMBtu/hr, LHV)	26.17	523.4
Heat content (Btu/lb, LHV)	18,302	18,302
Fuel usage (lb/hr)- calculated	1,430	28,597
Stack and Exit Gas Conditions		
Stack height (ft)	30	NA
Diameter (ft)	1.833	NA
Velocity (ft/sec)= Volume flow (acfm) / [((diameter)^2/4) x 3.14159] / 60 sec/min		
Volume flow (acfm)	21,350	NA
Diameter (ft)	1.8	NA
Velocity (ft/sec)- calculated	134.8	NA
Velocity (m/sec)- calculated	41.1	NA

Source: Genertek, 2001.
Note: Universal gas constant= 1,545 ft-lb(force)/°R; atmospheric pressure= 2,116.8 lb(force)/ft^2

Table 2-4. Maximum Emissions for Criteria and Other Regulated Pollutants for the Winston Peaking Station Project
20 GM EMD 20/645/E4B Diesel Engines, Distillate Oil, Peak Load

Parameter	One Engine	Twenty Engines
Hours of Operation - provided (a)	**876**	**876**
PM_{10} from Engines= Emission rate (lb/hr) from Engines manufacturer (a)		
Emission rate (lb/hr)- provided	**0.95**	**19.0**
(TPY) - based on provided value	**0.42**	**8.3**
Sulfur Dioxide (lb/hr)= Fuel Oil (lb/hr) x sulfur content(gr/100 cf) x (lb SO_2/lb S) /100 (b)		
Fuel use (lb/hr)	**1,430**	**28,597**
Fuel Sulfur content	**0.05%**	**0.05%**
lb SO_2/lb S (64/32)	**2**	**2**
Emission rate (lb/hr)- calculated	**1.72**	**34.3**
(TPY) - based on caculated value	**0.75**	**15.0**
Nitrogen Oxides (lb/hr)= Emission rate with 80% control (lb/hr) from Engines manufacturer (a)		
Emission rate (lb/hr)- provided	**13.9**	**278.0**
(TPY) - based on provided value	**6.1**	**121.8**
Carbon Monoxide (lb/hr)= Emission rate with 85% control (lb/hr) from Engines manufacturer (a)		
Emission rate (lb/hr)- provided	**0.95**	**19.0**
(TPY) - based on provided value	**0.42**	**8.3**
VOCs (lb/hr)= (40% control) * [0.09 lb/MMBtu x 91%] AP-42 x Fuel usage (MMBtu/hr) (b)		
Emission rate (lb/hr)- calculated	**1.03**	**20.6**
(TPY) based on calculated value	**0.45**	**9.0**
Sulfuric Acid Mist = SO2 emission rate (lb/hr) x conversion rate of SO2 to H_2SO_4 (%) x MW H_2SO_4/MW SO_2 (98/64) (b)		
SO_2 emission rate (lb/hr)	**1.72**	**34.3**
lb H_2SO_4/lb SO_2 (98/64)	**1.53**	**1.53**
Conversion to H_2SO_4 (%)	**5**	**5**
Emission Rate (lb/hr)- calculated	**0.158**	**3.15**
(TPY) based on calculated value	**0.069**	**1.38**

Source: (a) Genertek, 2001; (b) Golder Associates, 2001
Note: ppmvd= parts per million, volume dry; O_2= oxygen.

Table 2-5. Design Information and Stack Parameters for the Winston Peaking Station Project
20 GM EMD 20/645/E4B Diesel Engines, Natural Gas, 100 % Load

Parameter	One Engine	Twenty Engines
Engine Performance		
Gross power output (MW)	2.5	50.0
NATURAL GAS		
Heat rate (Btu/kWh, LHV) - provided	10,459	10,459
(Btu/kWh, HHV) - calculated	11,609	11,609
Heat Input (MMBtu/hr, LHV)- calculated	26.15	523.0
(MMBtu/hr, HHV) - estimated	29.02	580.5
Fuel heating value (Btu/scf, LHV)- estimated	946	946
(Btu/scf, HHV)- provided	1,050	1,050
(HHV/LHV)	1.11	1.11
FUEL OIL		
Heat rate (Btu/kWh, LHV) - provided	9,516	9,516
(Btu/kWh, HHV) - calculated	10,087	10,087
Heat Input (MMBtu/hr, LHV) - calculated	23.79	475.8
(MMBtu/hr, HHV) - estimated	25.22	504.3
(HHV/LHV)	None	None
Fuel heating value (Btu/lb, LHV)- estimated	18,302	18,302
(Btu/lb, HHV)- provided	19,400	19,400
(HHV/LHV)	1.06	1.06
Engine Exhaust Flow		
Temperature (°F)	740	740
Volume flow (acfm)- provided	21,350	427,000
Fuel Usage		
Fuel usage (lb/hr)= 94% * [Natural Gas Heat Input (MMBtu/hr) x 1,000,000 Btu/MMBtu (Fuel Heat Content, Btu/scf (LHV) x 0.048 lb/scf)] 6% * [Fuel OilHeat Input (MMBtu/hr) x 1,000,000 Btu/MMBtu (Fuel Heat Content, Btu/lb (LHV))]		
Natural Gas Heat input (MMBtu/hr, LHV)	26.15	523.0
Natural Gas Heat content (Btu/scf, LHV)	946	946
Fuel Oil Heat input (MMBtu/hr, LHV)	23.79	475.8
Fuel Oil Heat content (Btu/lb, LHV)	18,302	18,302
Natural Gas Fuel usage (scf/hr)- calculated	1,247.2	26,536
Fuel Oil Fuel usage (lb/hr)- calculated	78.0	1,560
Stack and Exit Gas Conditions		
Stack height (ft)	30	NA
Diameter (ft)	1.833	NA
Velocity (ft/sec)= Volume flow (acfm) / [((diameter)^2 /4) x 3.14159] / 60 sec/min		
Volume flow (acfm)	21,350	NA
Diameter (ft)	1.8	NA
Velocity (ft/sec)- calculated	134.8	NA
Velocity (m/sec)- calculated	41.1	NA

Source: Genertek, 2001.
Note: Universal gas constant= 1,545 ft-lb(force)/°R; atmospheric pressure= 2,116.8 lb(force)/ft^2

Table 2-6. Maximum Emissions for Criteria and Other Regulated Pollutants for the Winston Peaking Station Project
20 GM EMD 20/645/E4B Diesel Engines, Natural Gas, 100 % Load

Parameter	One Engine	Twenty Engines
Hours of Operation	4,460	4,460
PM_{10} from Engines= Emission rate (lb/hr) from Engines manufacturer (a)		
Emission rate (lb/hr)- provided	0.26	5.3
(TPY) - based on provided value	0.58	11.8
Sulfur Dioxide (lb/hr)= Emission rate (lb/hr) from Engines manufacturer (a)		
Emission rate (lb/hr)- provided	0.20	4.0
(TPY) - based on provided value	0.45	8.9
Nitrogen Oxides from Engines= Emission rate with 80% control (lb/hr) from Engines manufacturer (a)		
Emission rate (lb/hr)- provided	5.58	111.6
(TPY) - based on provided value	12.44	248.8
Carbon Monoxide from Engines= Emission rate with 85% control (lb/hr) from Engines manufacturer (a)		
Emission rate (lb/hr)- provided	4.29	85.7
(TPY) - based on provided value	9.57	191.1
VOCs (lb/hr)= (40% control) * [0.2 lb/MMBtu] AP-42 x Fuel usage (MMBtu/hr) (b)		
Emission rate (lb/hr)- calculated	2.09	41.8
(TPY) based on calculated value	4.66	93.3
Sulfuric Acid Mist = SO2 emission rate (lb/hr) x conversion rate of SO2 to H_2SO_4 (%) x MW H_2SO_4 /MW SO_2 (98/64) (b)		
SO2 emission rate (lb/hr)	0.2	4.0
lb H_2SO_4 /lb SO_2 (98/64)	1.53	1.53
Conversion to H_2SO_4 (%)	5	5
Emission Rate (lb/hr)- calculated	0.02	0.31
(TPY) based on calculated value	0.03	0.68

Source: (a) Genertek, 2001; (b) Golder Associates, 2001
Note: ppmvd= parts per million, volume dry; O_2= oxygen.

Table 2-7. Projected HAP Emissions for City of Lakeland Winston Peaking Station Project
20 GM EMD 20/645/E4B Diesel Engines

HAP	Emission Factor[a,b] lb/MMBtu	Fuel Usage[c] MMBtu	HAPS TPY
Benzene	7.8E-04	4,576,250	1.8E+00
Toluene	2.8E-04	4,576,250	6.4E-01
Xylenes	1.9E-04	4,576,250	4.4E-01
Formaldehyde	7.9E-05	4,576,250	1.8E-01
Acetaldehyde	2.5E-05	4,576,250	5.8E-02
Acrolein	7.9E-06	4,576,250	1.8E-02
Napthalene	1.3E-04	4,576,250	3.0E-01
Total HAP's			**3.41**

Footnotes:

[a] Values taken from October 96 AP-42; Large Uncontrolled Stationary Diesel Engines, 3.4-3

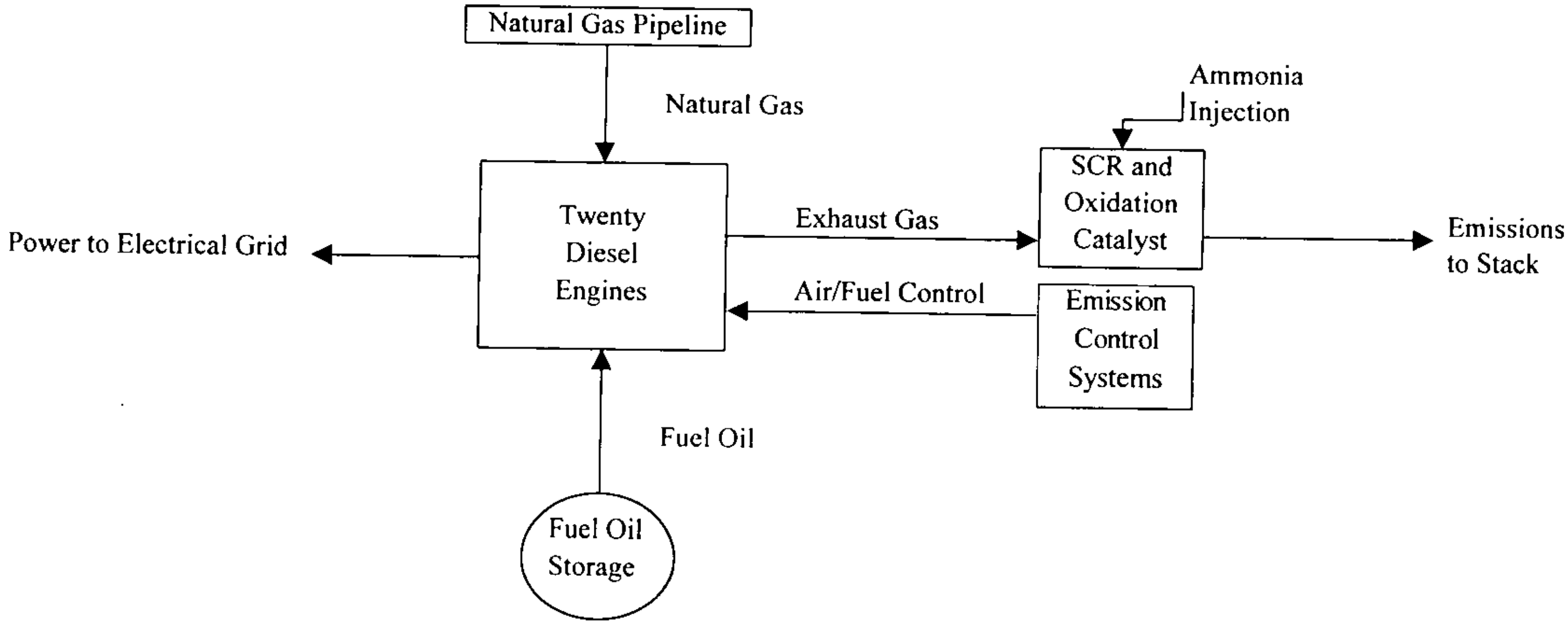
[b] Based on data from one uncontrolled diesel engine.

[c] Maximum fuel usage from natural gas firing only.

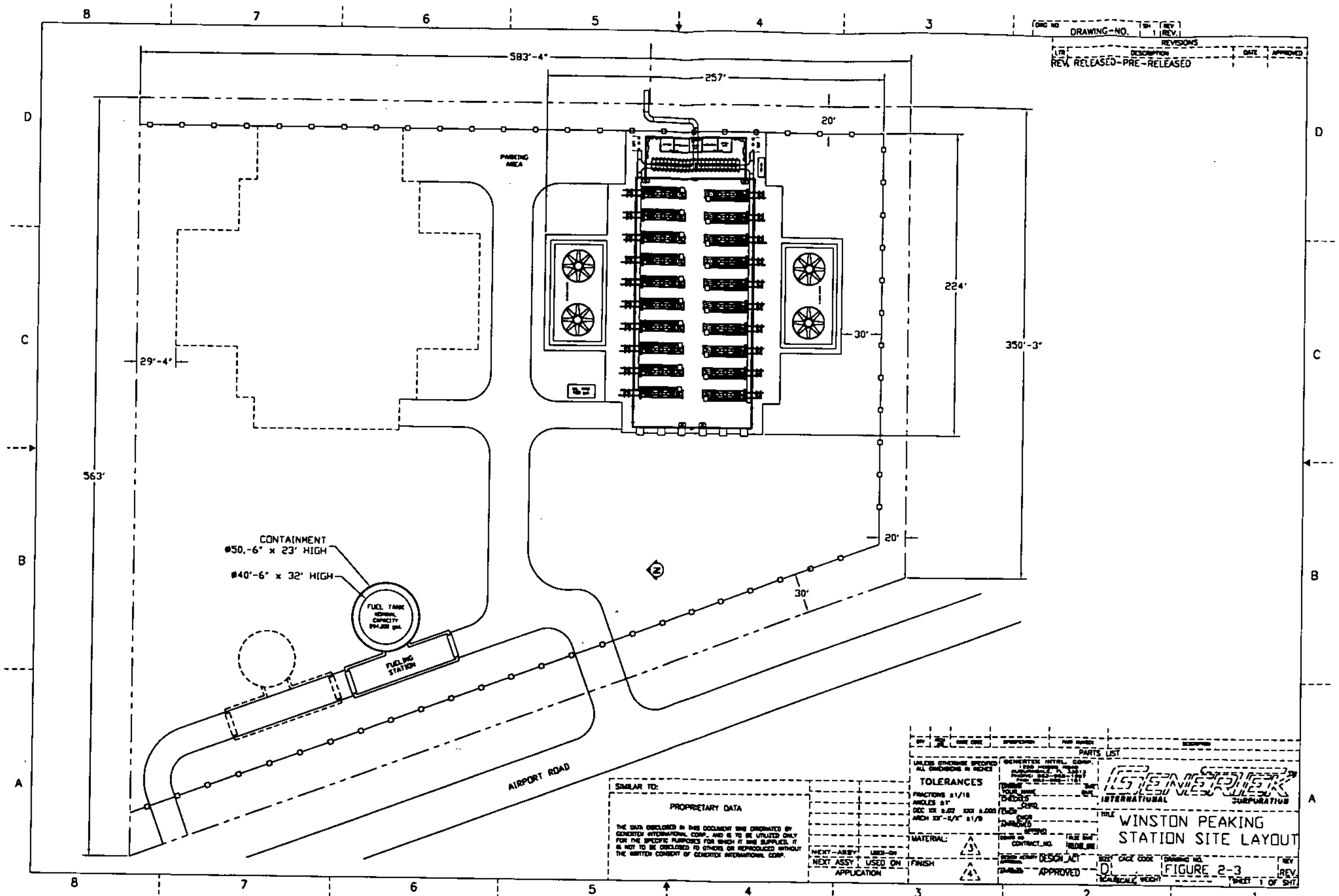
Figure 2-1: Project Site Topographical Map

Source: Lakeland Electric, 2001

Figure 2-2. Simplified Flow Diagram of Twenty Proposed GM EMD 20/645/E4B, Diesel Engines, Baseload, Annual Design Considerations



Source: Golder Associates Inc., 2001


DRAWING-NO.
REVISIONS
REV. RELEASED-PRE-RELEASED
583'-4"
257'
20'
PARKING AREA
224'
350'-3"
30'
29'-4"
563'
20'
30'
CONTAINMENT
ø50,-6" x 23' HIGH
ø40'-6" x 32' HIGH
FUEL TANK
FUELING STATION
AIRPORT ROAD
PARTS LIST
TOLERANCES
SIMILAR TO:
PROPRIETARY DATA
NEXT ASSY
USED ON
APPLICATION
MATERIAL:
FINISH
DESIGN_ACT
APPROVED
GENERTEK INTERNATIONAL CORPORATION
WINSTON PEAKING
STATION SITE LAYOUT
D
FIGURE 2-3
REV.

3.0 AIR QUALITY REVIEW REQUIREMENTS AND APPLICABILITY

The following discussion pertains to the federal and state air regulatory requirements and their applicability to the proposed simple-cycle reciprocating engines.

3.1 NATIONAL AND STATE AMBIENT AIR QUALITY STANDARDS (AAQS)

The existing applicable National and Florida AAQS are presented in Table 3-1. National primary AAQS were promulgated to protect the health of the general public, including the young, elderly, and those with respiratory ailments. National secondary AAQS were promulgated to protect the public welfare, including consideration of economic interests, vegetation, visibility, and other factors, with an adequate margin of safety from any known or anticipated adverse effects associated with the presence of pollutants in the ambient air. Areas of the country in violation of AAQS are designated as nonattainment areas, and new sources to be located in or near these areas may be subject to more stringent air permitting requirements.

Florida has adopted EPA's primary and secondary AAQS in Chapter 62-204, Florida Administrative Code (F.A.C.). In addition, Florida has additional AAQS for SO_2 of 60 and 260 micrograms per cubic meter ($\mu g/m^3$) for the annual and 24-hour averaging periods, respectively, not to be exceeded more than once per year.

3.2 GENERAL PSD AND PERMITTING REQUIREMENTS

3.2.1 PSD REQUIREMENTS

Under federal and State of Florida PSD review requirements, all major new or modified sources of air pollutants regulated under the CAA must be reviewed and a pre-construction permit issued. Florida's State Implementation Plan, which contains PSD regulations, has been approved by EPA; therefore, PSD approval authority has been granted to the Florida Department of Environmental Protection (FDEP).

A "major facility" is defined as any one of 28 named source categories that have the potential to emit 100 TPY or more or any other stationary facility that has the potential to emit 250 TPY or more of any pollutant regulated under CAA. "Potential to emit" means the capability, at maximum design capacity, to emit a pollutant after the application of control equipment.

A "major modification" is defined under PSD regulations as a change at an existing major facility that increases emissions by greater than significant amounts. PSD significant emission rates are shown in Table 3-2.

EPA has promulgated as regulations certain increases above an air quality baseline concentration level of SO_2, PM_{10}, and nitrogen dioxide (NO_2) concentrations that would constitute significant deterioration. The EPA Class designations and allowable PSD increments are presented in Table 3-1. The State of Florida has adopted the EPA Class designations and allowable PSD increments for SO_2, PM_{10}, and NO_2 increments.

PSD review is used to determine whether significant air quality deterioration will result from the new or modified facility. Federal PSD requirements are contained in 40 CFR 52.21, *Prevention of Significant Deterioration of Air Quality*. The State of Florida has adopted PSD regulations by reference [Rule 62-212.400 F.A.C.]. Major facilities and major modifications are required to undergo the following analysis related to PSD for each pollutant emitted in significant amounts:

1. Control technology review,
2. Source impact analysis,
3. Air quality analysis (monitoring),
4. Source information, and
5. Additional impact analyses.

In addition to these analyses, a new facility or emission unit also must be reviewed with respect to Good Engineering Practice (GEP) stack height regulations.

3.2.2 FLORIDA AIR PERMITTING REQUIREMENTS

The FDEP regulations require any new source to obtain an air permit prior to construction. Major new sources must meet the appropriate PSD and nonattainment requirements as discussed previously. Required permits and approvals for air pollution sources include NSR for nonattainment areas, PSD, NSPS, National Emission Standards for Hazardous Air Pollutants (NESHAP), Permit to Construct, and Permit to Operate. The requirements for construction permits and approvals are contained in Rules 62-4.030, 62-4.050, 62-4.052, 62-4.210, and 62-210.300(1), F.A.C. Specific emission standards are set forth in Chapter 62-296, F.A.C.

3.3 NEW SOURCE PERFORMANCE STANDARDS

The New Source Performance Standards (NSPS) are a set of national emission standards that apply to specific categories of new sources. As stated in the CAA Amendments of 1977, these standards "shall reflect the degree of emission limitation and the percentage reduction achievable through application of the best technological system of continuous emission reduction the Administrator determines has been adequately demonstrated."

The proposed Project will be subject to one NSPS. Diesel engines are not specifically identified as having NSPS, however, the fuel oil storage tank (0.294 million gallon capacity) will be subject to 40 CFR Part 60, Subpart Kb. The tank will be constructed and maintained as per this NSPS. Reporting and recordkeeping requirements will be followed and records will be kept for the life of the control equipment (fixed roof).

3.4 SOURCE APPLICABILITY

3.4.1 AREA CLASSIFICATION

The Project site is located in Polk County, which has been designated by EPA and FDEP as an attainment area for all criteria pollutants. Polk County and surrounding counties are designated as PSD Class II areas for SO_2, PM_{10}, and NO_2.

3.4.2 PSD REVIEW

The Project is a new facility and requesting a federally enforceable permit condition to limit the maximum potential emission rate to less than 250 TPY. For simple-cycle engines, the applicable major source PSD threshold is 250 TPY; therefore, no PSD review is required. Simple-cycle engines are not one of the 28 named source categories in the FDEP rules. The Project is also not associated with the existing City of Lakeland power plants. Lakeland Electric will own and control the operation of the project as a separate facility. Lakeland

Electric will purchase and own the diesel engines, transformers, and other associated equipment. The electric power from the units will be dispatched by Lakeland Electric.

3.4.3 OTHER CLEAN AIR ACT REQUIREMENTS

The 1990 CAA Amendments established a program to reduce potential precursors of acidic deposition. The Acid Rain Program was delineated in Title IV of the CAA Amendments and required EPA to develop the program. EPA's final regulations were promulgated on January 1, 1993, and included permit provisions (40 CFR Part 72), allowance system (Part 73), continuous emission monitoring (Part 75), excess emission procedures (Part 77), and appeal procedures (Part 78).

EPA's Acid Rain Program applies to all existing and new utility units except those serving a generator less than 25 MW, existing simple-cycle CT, and certain non-utility facilities; units which fall under the program are referred to as affected units. The EPA regulations would not be applicable to the proposed Project due to the enigines nameplate rating of 2.5 MW each, which is below EPA's Acid Rain Program applicability rating of 25 MW or greater.

The EPA has, and is currently developing, emissions standards for HAPs for various industrial categories. These new NESHAPs that result from the 1990 CAA Amendments are based on the use of Maximum Achievable Control Technology (MACT). The adopted standards are contained in 40 CFR 63. New sources that emit more than 10 TPY of a single HAP or 25 TPY of total HAPs are required to apply MACT for the promulgated industrial category or to obtain a case-by-case MACT determination from the applicable regulatory authority after submitting a MACT analysis. For the Project, emissions of HAPs will be less than 10 TPY of a single HAP and 25 TPY of all HAPs.

Table 3-1. National and State AAQS, Allowable PSD Increments, and Significant Impact Levels

Pollutant	Averaging Time	AAQS ($\mu g/m^3$)			PSD Increments ($\mu g/m^3$)		Significant Impact Levels ($\mu g/m^3$) [b]
		Primary Standard	Secondary Standard	Florida	Class I	Class II	
Particulate Matter[c] (PM_{10})	Annual Arithmetic Mean	50	50	50	4	17	1
	24-Hour Maximum	150	150	150	8	30	5
Sulfur Dioxide	Annual Arithmetic Mean	80	NA	60	2	20	1
	24-Hour Maximum	365	NA	260	5	91	5
	3-Hour Maximum	NA	1,300	1,300	25	512	25
Carbon Monoxide	8-Hour Maximum	10,000	10,000	10,000	NA	NA	500
	1-Hour Maximum	40,000	40,000	40,000	NA	NA	2,000
Nitrogen Dioxide	Annual Arithmetic Mean	100	100	100	2.5	25	1
Ozone[c]	8-Hour Maximum[d]	157	157	157	NA	NA	NA
Lead	Calendar Quarter Arithmetic Mean	1.5	1.5	1.5	NA	NA	NA

Note: Particulate matter (PM_{10}) = particulate matter with aerodynamic diameter less than or equal to 10 micrometers.
NA = Not applicable, i.e., no standard exists.

[a] Short-term maximum concentrations are not to be exceeded more than once per year.

[b] Maximum concentrations are not to be exceeded.

[c] On July 18, 1997, EPA promulgated revised AAQS for particulate matter and ozone. For particulate matter, $PM_{2.5}$ standards were introduced with a 24-hour standard of 65 g/m^3 (3-year average of 98th percentile) and an annual standard of 15 g/m^3 (3-year average at community monitors). These standards have been stayed by a court case against EPA and implementation of these standards are many years away pending EPA appeal.

[d] 0.08 ppm; achieved when 3-year average of 99th percentile is 0.08 ppm or less. These have been stayed by a court case against EPA. EPA is appealing. The 1-hour standard of 0.12 ppm is still applicable. FDEP has not yet adopted the new standards.

Sources: Federal Register, Vol. 43, No. 118, June 19, 1978.
40 CFR 50; 40 CFR 52.21.
Chapter 62-272, F.A.C.

Table 3-2. PSD Significant Emission Rates and *De Minimis* Monitoring Concentrations

Pollutant	Regulated Under	Significant Emission Rate (TPY)	*De Minimis* Monitoring Concentration[a] (μg/m3)
Sulfur Dioxide	NAAQS, NSPS	40	13, 24-hour
Particulate Matter [PM(TSP)]	NSPS	25	10, 24-hour
Particulate Matter (PM_{10})	NAAQS	15	10, 24-hour
Nitrogen Dioxide	NAAQS, NSPS	40	14, annual
Carbon Monoxide	NAAQS, NSPS	100	575, 8-hour
Volatile Organic Compounds (Ozone)	NAAQS, NSPS	40	100 TPY[b]
Lead	NAAQS	0.6	0.1, 3-month
Sulfuric Acid Mist	NSPS	7	NM
Total Fluorides	NSPS	3	0.25, 24-hour
Total Reduced Sulfur	NSPS	10	10, 1-hour
Reduced Sulfur Compounds	NSPS	10	10, 1-hour
Hydrogen Sulfide	NSPS	10	0.2, 1-hour
Mercury	NESHAP	0.1	0.25, 24-hour

Note: Ambient monitoring requirements for any pollutant may be exempted if the impact of the increase in emissions is below *de minimis* monitoring concentrations.

NAAQS = National Ambient Air Quality Standards.

NM = No ambient measurement method established; therefore, no *de minimis* concentration has been established.

NSPS = New Source Performance Standards.

NESHAP = National Emission Standards for Hazardous Air Pollutants.

g/m^3 = micrograms per cubic meter.

[a] Short-term concentrations are not to be exceeded.

[b] No *de minimis* concentration; an increase in VOC emissions of 100 TPY or more will require monitoring analysis for ozone.

[c] Any emission rate of these pollutants.

Sources: 40 CFR 52.21.
Rule 62-212.400.

APPENDIX A

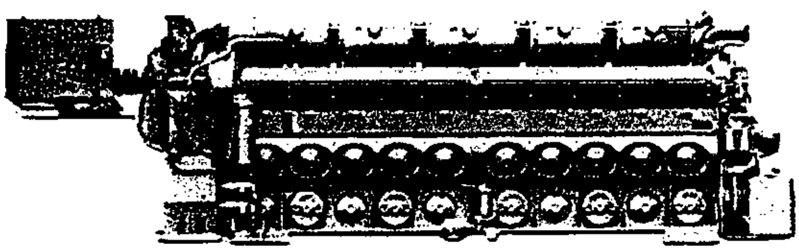
MECHANICAL DESCRIPTION AND SUPPORTING DATA FOR GENERTEK GM EMD 20/645/E4B DIESEL ENGINES

MECHANICAL DESCRIPTION

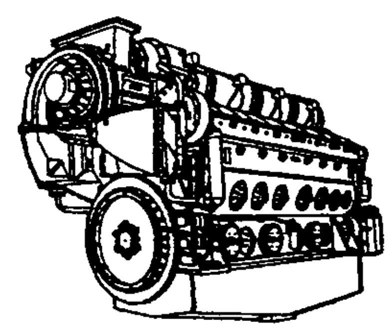
SUB SECTION	TITLE DESCRIPTION	PAGE
1.00	Engine Model and Specifications	1
2.00	Engine Ancillary Equipment	3
3.00	Generator Model and Specifications	4
4.00	Generator Set Technical Specifications	5
5.00	Generator Set Weights and Dimensions	6
6.00	Standard Drawing Package / Documentation	14
7.00	Technical Support and Training	15
8.00	Standard Warranty	16

1.00 Engine Model and Specifications

Each Generator set in this proposal contains a **GM/EMD** 20cylinder 645E4 turbocharged Diesel Engine which shall be supplied with all new sub assembly components and a remanufactured crankcase assembly, common skid mounted to a New Baylor Generator and new Accessory Rack with integrally mounted new engine oil and water cooling equipment, engine water day tank, engine air filters, engine primary and secondary fuel filtration equipment, engine oil filtration equipment, engine air start equipment, and new engine controls and alarm panels.

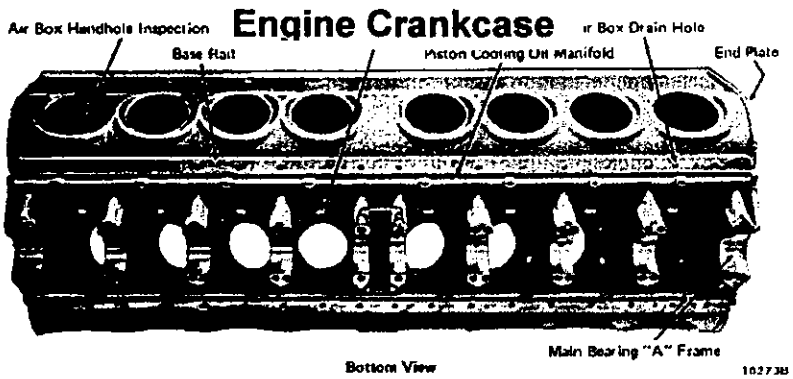


EMD	20 645 E4 **Diesel Engine**



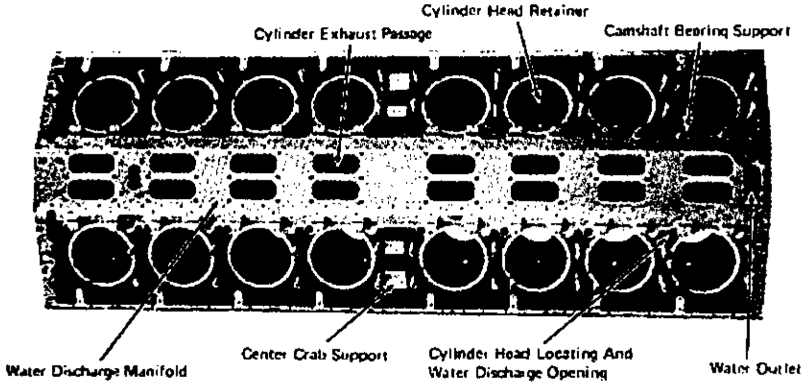
Engine Operation:
The GM/EMD 20/645E4 two stroke engine, as well all EMD engines have a 9-1/16" bore with a 10" (254MM) stroke and provide a high degree of interchangeability of basic components between engine models. All engines are of the "V" type with 45 degree angle between cylinder banks, and operate on the two-cycle, single acting principle with uniflow scavenging.

The crankcase and oil pan are steel fabrications of forgings, rolled sections, and steel plates welded together into a single structure of great strength. The firing load is transferred through the rolled sections of the crankcase to the main stress members supporting the crankshaft and main bearings.



Number of Cylinders	20 cylinder
Horsepower Rating	3600 HP
Displacement Per Cylinder	645 cu/in
Bore and Stroke	9 1/16 x 10
Type	2 cycle V45
RPM	900 RPM
Fuel	Diesel
Number of turbochargers	1
Piston Speed	1500 ft/min
Crankshaft Diameter	7-1/2"
Engine Condition:	Remanufactured to OEM Specs

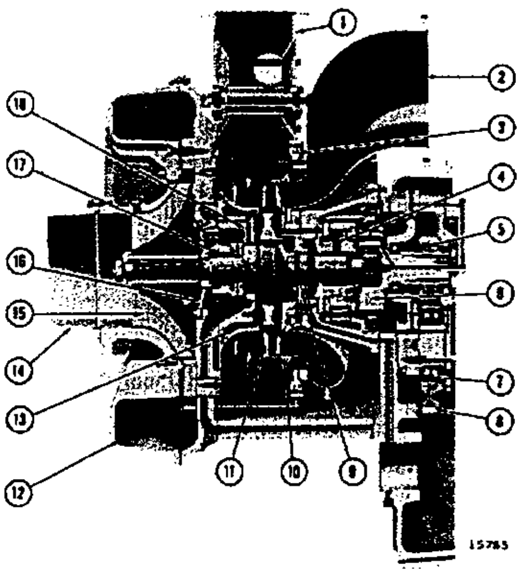
Engine Operation: continued...



Top View

The upper and lower decks of each bank are bored to receive the cylinder liners and the space surrounding the liners together with the V-shaped area between the cylinder banks form the scavenging air reservoir. The upper center portion of the crankcase forms the water discharge manifold. Large openings along the sides of the crankcase permit access to the scavenging air reservoir form maintenance purposes.

Engine cylinders are charged with fresh air by means of a single turbocharger located at the



1. Exhaust Duct
2. Turbine Inlet Scroll
3. Carrier Ring
4. Overrunning Clutch
5. Carrier Drive Gear
6. Carrier Shaft Assembly
7. Roller Bearing
8. Turbo Idler Gear
9. Support Assembly
10. Nozzle Ring
11. Turbine Wheel
12. Compressor Discharge Scroll
13. Exhaust Diffuser
14. Air Inlet Assembly
15. Impeller
16. Impeller Seal
17. Spherical Thrust Bearing
18. Spherical Seat Thrust Brg.

Cutaway View of Turbocharger

Turbocharged Engines

flywheel engine of the engine. The turbocharger design permits positive drive from the camshaft drive gear train at lower speeds and loads to supply the necessary air for combustion. Full drive from the exhaust turbine is achieved as the engine approaches full load and the heat energy in the exhaust is sufficient to drive the turbocharger without help from the engine. At this point an overrunning clutch in the turbocharger disengages and the turbocharger is mechanically disconnected from the engine gear train.

Engine Operation: continued...

Air is taken from the atmosphere through an engine mounted air filter and is forced under pressure into the crankcase air box. It is this air, under pressure that scavenges the burned gases from the cylinders.

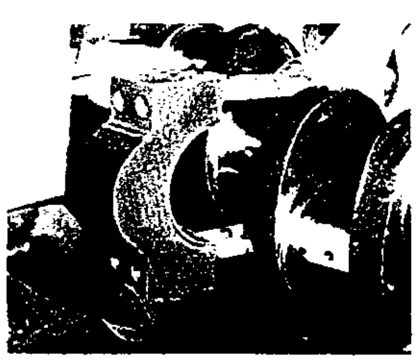
Before the end of the power stroke, the exhaust valves in the cylinder open, and allow the exhaust gases in the cylinder to escape through exhaust ports cast into the cylinder head. The gases pass through the attached water-jacketed exhaust elbow, into the exhaust manifold and out through the exhaust piping.

As the trunk-type piston continues to move downward, it uncovers the air intake ports in the cylinder liner, permitting air in the air box surrounding the cylinders to flow through the ports and scavenge the cylinder. Upon upward movement of the piston, the exhaust valves close. The piston covers the cylinder liner air intake ports and begins compressing the air in preparation for fuel injection.

The crankshaft is made of a high-grade carbon steel alloy forging with induction hardened main crankpin journals. The 7-1/2" diameter main journals and 6-1/2" diameter crankpins result in conservative loadings and long bearing life. Counterweights are provided to give stable operation and the crankshaft is statically and dynamically balanced. The main bearings are supplied with clean oil lubricating oil under pressure from a main lubricating oil manifold extending the length of the engine. Drilled oil passages in the crankshaft conduct oil from the main journals to the crankpin journals. The crankshaft on 20 cylinder engines consists of two halves joined by bolted, forged-on flanges.

CRANKSHAFT

Main Bearings are steel shells of ample thickness to avoid distortion. Each bearing half is lined with a centrifugally cast lead-bronze alloy with a lead-tin overlay of break in purposes. The bearings are of the precision type and are fitted without shims or scraping.



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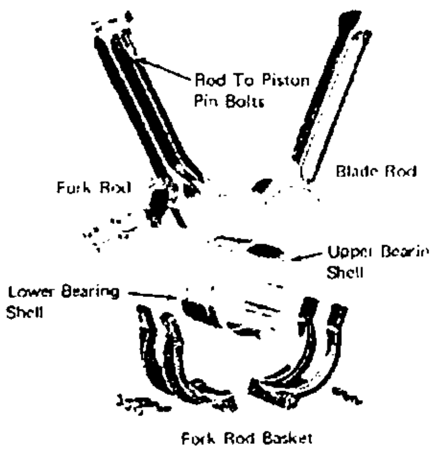
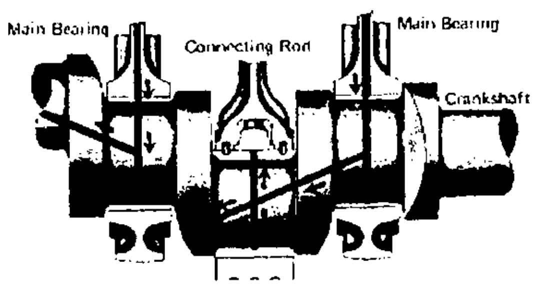
Engine Operation: continued…



The connecting rods are of drop forged, heat treated alloy steel with I-section shanks. The trunnion type rods are interlocking blade and fork construction, which eliminates cylinder offset and improves connecting rod bearing load conditions.

The blade rod oscillates on the back of the upper connecting rod bearing and is held in place by a counter bore in the fork rod. Serrations on the sides of the fork rod match similar serrations on the fork rod basket. The fork rods and baskets are bolted together at the serrations

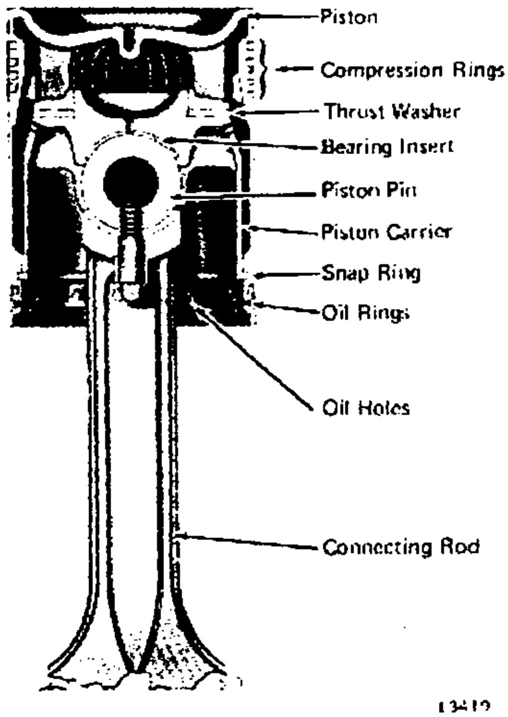
The upper end of each rod is formed into a "saddle"
To which the piston pin is bolted.

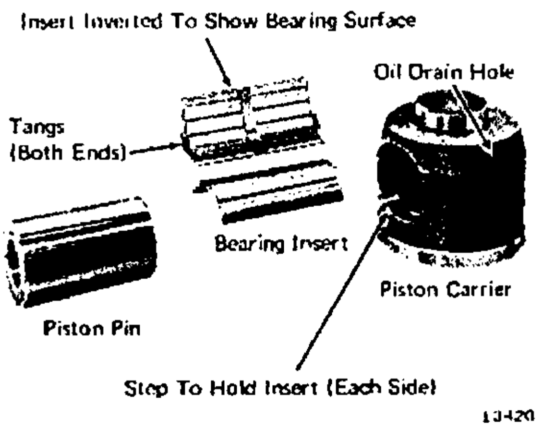


The steel backed halves are lined with a centrifugally cast lead-bronze alloy material and a lead-tin overlay for the break-in purposes. The outer surfaces of the upper connecting rod bearing is provided with layer of lead-bronze material covered by a lead-flashed overlay for the blade rod to ride on. Oil is distributed over this surface through a pattern of oil grooves in the bearing, which efficiently lubricates the slipper rod surface of blade rod. Oil is received from the adjacent main bearing through a drilled passage in the crankshaft. Oil is received from the adjacent main bearing through a drilled passage in the crankshaft.

The connecting rod bearings extend the full width of the crankpin journal and are of the precision type. The bearing halves are applied without shims or scraping.

Engine Operation: continued...





The piston assembly consists of a cast iron allow piston, four compression rings, and two oil control rings. A trunnion type forged steel piston carrier containing a piston pin and bearing is used with the piston to allow the piston to rotate or "float" during engine operation.

The carrier supports the piston at the internal piston platform. A replaceable thrust washer is used between the piston and the carrier and a steel snap ring in the piston skirt retains the carrier in the piston. This floating-type construction equalizes thermal expansion, improves ring performance, and reduces piston skirt and liner bore wear.

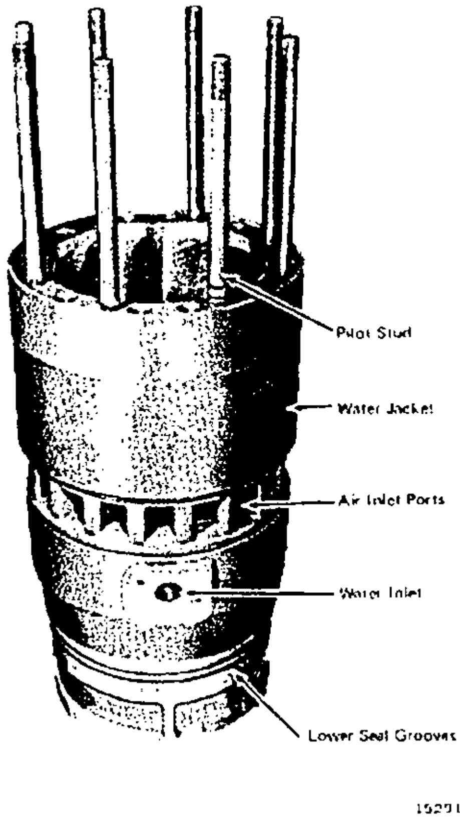
The internal parts of the piston are lubricated and cooled by oil, which is directed through a drilled passage in the piston carrier. The oil circulates about the piston crown area and then drains through two holes in the piston carrier.

Each Piston is cooled and lubricated internally by a stream of oil from a piston cooling pipe which directs

The piston pin is made of steel alloy material with the outer surface polished to a mirror finish. The pin is applied in the piston carrier with the insert bearing and the assembly is bolted directly to the concave saddle contour at the top of the connecting rod. The bolted construction insures that the piston pin will oscillate in the piston carrier bearing.

The steel-backed insert bearing is retained in broached slot in the carrier. The replaceable insert is lined with a silver bearing material and an overlay of lead for "break-in" purposes.

Engine Operation: continued...



Each bore in the engine crankcase is provided with a replaceable cylinder liner, which is water-jacketed over the active length of the liner. The liners are fabricated from iron alloy castings with brazed-on steel cooling water jackets.

A row of scavenging air intake ports, which completely encircle the liner. Are located just above the position of the piston top when it is at the bottom dead center. Visual inspection can be made of the liner inner wall, Piston crown and skirt, and all compression rings.

The liner ports are arranged at an angle so as to produce an efficient swirling action of the scavenging air stream. A water inlet flange on the liner, located below the ports, provides a connection for the liner water supply line. Cooling water circulates within the liner walls and discharges upward through twelve drilled passages into the cylinder head.

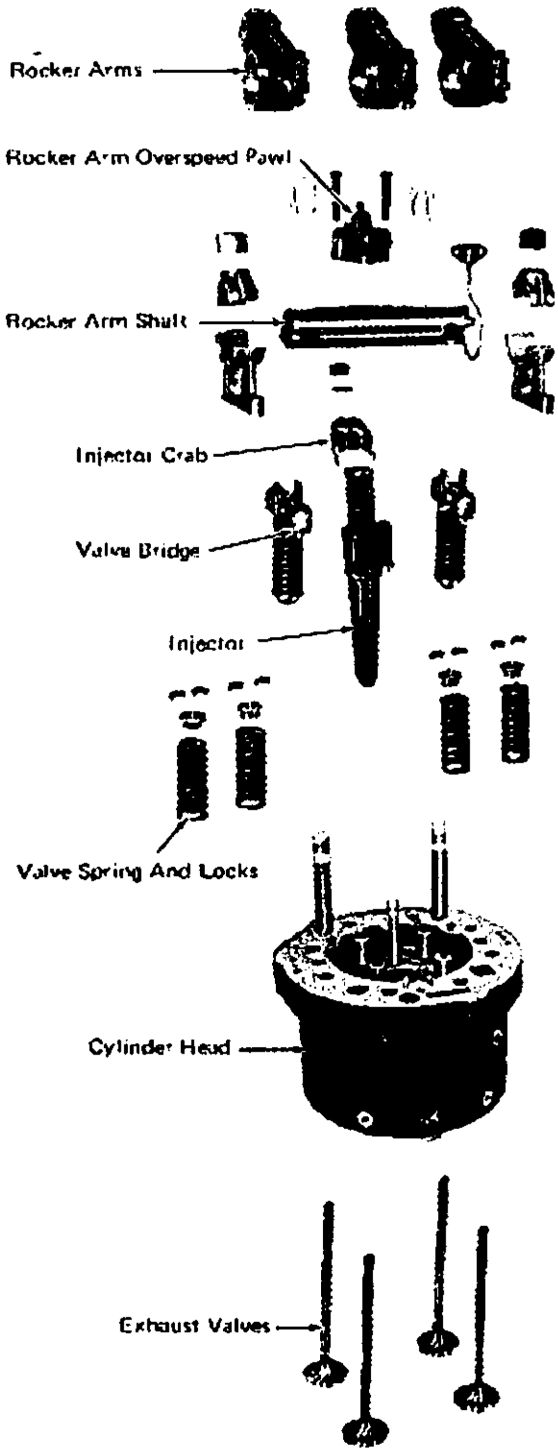
A counter bore around each drilled hole accommodates a Teflon ring in combination with a silicone rubber seal which seals the water passage when the cylinder head is installed.

A thin copper-steel gasket provides a combustion seal between the cylinder head and the liner.

The liner is supported from the cylinder head by studs and does not carry tensile or compressive operating loads.

Chrome liners are used for installations, which may receive fuel with high sulfur content. The engines for this installation include chrome liners in the buildup of the engines.

Engine Operation: continued...



An easily removed cylinder head is installed on top of the each cylinder liner in the engine. Four crab bolt nuts and crabs hold each cylinder head securely to the cylinder head retainer in the crankcase.

The head is secured to the liner by eight equally spaced studs and nuts and the assembly is firmly retained in the crankcase by the crabs.

The head is cast of a high strength iron alloy with scientifically cast passages for water and exhaust gases.

Valve seats are machined directly in the head. Drilled water holes at the bottom of the head match the water discharge holes in the liner.

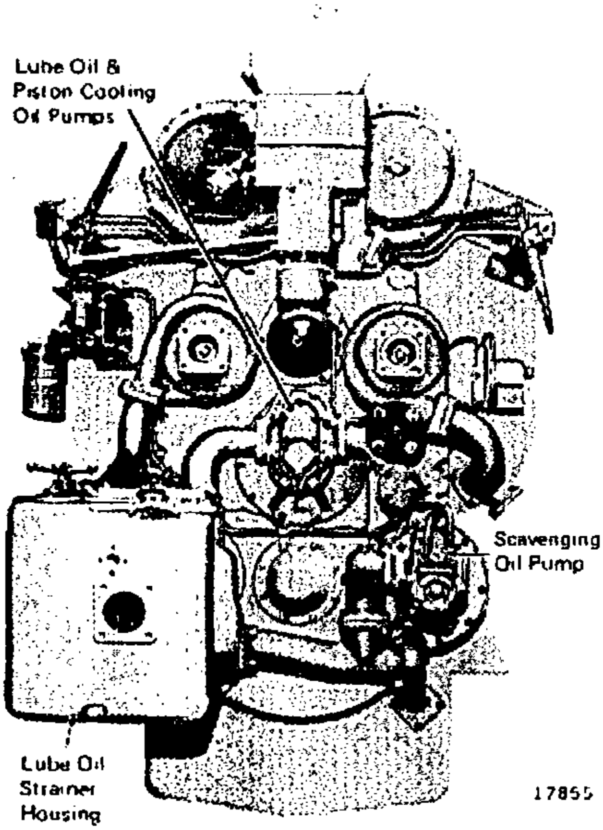
Exhaust passages in the head line up with mating elbows in the crankcase to conduct exhaust gases through the water manifold to the exhaust manifold.

Four high temperature corrosion resistant exhaust valves are grouped around a Unit type injector located in the center of the head.

Each cylinder head is equipped with three forged steel rocker arms with roller followers, which are directly actuated by overhead camshafts. Two rocker arms operate the two pairs of exhaust valves and the third operates the fuel injector.

Each rocker arm is lubricated with oil received from and adjacent camshaft bearing.

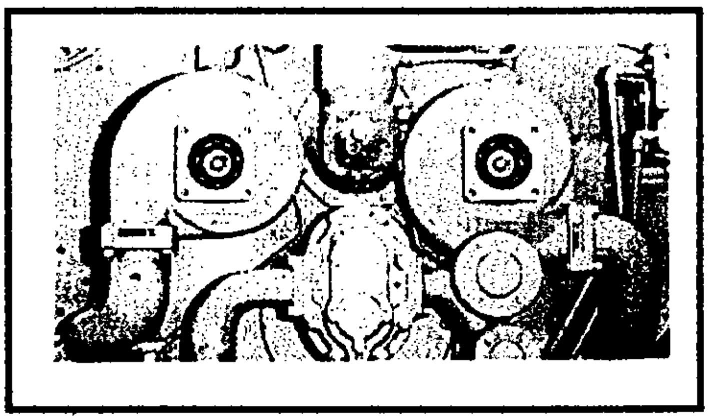
Engine Operation: continued...



The engine oil lubricating system is a combination of three separate systems: the main lubricating system, piston cooling system, and scavenging system. Each system has its own pump.

The main lube oil pump and piston cooling pump, although individual pumps, are both contained in the one housing and driven form a common drive shaft. The scavenging oil pump is a separate pump. All pumps are driven from the accessory gear train at the front of the engine.

The lube oil strainer housing serves both as a n oil reservoir and a strainer to protect the oil pumps.



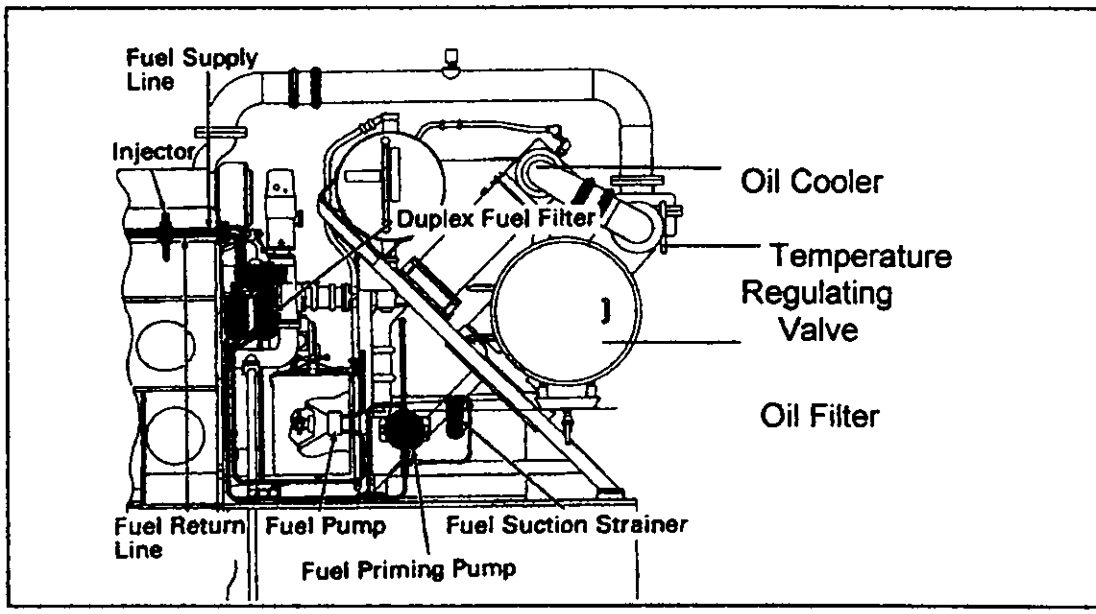
The engine cooling fresh water pumps are of the centrifugal type and are engine driven by the govenor drive gear. Two pumps are used to circulate water through the engine water-cooling passages. Ample cooling water is supplied at all engine speeds.

Coupling connections between the fresh water pumps and the accessory rack are provided.

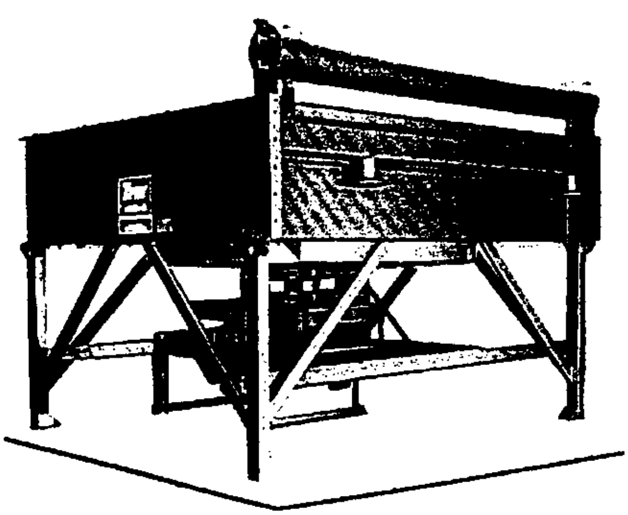
2.00 Engine: Ancillary Equipment

Each generator set includes the required support equipment necessary to operate the engine. Support equipment for the engine is mounted on an "Engine Accessory Rack" that is located just behind the engine and common skid mounted to the engine/generator.

Engine Accessory rack: The engine accessory equipment includes the engine oil cooler, primary and secondary oil and fuel filtration equipment, engine water day tank, engine alarms/control panel, fuel priming pump, oil priming pump, water temperature regulating valve, engine piping to each piece of equipment, and skid mounted steel rack for the mounting of all equipment.



Engine Radiator

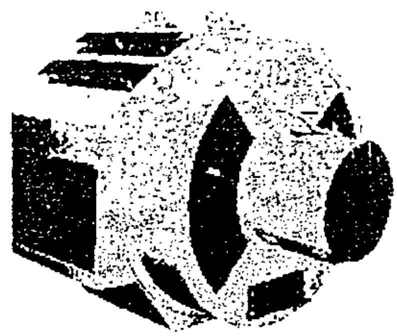


The engine radiator supplied for this installation is remote mounted outside of the power house and piped to and from the engine to the radiator with 8" steel pipe. The radiator incorporates a 50 HP motor, and has a belt driven radiator fan. The radiator specified for delivery herein is rated for an ambient temperature of 100 degrees F.

Each Engine/Generator set uses one radiator per engine. Cooled water from the radiator circulates through an oil cooler mounted on the accessory rack, then passes to the engine water pumps.

3.00 Generator Model and Specifications:

Each generator set supplied for this installation contains a new Baylor™ "Stallion" Series synchronous alternator Model No. G8558RNV. The alternator will be common skid mounted and double flex plate coupled to each engine.



Baylor *Stallion*

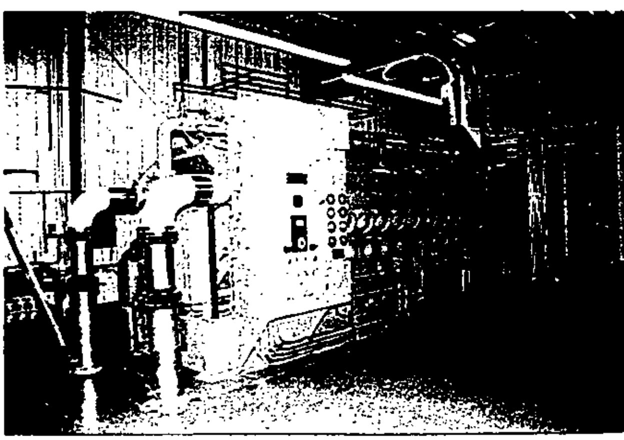
Baylor - *Stallion* SERIES
MODEL No. G8558RNV

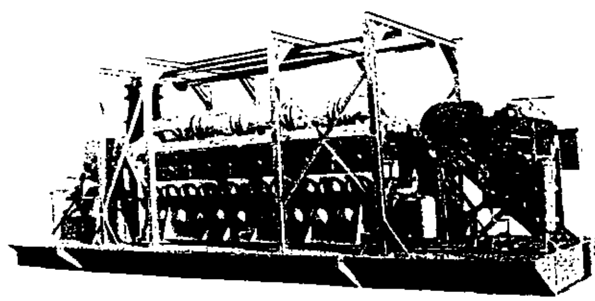
Specifications

Electrical Rating:	2500 kW Cont.
Electrical Rating:	2865 Standby
Power Factor:	0.8
Phase:	3ph
Rpm:	900
Hertz:	60
Volts:	4160 VAC
Ambient:	40deg C STD
Temperature Rise:	80 degree C
Duty:	Continuous
Insulation:	Class " f "
Enclosure:	Drip-proof
Weight:	22,500 Lbs.

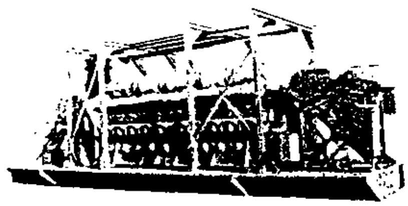
Single bearing construction w/ ins roller bearing construction.
Vacuum pressure impregnation
Standard Baylor test and documen
PMG excitation support
RTD's two per phase, 100 ohm
Space heaters Basler SSR 125-12 regulator

Each Generator Set is shipped complete. Each unit will be set in place ready to receive water and fuel line tie-ins. Each unit will be supplied and installed with a new residential grade silencer, exhaust piping and flex joints, wrapped in insulated stainless steel capping.





4.00 Generator Set Technical Specifications:



20/645/E4 Generator Set in Simple Cycle Operation

Electrical power output net at main generator terminal ---→	2500 kW continuous
Heat rate at above rating ---→	9240 BTU/KW hr

MPU 2500 Megawatt Unit Operation Data – per unit

Availability Factor	95%
Total hours per year required for scheduled maintenance	385
Total operating hours per year at rated capacity	8322
Total allowable operating hours per year at a 110 % load factor	876
Percent of full load rating required achieving optimal heat rate	75%

Sound Level: 85 dbl's at 10 feet with sound attenuated house
Optional single house for multiple units available

Site Conditions at Performance Ratings

Ambient Air Temperature	(degrees F)	100
Barometric Pressure	(In Hg)	28.25
Fuel caloric value	(BTU/LB)	19420
Site Conditions		
Ambient Air Temperature		(100)
	MIN	(10 degrees f)
Barometric Pressure	(In Hg)	(LATER)

Genertek International Engineering

5.00 Generator Set Weights and Dimensions:

MODEL: GM EMD 20/645/E4b Engine

Units	Lbs.	kg
Engine – Dry	42,500	19,280
Drive Line Couplings and Driving Disc	725	330
SUB-TOTAL	43,225	19,610
Basic Generator End	22,500	10,207
Total - unit less Common Base and Accessory Rack	65,725	29,817
Common Base	10,800	4,900
Total - unit with Common Base less Accessory Rack	76,525	34,717
Accessories – as described and supplied	8,425	3,822
Total – unit with Common Base and Accessory Rack	84,950	38,539

Liquid Weights:

Lube Oil in Engine	1,400	635
Lube Oil in Accessories	800	159
Water in Engine	1,270	576
Water in Accessories	910	413

6.00 Standard Drawing Package / Documentation:

6.01 Package:

Finalized one line, plain and elevation drawings, schematics and bill of material drawings issued.

(3) Three sets of 36"x 24" non-reproducible approval drawings, and 6 sets of manuals and 36" x 24" non-reproducible as-built drawings are included. " B " size drawings are included.

Equipment build up & documentation data sheets will be available for review when the equipment is " in process ", and all completed documentation will be presented to the customer upon completion.

Basic Engineering data sheets are included with this proposal. Specific information not included within this proposal will be supplied upon customer request.

7.00 Technical Support and Training:

7.01 Technical & Engineering Services: GENERTEK will provide all necessary installation specifications and engineering data with drawings. Plant Operation and Maintenance Training manuals, materials and onsite instruction are provided.

7.02 On-Site Supervision: On-site installation supervision services are provided for completion of site installation supervision and start up.

7.03 Performance Test: will be documented PRIOR to on-site installation (at our Facility) and AFTER on-site installation for the equipment supplied as specified within this proposal.

7.04 Pre-Contact Engineering Services: Technical support services, complete power plant engineering, and site inspection are provided in order to gather information regarding actual requirements for installation, engineering data and bill of materials list.

7.05 Training: Genertek will perform onsite training for two weeks following installation of the power plant equipment. In shop training while the equipment is being packaged for delivery will provide for two employees of the customer. This training is recommended. Any additional personnel provided for in shop training or additional training requested by the customer which is outside of the services described within the scope this proposal shall be requested in writing by the customer, and a price for such services shall be provided.

8.00 Standard Warranty

GENERTEK WARRANTY

GENERTEK WARRANTS remanufactured and new parts or equipment sold by Genertek to be free from defects in the material and workmanship in course of normal commercial use subject to the following terms and conditions:

THIS WARRANTY is made solely to the original CUSTOMER exclusive and in lieu of any warrant of merchantability, warranty of fitness for a particular purpose, or any other warranty express or implied.

THIS WARRANTY shall continue for a period of not more than two years from the date of receipt by CUSTOMER. THIS WARRANTY is limited to the repair or replacement of the defective part/s and shall not include the cost of shipping and/or labor to repair or replace the defective item/s.

THIS WARRANTY shall not apply if the part/s or equipment have been subject to misuse, neglect, accident or have been repaired or altered by any other party other than Genertek or it's representative.

THE CUSTOMER in order to recover under THIS WARRANTY must do the following:

a). Notify Genertek in writing within 30 days from the time of discovering the defective part/s or workmanship.

b). Wait for authorization from Genertek for the return of a defective item for replacement or repair.

c). Genertek shall have the opportunity to inspect the defective item/s and at its discretion repairs the part on site.

d). In an emergency event, the CUSTOMER may repair or replace a defective item/s. However, during such an emergency the customer shall seek prior verbal council and authorization from Genertek before any repairs are made.

Genertek shall in no event be liable for incidental or consequential damages. Incidental or consequential damages are defined as follows. :

a). Incidental Damages are expenses incurred in the inspection, transportation, care or custody of the part/s of any commercially reasonable charges, expenses or commissions.

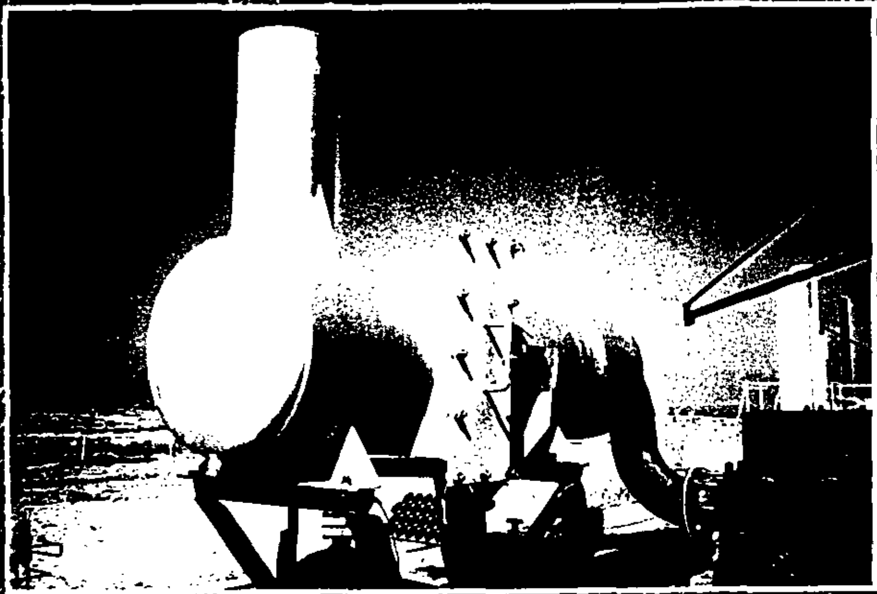
b). Consequential Damages are injury to person or property resulting from the defective part, lost revenues, or any claims made by third parties.

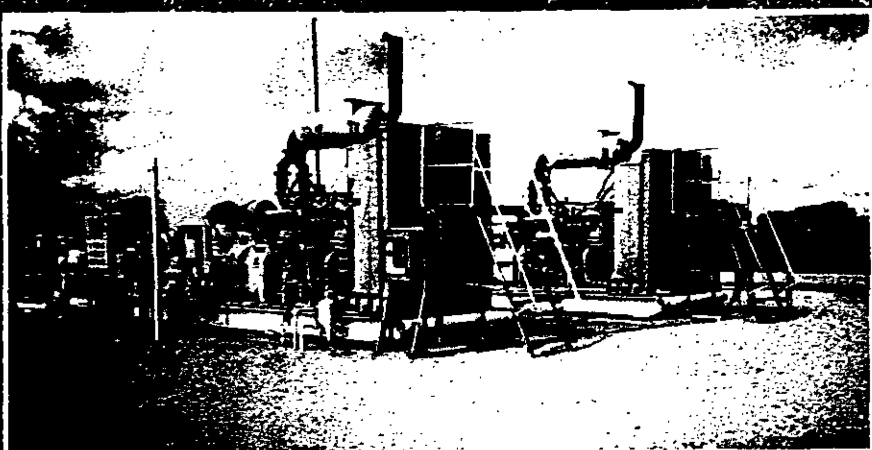
In no event shall Genertek be liable for any breach of warranty in an amount exceeding the replacement price or invoiced price for the repair of the part.

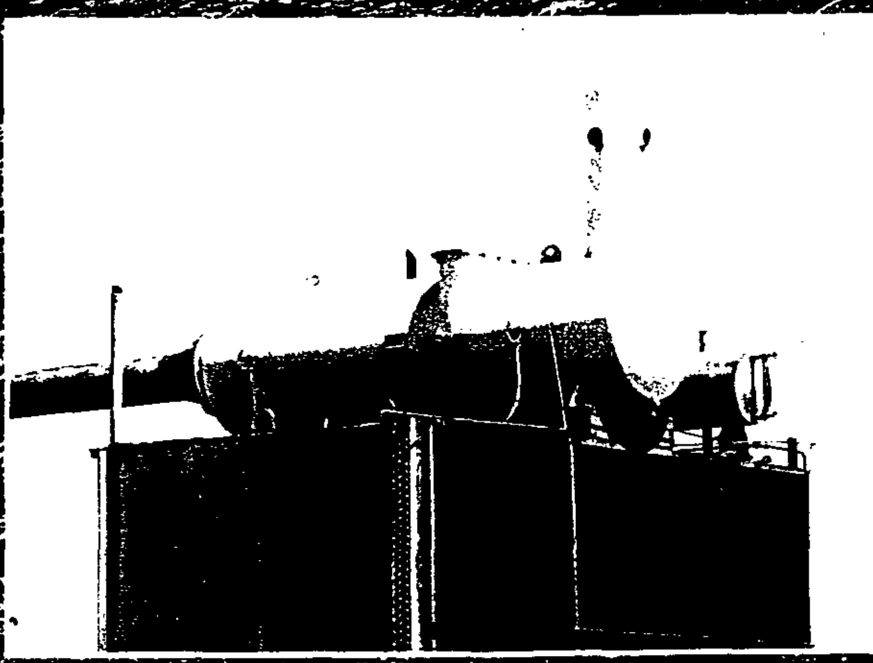
APPENDIX B

SUPPORTING DATA FOR THE H.I.S. EMISSIONS REDUCTION SYSTEM

HIS Emissions Reduction Systems





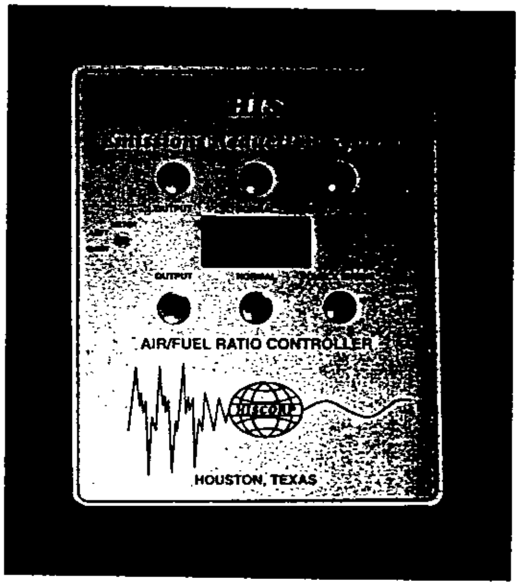


HISCORP

Sound Engineering

Harris International Sales Corporation was incorporated in 1977 as a manufacturer of engineered products for engines, compressors and turbines serving the natural gas and power generation industries.

In response to legislation and ever-increasing demand to reduce air pollution, the DeNOx Silencer, a combination catalytic converter/silencer, was developed and patented. In April 1985, the first DeNOx Silencer was put into operation under Houston Industrial Silencing *(HIS)*.



The HIS 88EM Automatic Air Fuel Ratio Controller is microprocessor-based and programmed to govern (fuel to air) system balance within the catalyst window and track load change automatically and efficiently.

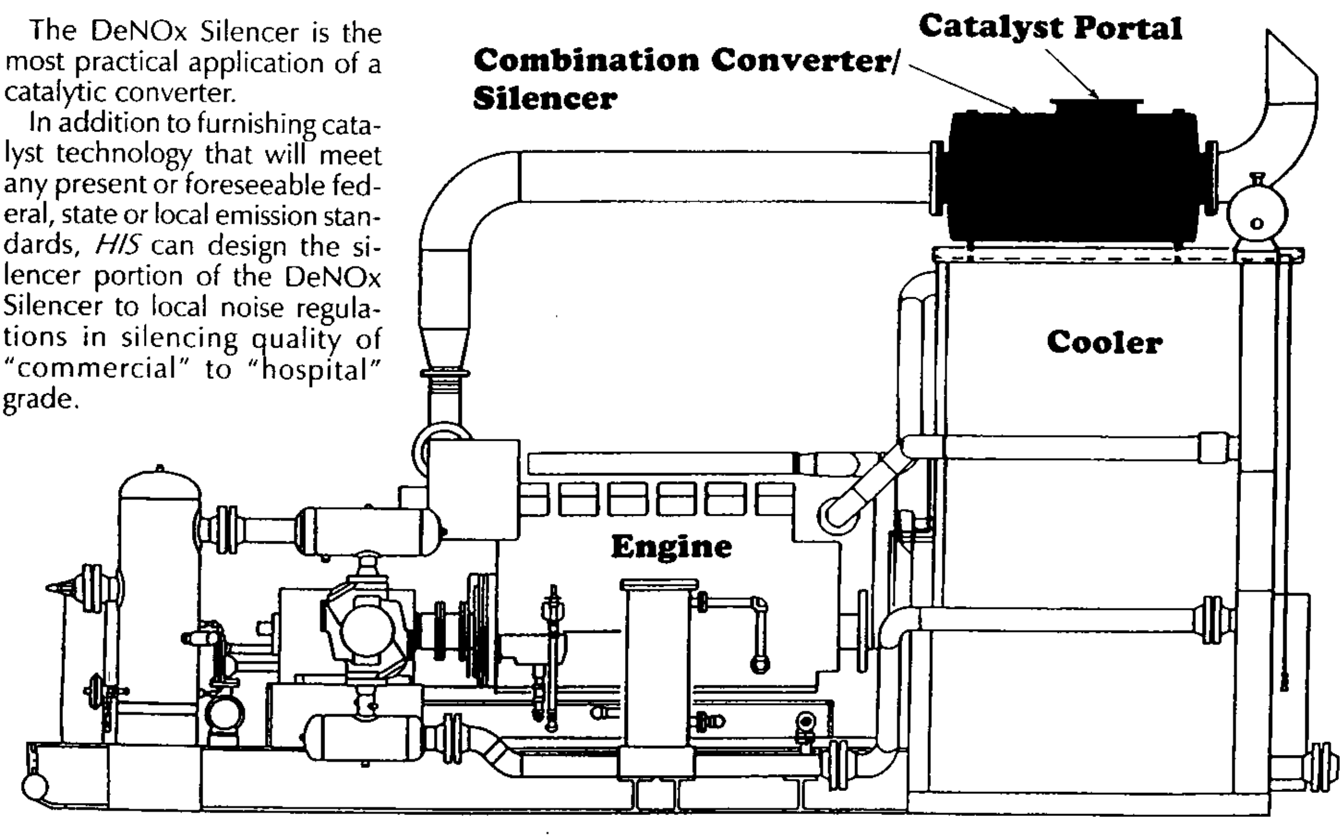
The Most Advanced Design Technology in Catalytic Converter Design.

HIS has taken the DeNOx Silencer technology to higher levels of performance and reliability with concentrated research and field experience. The combining of the catalytic converter and exhaust silencer has several advantages beyond the obvious economy of a single vessel.

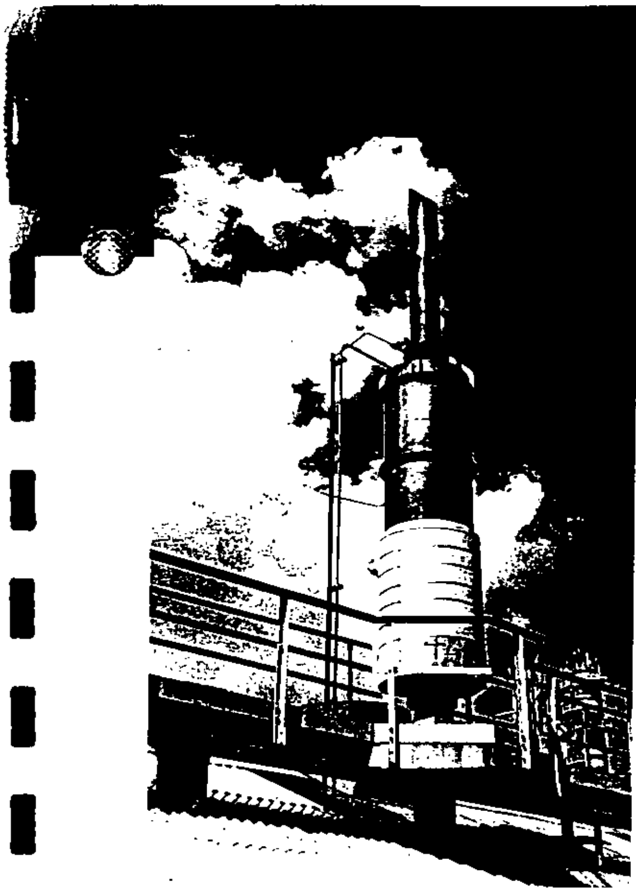
- More Catalyst Contact Surface - than common catalytic converters.
- Velocity Reduction - for more efficient emission conversion and longer cleaning intervals.
- Pulsation Reduction - for longer catalyst life.
- Emissions Reduction - for EPA and other air quality district compliance.
- Noise Reduction - for OSHA compliance.

The DeNOx Silencer is the most practical application of a catalytic converter.

In addition to furnishing catalyst technology that will meet any present or foreseeable federal, state or local emission standards, *HIS* can design the silencer portion of the DeNOx Silencer to local noise regulations in silencing quality of "commercial" to "hospital" grade.



Supreme Chemistry



HIS developed the DeNOx Silencer for Selective Catalytic Reduction (SCR) service which employs ammonia injection with a catalyst, formulated specifically for reduction of NOx and CO to required levels.

Selective Catalytic Reduction - SCR

The DeNOx silencer was originally designed to achieve specific emissions reduction, with stoichiometric or "rich-burn" gas engines. Since 1984, the DeNOx silencer system has evolved to also provide emissions reduction with oxygen-rich exhausts such as lean-burn, clean burn fuel injected two-cycle and four-cycle gas engines, diesel engines and gas turbines.

In areas of severe pollution, federal, state or local agencies may have more stringent control requirements. In these instances, *HIS* can design a DeNOx Silencer for maximum emissions reduction. The DeNOx Silencer employs Selective Catalytic Reduction (SCR) technology for two-cycle and four-cycle lean burn engines in which ammonia is injected ahead of the catalyst. Ammonia slip is controlled to barely detectable levels.

DSOPH - Destroy Smoke, Odor, Particulates, and Hydrocarbons

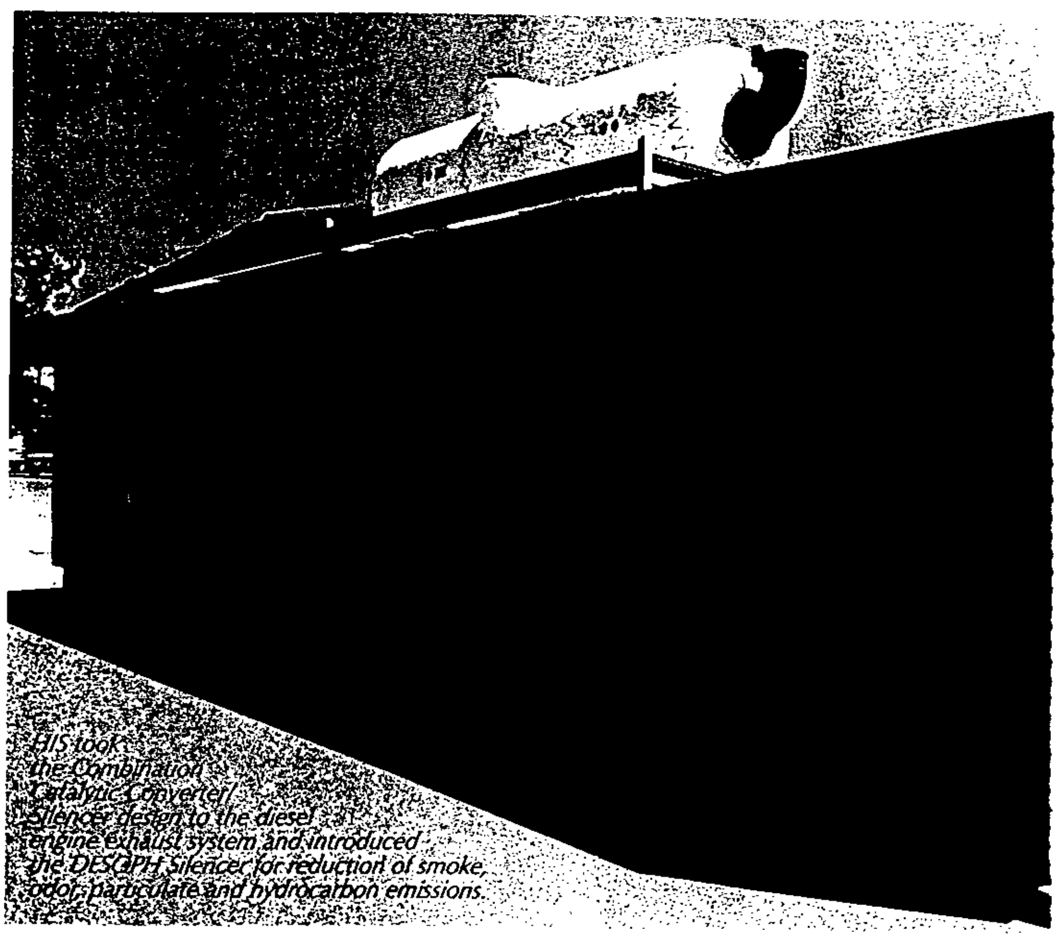
The 1990 Clean Air Act mandated a reduction in sulphur content. The sulphur contributes to acid rain and the black exhaust plume injects larger volumes of particulate into the atmosphere.

The DeNOx Silencer equipped with a cyclonic oxidizing particulate control system can eliminate odor, carbon monoxide and reduce the exhaust plume to a colorless exhaust vapor.

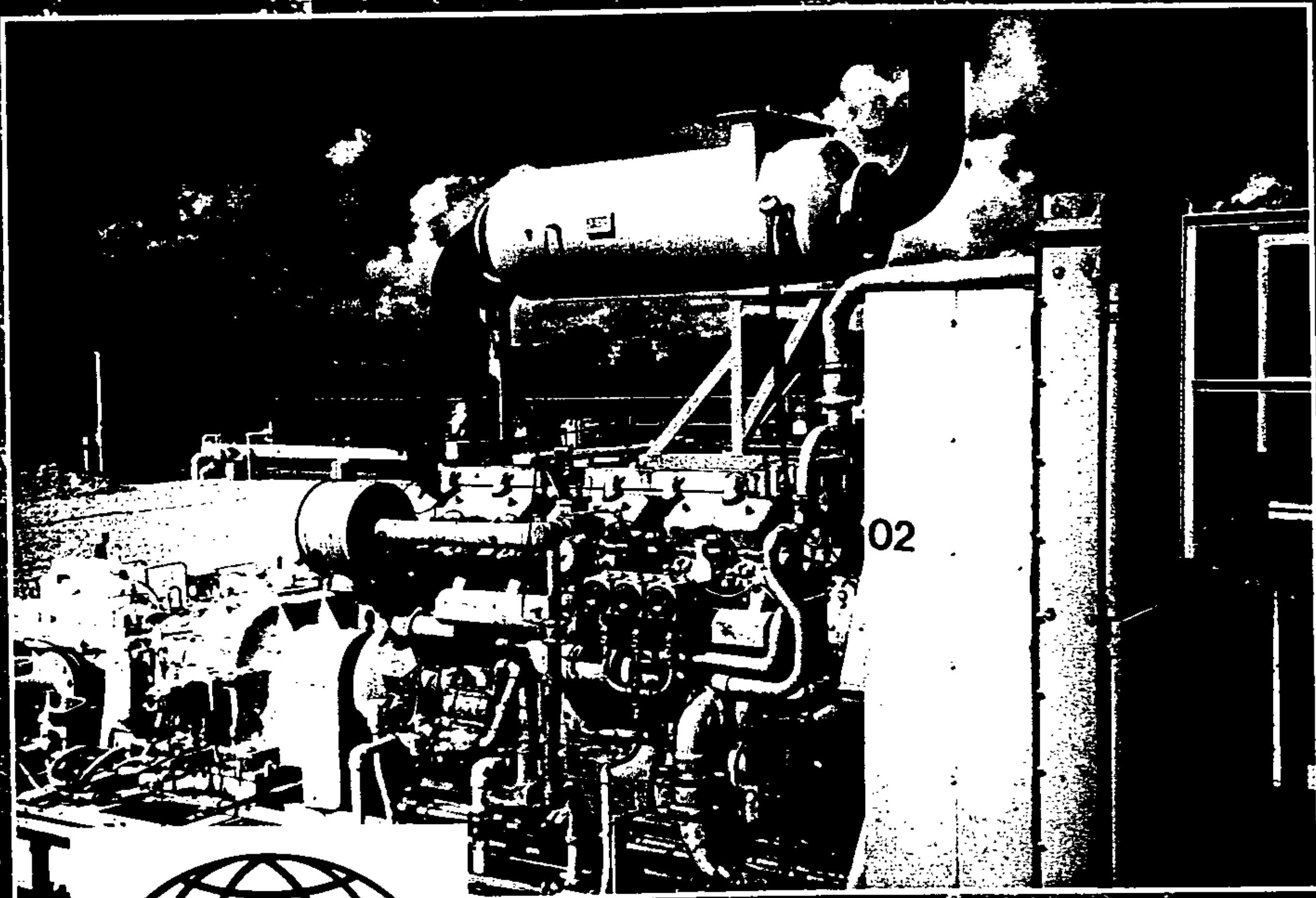
Air Fuel Ratio Controller

For maximum effectiveness, a three-way catalyst must operate in a very narrow "window" that is slightly rich of stoichiometry. An engine can be manually tuned to this condition at a steady load, speed, and ambient temperature, however, if one or more of these parameters varies significantly, as is almost always the case, an automatic air/fuel ratio controller is required.

HIS offers a microprocessor-based air/fuel ratio controller that operates in conjunction with an oxygen sensor (per bank of cylinders) in the engine exhaust to maintain proper exhaust gas composition even under varying load conditions. Lights display "normal" operation, computer activity, and a "check engine" light that warns that the engine is badly out of tune.



HIS took the Combination Catalytic Converter/Silencer design to the diesel engine exhaust system and introduced the DESOPH Silencer for reduction of smoke, odor, particulate and hydrocarbon emissions.



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HIS Emissions Reduction Systems

9837 Whithorn Drive
Houston, Texas 77095

P. O. Box 1639
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281-463-8883
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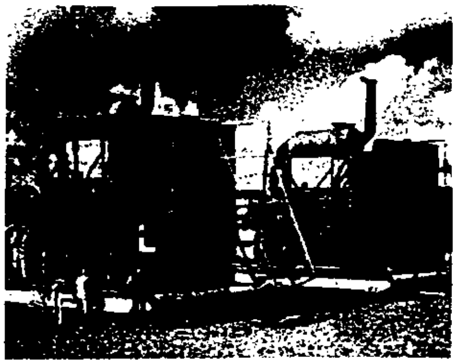
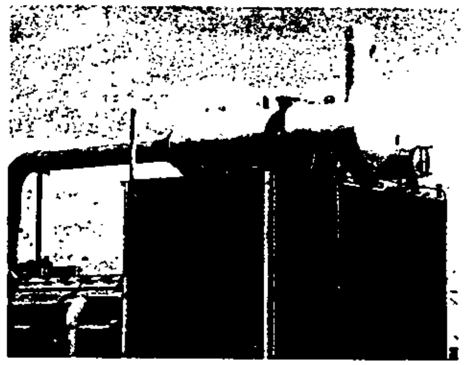
HIS Emissions Reduction Systems

DeNOx Silencer - *The Combination Catalytic Converter/Silencer*





Three Year Performance Guarantee

The DeNOx Silencer, the combined catalytic converter/silencer, as the name implies, is a system, not a commodity. Lower pressure drop, lower velocity, and lower pulsation are the synergy for simultaneous reduction of exhaust emissions and exhaust noise. Engine piping coupled with the companion nozzles from the DeNOx Silencer completes the exhaust system in a "CRAFTED, NOT COBBLED" design.

The velocity control and pulsation reduction ahead of the catalyst assures equal distribution of exhaust gasses across the catalyst face; no channeling, or cold spots.

The stainless steel substrate design gives the catalyst module more contact surface per unit of measure than common catalytic converters. Catalyst design and selection is by precise mass flow calculations and emissions reduction requirements.

The DeNOx Silencer is ideal for original installation, and minimizes pipe fitting and welding time in retrofit installation. Design flexibility allows design freedom to fit most any piping configuration. Use of the DeNOx Silencer in retrofit applications provides a free upgrade to the exhaust system for lower back pressure and more noise reduction.

The DeNOx Silencer provides "Residential" quality silencing as a standard for most engines. While there may be no need for silencing, it is desirable to have the benefits of the "reactive" design of the DeNOx Silencer. The "reactive" design of the DeNOx Silencer defines the dimensions for larger diameter and length based on fluid flow dynamics and acoustics technology. The "reactive" design of the DeNOx Silencer provides the dynamic platform for control of the velocity and exhaust gas pulsation and most importantly, flow distribution, evenly, across the catalyst face.

HIS has adopted the principle of "Absolute Standards" as a commitment to provide the internal combustion engine industry with the highest quality product and the highest catalytic performance at a value added price. *HIS* will not compromise the DeNOx Silencer design with undersized catalysts.

Sound Engineering/Supreme Chemistry HISCORP

9837 Whithorn Drive Houston, TX 77095
(281) 463-8883 FAX (281) 463-8951 E Mail address: HISDNOXSIL@aol.com

HIS Emissions Reduction Systems

Air Fuel Ratio Control:

HIS 88EM Automatic Air Fuel Ratio Controller is microprocessor-based and programmed to govern system balance within the catalyst window and follows load change quickly and efficiently to assure continuous high conversion rate. The controller utilizes advanced design, high technology circuitry and processing, built around an Intel 8088 16 byte processor. The *HIS* 88EM has memory storage over 168 operating hours as a diagnostic assist for compliance assurance monitoring.

The *HIS* 88EM Controller is available for single and dual carburetor engines, and can be 12/24 VDC or 110/120 VAC power. The enclosure is weatherproof, NEMA 4, explosion-proof enclosure optional.

Design Flexibility:

Catalyst portal orientation can be positioned, ergonomically, to reduce effort in removing and installing the catalyst module. Inlet and outlet nozzles can be oriented to reduce the need for pipe fittings and welding time. Flow orientation can be vertical or horizontal.

As a result of backfire or other damage, the *HIS* catalytic converter is the only catalyst module which can be repaired, at a fraction of replacement cost. Other catalytic converters have the potential to expose uncoated, catalyst surfaces or have loss of catalyst from internal rods.

Standard:

Gas sampling couplings
Temperature sensor coupling
Inlet and outlet nozzle size, orientation and location at no cost.
Metallized, flame sprayed aluminum finish.

Optional:

Exhaust stack with appropriate couplings for compliance test.
Support brackets, cradle or Turnnion pins.
Noise control for "HOSPITAL" quality silencing or other specific noise level

Other specific applications:

The DeNOx Silencer is easily adapted to "Clean Burn", "GL" and "Low Emissions" gas engines for oxidation of carbon monoxide and NMHC, aldehydes and HAP.

For lean burn two cycle and four cycle gas engines, the DeNOx Silencer in Selective Catalytic Reduction (SCR) service has exceptionally high performance levels for NOx and CO, in addition to practically no ammonia slip and low pressure drop design.

For a free quotation and evaluation, call us to discuss specific applications at anytime.

9837 Whithorn Drive Houston, TX 77095
(281) 463-8883 FAX (281) 463-8951 E Mail address: HISDNOXSIL@aol.com

New, State-Of-The-Art DeNO$_X$ Silencer With Integral Backfire Port

- Improved flow characteristics — Provide even distribution of exhaust gasses across catalyst face.
- Integral backfire port — protects catalyst from backfire damage.
- "Synergy" of disciplines of fluid flow dynamics, chemistry and acoustics — accounts for high conversion efficiency and better noise environment.
- Catalyst module designed to full diameter of DeNO$_X$ Silencer housing — no catalyst volume lost; maintains maximum conversion efficiency.
- Three-year guarantee — provides assurance of quality, efficient and long-life product.

High velocity exhaust gasses cause maldistribution of flow at the catalyst face leading to frequent cleaning of the catalyst module and ultimately reduces conversion efficiency. *HIS* has improved the flow characteristics within the DeNO$_X$ Silencer to provide an even distribution of exhaust gasses across the catalyst face.

In addition to improving flow dynamics within the DeNO$_X$ Silencer, the catalyst module has been designed to incorporate an "*integral backfire port.*" The "*integral backfire port*" is installed in the center of the catalyst module in the direct path of the pressure wave resulting from the backfire explosion. Improving exhaust flow characteristics within the DeNO$_X$ Silencer resulted in a larger diameter. Design harmony calls for the catalyst module to be the full diameter of the DeNO$_X$ Silencer housing. With the catalyst module at full diameter, no catalyst volume is lost to the "*integral backfire port.*" The "*integral backfire port*" is Intellectual Property and protected by Patent No. 5,921,079.

Managing the disciplines of fluid flow dynamics, chemistry and acoustics in the new generation DeNO$_X$ Silencer is the "*synergy*" that sustains high conversion efficiency and a better noise environment.

Successful adoption of the "*Absolute Standards*" policy has propelled *HIS* to the forefront in the leadership of the catalytic converter industry with technology, performance — and still keeping the "Three Year Guarantee."

Emissions Reduction Systems

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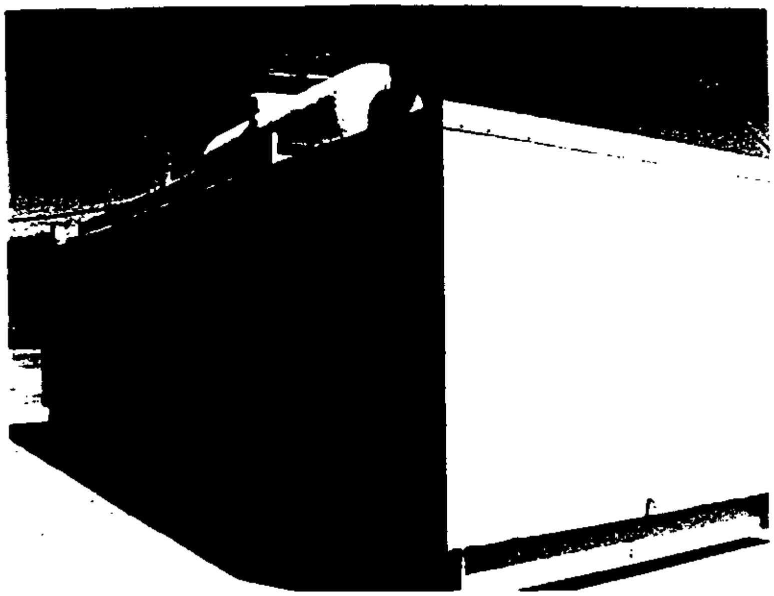
HIS Emissions Reduction Systems

Introduces the DeSOPH Silencer



Destroy
Smoke
Odor
Particulate
Hydrocarbons

"Quietly Cleaning the Air"

HIS takes the combination catalytic converter/silencer design to the diesel engine exhaust system for reduction of smoke, odor, particulate and hydrocarbons emissions.

The product is named the **DeSOPH** Silencer and is of the reactive (multi-chamber) silencer design with "pressure vessel like" construction which incorporates a cyclonic oxidizing particulate control system.

The patented **DeSOPH** Silencer is of low pressure drop design, however the cyclonic oxidizing control system adds pressure drop but stays well with in the engine manufacturers specified limit. Besides, there is no need to impose more back pressure than a well-designed silencer alone.

Catalyst design is directed to the oxygen rich exhaust stream of the diesel engine. The platinum rich or other noble metal formulation is deposited on a stainless steel substrate with vast contact surface and low light off temperature which minimizes visible start up smoke.

The **DeSOPH** Silencer is ideal for original installation as it is a single vessel which minimizes piping fitting and welding time. Where NOx reduction is also required, a Selective Catalytic Reduction system can be added for overall emissions reduction.

Retrofit with the **DeSOPH** Silencer is minimized by direct replacement of the existing muffler and usually provides a no cost upgrade in silencing quality. Silencing quality is tailored to the surrounding environmental requirements. Flexibility in design allows freedom to fit most any piping configuration.

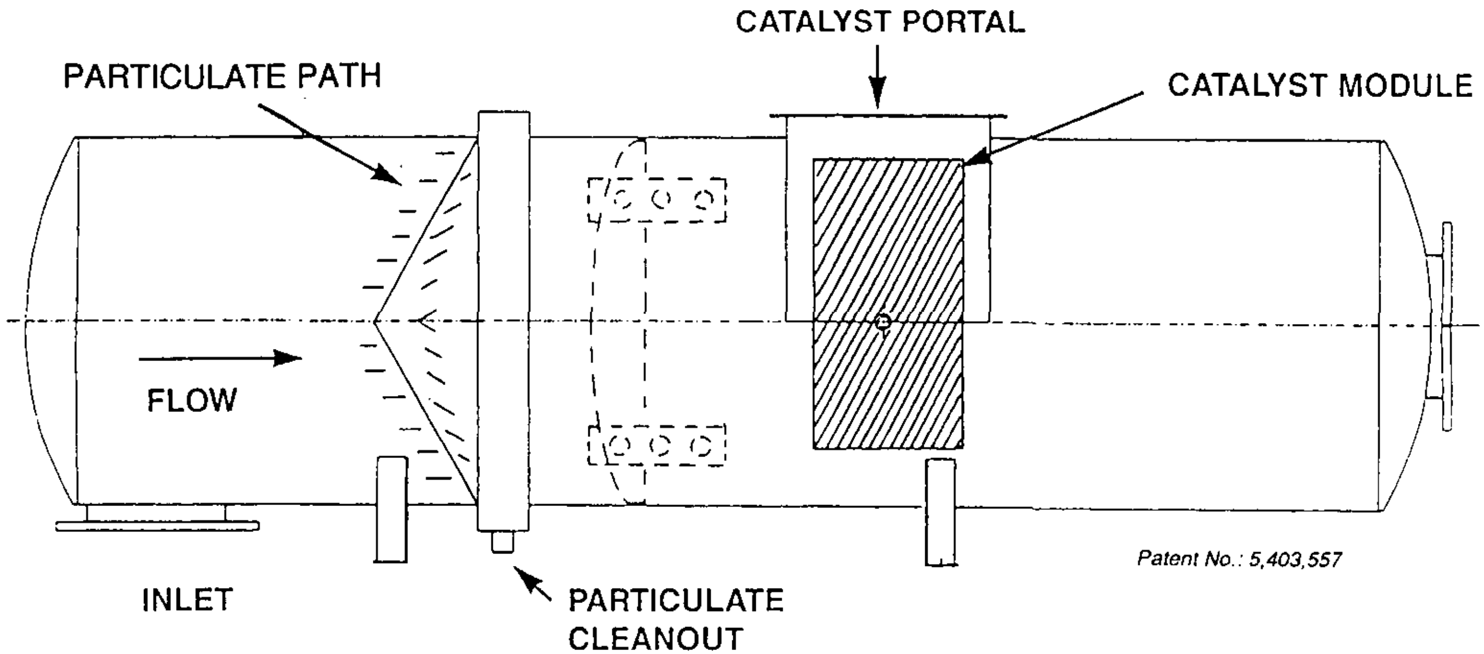
The **DeSOPH** Silencer can be custom designed for specific installations which call for ultimate and immediate performance on start-up. A preheater control is available to keep the catalyst temperature above catalyst light off temperature for instant-on performance.

Exceptional Features:
- -Platinum group metals catalysts
- -Design to noise specifications
- -Long life catalyst
- -Three Year Guarantee
- -Retrofit construction minimized
- -Pressure vessel like construction
- -Metallized finish or stainless steel construction
- -Install vertical or horizontal

HISCORP

9837 Whithorn Drive • Houston, Texas 77095 • 281-463-8883
P.O. Box 1639 • Cypress, Texas 77410 • Fax 281-463-8951

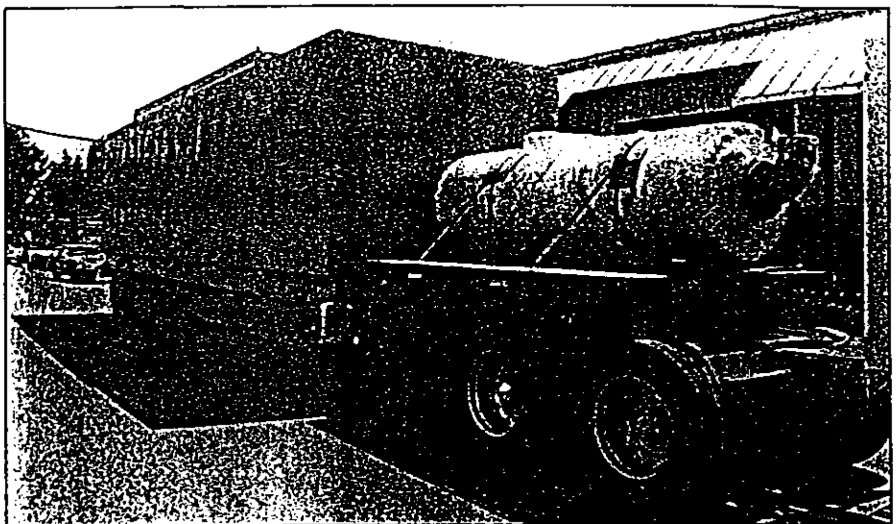
The HIS DeSOPH Silencer



A schematic diagram of the ***HIS DeSOPH*** *silencer. This silencer is a combination silencer and exhaust emissions catalytic control device. It also serves to control smoke, odor and particulates, allowing diesel driven equipment to be environmentally compatible with the surrounding neighborhood.*

Standby Gen-Set Meets Increased Noise, Exhaust Emissions Standards

By Mark McNeely



The 35 ft. long, sound attenuated gen-set enclosure, manufactured for Atlantic Detroit Diesel-Allison by Floyd Manufacturing, is readied for transport. The package also included a Houston Industrial Silencer DeSOP catalytic converter/silencer.

In congested city centers and other urban settings, standby generator sets designed to provide power for emergency building services are often installed on rooftops. In such locations, the impact of noise and exhaust emissions on the general population can be limited and it can be conveniently packaged with other building support systems such as HVAC equipment.

At times, however, back-up gensets must be placed at street level. In these situations, sound attenuation and exhaust treatment strategies become a primary concern because of pedestrian traffic. A case in point is a recent 400 kW standby generator installation by Atlantic Detroit Diesel-Allison, Lodi, N.J., for a communications business complex in White Plains, N.Y.

The gen-set consists of a Detroit Diesel 8V-92TA diesel engine rated 643 hp at 1800 rpm driving a 400 kW Marathon 433RSL7021 synchronous generator with a Marathon DVR 2000 voltage regulator. The unit includes an NFPA 110, level one control panel featuring Frank W. Murphy Mfr. controls. Other components include a Bearward radiator, Nife-Pak 2000 battery charger with Nife SPH 45 NiCad starting batteries and ACE 122G spring vibration isolators.

What began as a fairly standard gen-set installation, changed quickly when local officials required higher sound attenuation and abatement of smoke and odors from the engine. The generator is located in a parking lot area adjacent to office buildings, and public walkways are also within a few feet of the enclosure, according to Trux Mann, vice president of sales for Atlantic DDA.

"We were halfway through with the project when city officials stepped in with some environmental concerns — both with noise and emissions — that were not part of the original specification," said Mann. "The primary concern was with diesel odor, because the exhaust is in close proximity to people and office buildings. This application brings environmental issues to a much higher level for this category of power generation."

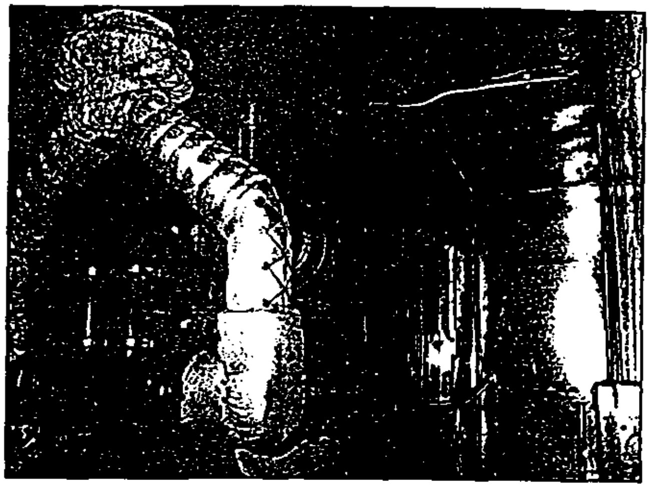
To meet the revised requirements, Atlantic worked with Floyd Manufacturing, Norfolk, Va., to develop an enclosure that would address the noise requirements. The new specifications called for an enclosure length not to exceed 35 ft. and an increased sound reduction to 55 dB(A) at 15 ft. from the enclosure. The original untreated sound level for the unit was 112 dB(A).

"The entire enclosure is sound attenuated, but this also incorporated a special baffle design for the air intake and radiator exhaust areas," said Joe Floyd III, sales manager of Floyd Manufacturing. "In addition, we had to ensure that there would be no airflow restriction once the unit was at full load."

Using a computer-aided design program to create a mock-up of the air flow patterns inside the enclosure, Floyd designed sound baffles with specially engineered angles to knock down the sound in the critical areas. The baffles are constructed of an 8 lb. density attenuating material within a perforated aluminum framework. The aluminum acts to limit heat absorption or retention.

The enclosure also features an architectural sound insulated wall surrounding the gen-set to further isolate noise. The exterior was made of thicker than normal steel for its rigidity and resistance to "drumming" created by sound waves. The composite

continued on page 40



A look inside the enclosure where a Detroit Diesel 8V-92TA engine drives a Marathon generator.

steel I-beam base houses an integral 500 gal. double wall fuel tank that provides an eight hour fuel supply.

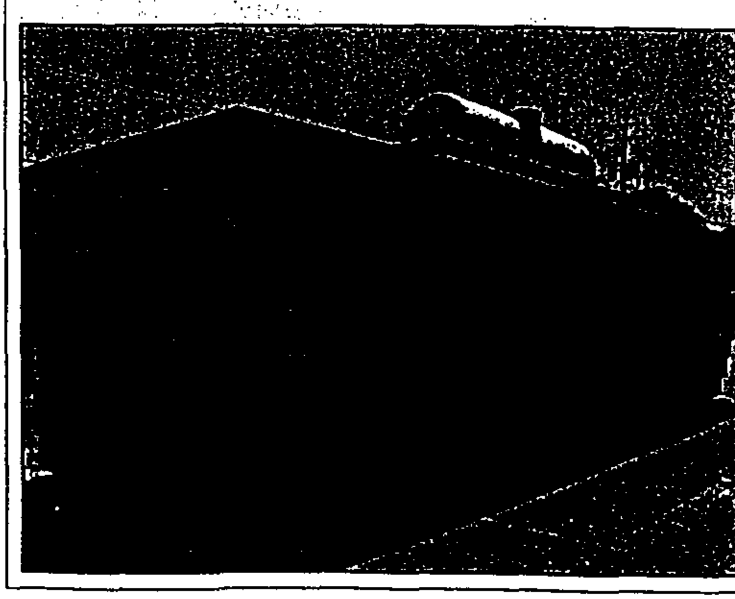
For further sound attenuation and exhaust emissions treatment, the installation was equipped with a DeSOP oxidation silencer from Houston Industrial Silencer Corp. With a sound attenuation rating of 53 dB(A), the silencer incorporates a catalytic converter designed to reduce CO, VOC, SO_2 and particulates in the 80 to 90 percent range, according to Mann. "What results is an exhaust plume that is an opaque, almost transparent white color and odor is virtually eliminated," he said.

Because of the silencer's size — 3 ft. wide x 12 ft. long — special supports were fabricated by Floyd for mounting the unit on the enclosure's roof. A 2 in. thick insulation blanket covers the silencer to retain the heat necessary for catalytic functions.

The final dimensions of the enclosure were 14 ft. high (with silencer), 35.5 ft. long and 10 ft. wide.

Bill Mercer, Atlantic DDA's vice president of engineering, commented, "The typical sound attenuated unit is 80 to 85 dB(A) at 3 to 10 ft. To bring the sound down at least an extra 20 dB(A), you've really gotten into some serious attenuation engineering. And these requirements were especially difficult in terms of the space limitations and the project's overall schedule."

In addition to this unit, Atlantic DDA previously installed a 1000 kW backup power unit, using a Detroit Diesel 12V-149, inside another building at the same site. The complex of office buildings also utilizes Cooper-Superior and EMD generator sets. ★



The gen-set package as installed at a communications complex in New York. The unit was designed for low noise and exhaust emissions because of its proximity to pedestrian traffic.

HIS Emissions Reduction Systems

Selective Catalytic Reduction System

High Efficiency NOx Conversion
Low Ammonia Slip
Extremely Low Maintenance

"Lean Burn" two-cycle and four-cycle natural gas fueled engines and liquid fueled diesel engines operate with exhaust oxygen greater than 8% by volume. *HIS* has developed the DeNOx Silencer for Selective Catalytic Reduction (*SCR*) service. This *SCR* process employs ammonia injection with a catalyst formulated specifically for reduction of NOx and CO to required levels.

The selection of catalyst is determined by operating exhaust gas mass flow, temperature and composition. Each engine is evaluated for untreated emissions levels, and the usage of each engine is considered in the design of the entire *SCR* System. Heat recovery and steam production are also available as optional equipment. The *HIS* DeNOx Silencer design meets all installation requirements. Direct replacement of the existing silencer minimizes retrofit costs and simplifies piping in new engine installations.

The outstanding feature of this catalyst application (and the others mentioned here) is that there is virtually no slip of ammonia to atmosphere. At operating conditions (temperature), the ammonia will be consumed in the catalyst. Hence, elaborate ammonia control and monitoring are not necessary.

Ammonia slip to atmosphere is limited to 3ppm to 5ppm. The proper reaction between the injected ammonia and the exhaust gases will only produce high conversion rates if the reaction components make direct contact with the vast catalyst surface area. Catalyst substrate is of a honeycomb structure, coated with the base vanadium and other reactive elements which are used in order to provide the most active surface areas, and ensure a low pressure drop and lowest possible operating costs. The active catalyst elements are fitted to a stainless steel support by means of a fusion bonded method in the manufacturing process.

To achieve the best possible reduction of emissions, it is extremely important that a uniform reaction temperature, and a constant residence time of the exhaust on the catalyst, be maintained. The pulsation damping effect of the DeNOx Silencer provides this stable atmosphere.

Ammonia, in either aqueous or anhydrous form, may be used in the injection process. Aqueous ammonia must be injected in a distilled water stream. Anhydrous ammonia can be mixed with air or stream to reach exhaust flow or vaporized directly in the exhaust stream. The aqua ammonia solution of 75% deionized water to 25% ammonia keeps the solution from the hazardous material handling requirements.

NOx reduction by more than 80% has been experienced over a two year period of continuous maintenance free operation on a natural gas fuel spark ignited two-cycle engine. Carbon monoxide reduction is greater that 80% and ammonia slip to atmosphere has never exceeded 10ppm when NO_x reduction is at the level of 75ppm. This outstanding performance can be duplicated for your emissions reduction requirements.

We would be happy to discuss this equipment with you at any time.

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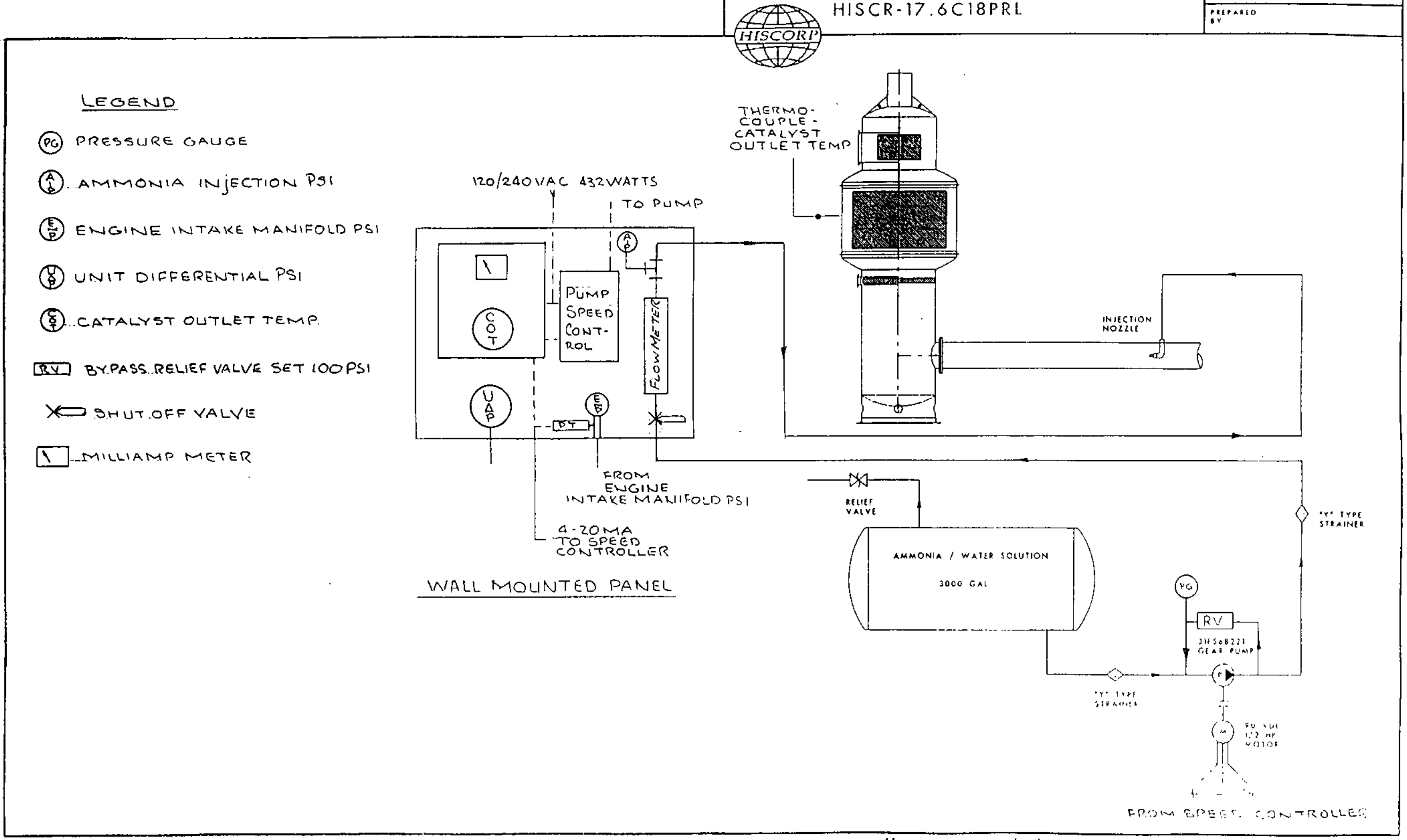
AMMONIA CONTROL SYSTEM FOR DeNOx SILENCER MODEL HISCR-17.6C18PRL

DATE	
REFERENCE	
PREPARED BY	



Selective Catalytic Reduction System

System Exhibits High Efficiency No_X Conversion, Low Ammonia Slip, Extremely Low Maintenance

Clean Burn two-cycle and four-cycle natural gas-fueled engines and liquid-fueled diesel engines operate with exhaust oxygen greater than eight percent by volume. Because these engines often need additional exhaust treatment to bring them into compliance with environmental regulations, Houston Industrial Silencing (HIS) of Houston, Texas, has developed the DeNOx Silencer for Selective Catalytic Reduction (SCR) service. This SCR process employs ammonia injection with a catalytic formulated specifically for reduction of NO_X and CO to required levels.

The selection of catalyst is determined by operating exhaust gas mass flow, temperature and exhaust composition. Each engine is evaluated for untreated emissions levels, and the usage of each engine is considered in the design of the entire SCR System. Heat recovery and steam production are also available as optional equipment. The HIS DeNOx Silencer design meets all installation requirements. Direct replacement of the existing silencer minimizes retrofit costs and simplifies piping in new engine installations.

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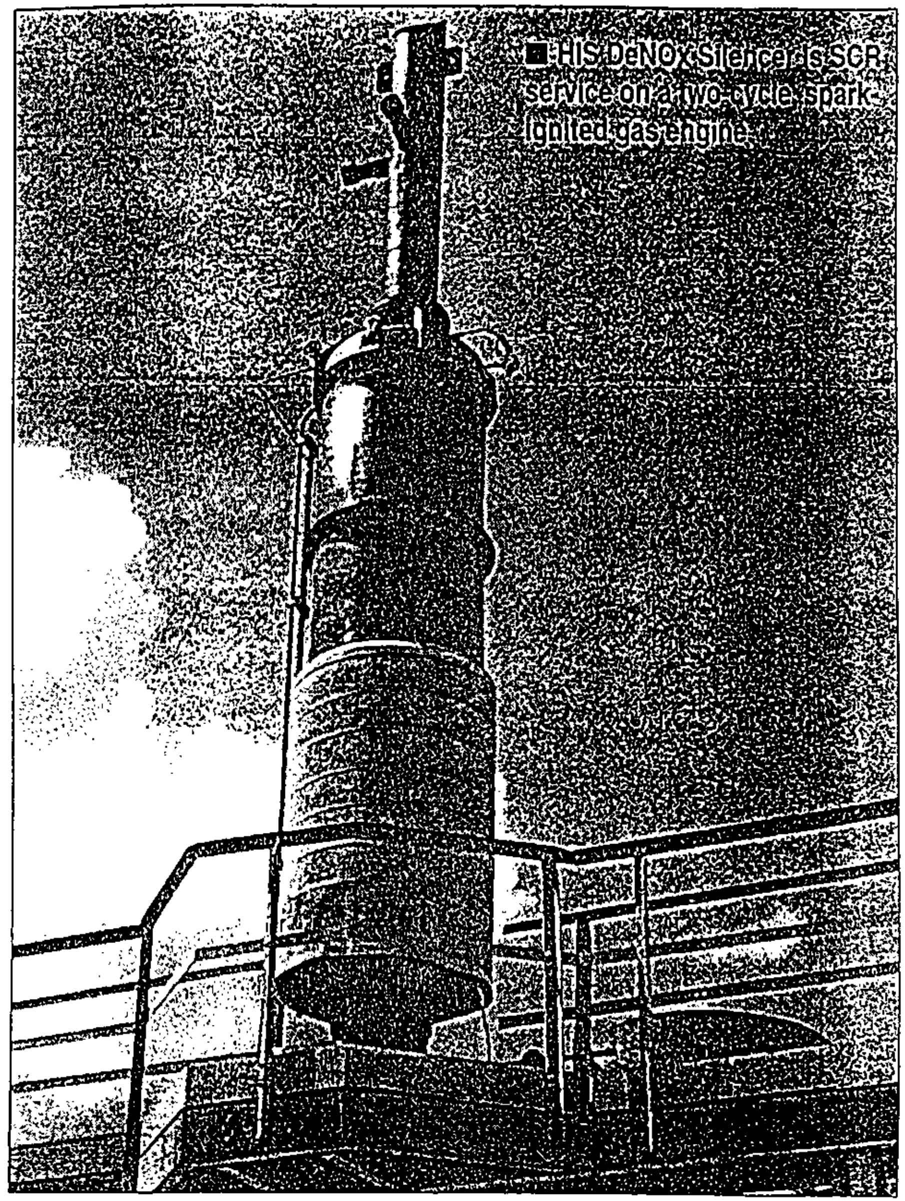

■ HIS DeNOx Silencer is SCR service on a two-cycle spark-ignited gas engine.

monitoring are not necessary.

Ammonia slip to atmosphere is limited to three to five ppm. The proper reaction between the injected ammonia and the exhaust gases will only produce high conversion rates if the reaction components make direct contact with the vast catalyst surface area. Catalyst substrate is a honeycomb structure, coated with the base vanadia and other reactive elements which are used in order to provide the most active surface areas, and ensure a low pressure drop and lowest possible operating costs. The active catalyst elements are fitted to a stainless steel support by means of a fusion bonded method in the manufacturing process.

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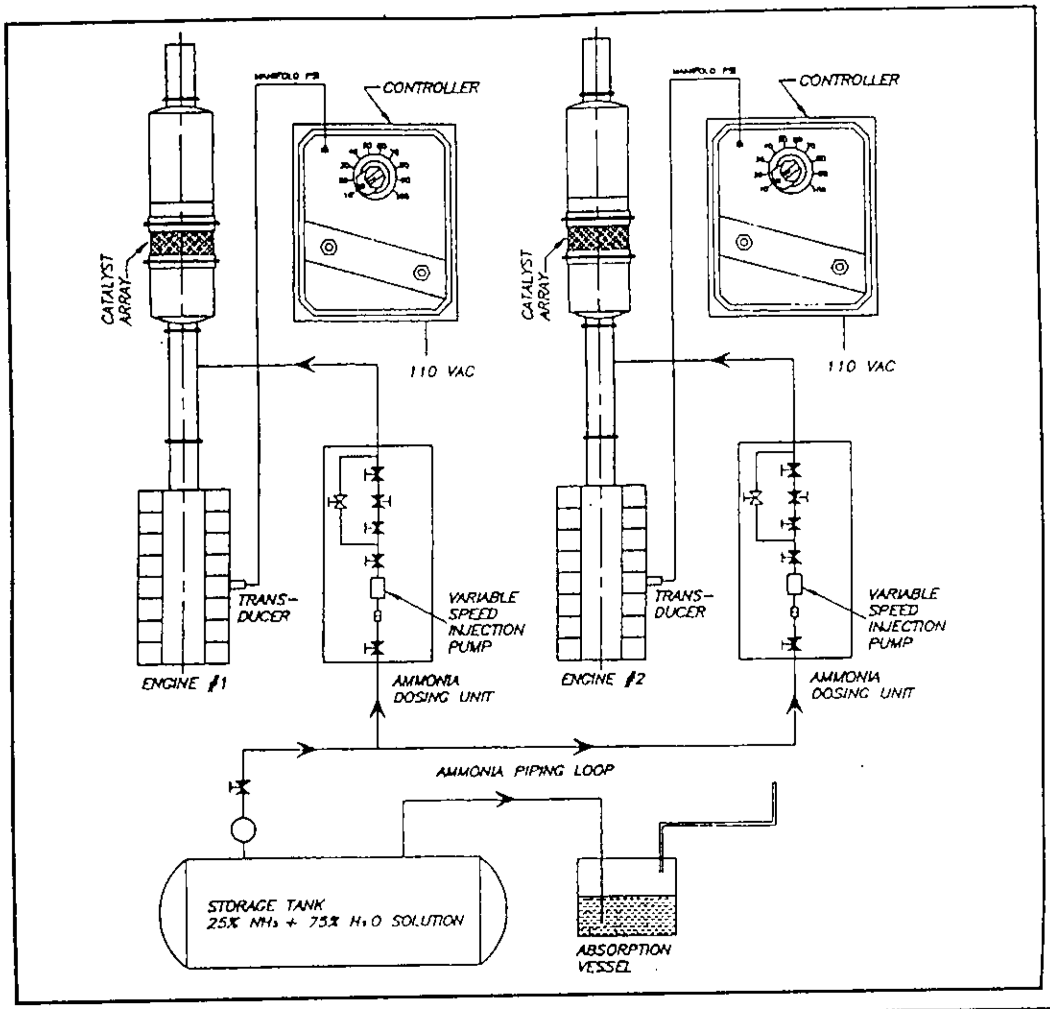
Ammonia, in either aqueous or anhydrous form, may be used in the injection process. Aqueous ammonia must be injected in a distilled water stream. Anhydrous ammonia can be mixed with air or stream to reach the exhaust flow or vaporized directly in the exhaust stream. The aqua ammonia solution of 75% deionized water to 25% ammonia keeps the solution from hazardous materials handling requirements.

NO_x reduction by more than 80% has been experienced over a two year period of continuous maintenance-free operation on a natural gas-fueled, spark-ignited, two-cycle engine. Carbon monoxide reduction is greater than 80% and ammonia slip to atmosphere has never exceeded 10 ppm when NO_x reduction is at the level of 75 ppm. This performance can be duplicated for virtually all emissions reduction requirements. ■

CIRCLE 94 ON READER SERVICE CARD



■ Schematic diagram of the HISCR Series DeNOx Silencer selective catalytic reduction system.

HIS Emissions Reduction Systems

The *HIS* Model 88EM Automatic Air/Fuel Ratio Controller

The *HIS* 88EM Automatic Air Fuel Ratio Controller is microprocessor-based and programmed to govern (fuel to air) system balance within the catalyst window and track load change automatically and efficiently. Efficient tracking of the 88EM Controller assures continuous high catalytic conversion rate for NOx, CO and NMHC, to meet the most stringent emissions requirements. This Controller is available for single and dual carburetor engines and can be powered with either 12/24 VDC or 120 VAC power. A number of interface options are available.

All air/fuel ratio controllers used with stoichiometric SI natural gas engines, normally or TC aspirated are oxygen sensor driven in closed loop sampling circuitry. With the *HIS* 88EM Controller oxygen sensor voltage is sampled many times per second to assure fast response to speed and load change which keeps exhaust emissions in compliance. All modern day air fuel controllers respond automatically to engine speed and load change.

The *HIS* 88EM Controller with the total fuel control method is the most recognized style of air fuel ratio control. The *HIS* total fuel control method utilizes a heavy duty modulating valve (Model FMV-15) with wide range resolution to control fuel flow to the engine and provide precise combustion control.

The *HIS* 88EM Controller can be used with either the supplemental "trim-in" fuel method or the total fuel flow control method. The "trim-in" fuel method utilizes a rotary metering valve to introduce the supplemental fuel to the air horn or intake manifold or ahead of the mixing valve, as in the low fuel pressure systems used on many late model engines.

With either method, "trim-in" or total fuel control, the controller can handle a load swing between forty (40) percent to one hundred (100) percent with corresponding engine torque. The fuel flow to combustion air flow is a delicate balance totally dependent on controller response when tracking engine load change.

HIS has had memory storage available for diagnostic and trending since 1983, and now that emissions regulations are more strict and leaning toward compliance assurance monitoring, this feature will prove invaluable. Sensor voltage, over time when analyzed after downloading, will indicate controller response to load change, ambient temperature change, intermittent and consistent misfire and ultimately sensor aging. This memory bank is collected from a precatalyst location. Controller response to load change and ambient temperature change including variations in fuel quality is absolutely essential to precise combustion control for engine produced exhaust gas composition compatible with optimum catalyst conversion rate. Outlet oxygen level should be zero (0) or maximum one one hundredth to two one hundredths volume percent with normal engine operation.

We would be happy to discuss the equipment with you at any time.

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HIS 88EM SERIES AIR/FUEL RATIO CONTROLLER

SYSTEM DESCRIPTION
The HIS 88EM Automatic Air/Fuel Ratio Controller is microprocessor based, utilizing advanced design, high technology circuitry and processing, built around an Intel 8088 16 byte processor.

The controller continuously monitors exhaust oxygen content and automatically activates the butterfly valve(s), adjusting the fuel flow to the carburetor(s) to maintain air/fuel ratio that will maximize converter performance and track engine load change quickly and efficiently. The HIS 88EM is unique in its simplicity. It requires no maintenance and, after calibration and set up, there are no internal field adjustments required.

The HIS 88EM Series Automatic Air/Fuel Ratio Controller is available in the following power supplies:

Model 88EM-A1-M - 110/120 VAC - Single Carburetor Engine or Inline Cylinders
Model 88EM-A2-M - 110/120VAC - Dual Carburetor Engines or V-Type Engines
Model 88EM-A1-M - 12/24VDC - Single Carburetor Engines or Inline Cylinders
Model 88EM-A2-M - 12/24VDC - Dual Carburetor Engines or V-Type Engines

SYSTEM COMPONENTS
Enclosure - Nema 4
Butterfly Valve - Single (1), Dual (2)
O_2 Sensor - Single (1), Dual (2)
Sensor Cable w/conn. - Single (25'), Dual (50')

SPECIFICATIONS
Enclosures:
-Nema 4, weatherproof enclosure with hinged door
-Class 1, Group D, Div. 2 - Electrical

Control Electronics:
- All solid state low power microprocessor. 24K Byte RAM, 8K Byte EPROM, 8 Byte resolution A/D converter input, 8 Byte D/A converter output.

Utility Requirements:

-110/120 VAC or 12/24 VDC

Inputs:
-Analog to digital 0-5VDC, 4-20 Special ma DC. normal 2 inputs max.

Outputs:
-0-5 VDC.

Options:
-Serial communication, advanced operator interface, data logging capabilities, customized software. Explosion-proof enclosures. Added A/D inputs, D/A outputs available.

HIS Emissions Reduction Systems

Prospectus for the DeNOx Silencer Operating with The Natural Gas, Spark Ignited Engine

In 1980, *HIS* began the design and development of a combination catalytic converter silencer for use with gas engines and called it "The DeNOx Silencer." The silencer is a reactive design with multiple chambers. It was obvious that the catalyst module should be located in a second quiescent chamber removed from intense pulsation and where lower velocity exhaust gasses are evenly distributed across the catalyst face. The DeNOx Silencer design was awarded Patent No. 4,601,168 in 1986, and was the first catalytic converter/silencer combination with a metallic converter module. The DeNOx Silencer was the first technological design breakthrough in catalytic converter application since the late 1960's.

The catalytic converter, in a simple housing, was first used in the mid 1960's, in California on automobile engines. The present day automotive catalytic converter has a short conical inlet and short conical outlet. That same short entrance and exit configuration exists today in the catalytic converter housings manufactured by competitive brands.

The first catalytic converter was used on a natural gas engine/compressor package around 1976. As mentioned, the catalytic converter and housing configuration has not changed much since 1976, except to go from a square/rectangular shape to a round shape.

With the 1970 Clean Air Act and local regulation of exhaust emissions, the use of a catalytic converter meant another piece was added to the engine exhaust in company with the muffler. Some people claimed that no muffler was needed when a catalytic converter was used. Those early converters were square or rectangular and the catalyst substrate was ceramic. The short conical entrance and exit configuration has not changed. One can recognize what exhaust gas pulsation and engine backfire did to ceramic, reduce it to gravel.

There has been a great deal of research and technology applied to the carrier (substrate) of the catalyst formulation beginning with the original pellet type and the present day metallic honeycomb. Laboratory and field research continues in the effort to improve conversion efficiency and reduce costs outside of the (commodity) market swings for platinum, palladium and rhodium. There has been no technological breakthrough in three-way catalyst formulation since the early 1960's or even earlier. So where is improvement coming from except in the catalyst module design and it's placement in the silencer housing.

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Research has centered on two areas relating to engine exhaust dynamics, gas distribution at the catalyst face and exhaust gas pulsation. Distribution of exhaust gasses at the catalyst face has gathered more attention in the effect to improve performance because of the more strict regulations to reduce emissions from automobiles.

In the industrial engine, cylinder bore and stroke are larger and RPM slower (than automotive engines) contributing to higher levels of exhaust gas pulsation particularly in higher horsepower engines. The pulsation dynamic alone calls for a larger diameter housing to control pulsation intensity.

The industrial catalytic converter module suffers the same mal-distribution of gasses across the face as the automotive converter. Because of the larger cross-sectional area of the industrial converter module, exhaust gas pulsation can be damaging to the module. Exhaust gas pulsation has the energy to move the catalyst module against opposing support members, thus breaking the sealing surfaces to cause bypass.

The natural progress of product development produced the latest technological design breakthrough in the new and larger DeNOx Silencer (for the New Millennium) which incorporates the "Integral Backfire Port" built into the catalyst module. The "Integral Backfire Port" in the center of the catalyst module is a spring-loaded port or rupture disc designed to reduce backfire damage to the catalyst module.

No catalyst volume is lost to the "Integral Backfire Port". The larger diameter housing benefits both exhaust gas pulsation and velocity reduction for uniform distribution of exhaust gasses to the catalyst face. Additionally, the larger diameter of the silencer housing provides better silencing qualities for the DeNOx Silencer even at the

commercial level. This new *HIS* DeNOx Silencer design innovation and the "Integral Backfire Port" is Intellectual Property and is a patented product. The cost of the increased diameter of the DeNOx Silencer housing to accommodate the full (shell) diameter of the catalyst module is small considering the added benefit.

Engine backfire severely damages or destroys catalytic converter modules. Until recently, backfire ports were external to the converter module and located in the exhaust pipe or in the converter housing. When engine backfire occurs, the peak explosion reaches 100 psi, is less than two tenths of a second and the pressure wave travels at sonic velocity to atmosphere. With the pressure wave at sonic velocity, an external backfire port cannot react quickly enough to relieve the pressure before

reaching the catalyst module. At peak explosive pressure of 100 psi, a 24 inch diameter catalyst module is subjected to a force of over 45,000 pounds impact at sonic velocity. It is doubtful that a converter module can withstand that impact pressure without damage or destruction.

It is evident, recognizing exhaust flow dynamics, the effects of exhaust gas pulsation and mal-distributed flow to the catalyst module, that the catalytic converter can not be a commodity product. There is no advantage at this point in time to use a simple catalytic converter in a simple housing plus a typical exhaust silencer considering the advantages of the combination catalytic converter silencer.

HIS experience is derived from over thirty years in the silencing industry with engine exhaust and compressor pulsation equipment. The distinction between engine exhaust and compressor pulsation is that exhaust gas pulsation results in audible noise while compressor piping results in suction and discharge piping vibration.

The engine exhaust with the flow dynamics of exhaust gas pulsation, velocity and temperature are essentials which must be recognized to build an efficient exhaust system. The engine builder designs the exhaust manifold to collect the exhaust gasses and allow passage to atmosphere at low pressure loss for proper engine scavenging. The Emissions reduction system must be compatible with the specific engine character.

The wide range of engine horsepower, RPM and the number of engine families call for custom engineered emissions reduction systems. The standard "off the shelf products", the pre-selected sizes of catalyst modules and commodity standardization of catalyst modules and housings, leave room for undersize or marginal sizing of the catalytic system. The *HIS* DeNOx Silencer customized for the specific engine operation and emissions requirements and the *HIS "Absolute Standards"* policy leaves no room for undersize or even marginal size.

HIS began in-house manufacture of catalyst modules over five years ago in order to provide infinite sizes of catalyst modules to fit the exacting requirements of emissions reduction, exhaust mass flow and temperature specific to each engine.

The DeNOx Silencer has been adapted to oxidation service and called the DeCOHx Silencer for operation with lean/clean burn gas engines where CO, VOC and aldehydes are effectively reduced.

For diesel engines, the DeNOx Silencer utilizes the Selective Catalytic Reduction process for NOx, CO and VOC reduction. Where NOx reduction is not required, the DeSOPH Silencer is used for reduction of Soot, Odor, Particulates and Hydrocarbons.

The point to be made is the highly favorable cost benefit ratio of the DeNOx Silencer designed to the specific engine character to the "commodity-ized" catalytic converter module installed in a "commodity-ized" exhaust silencer.

The advantages described here are those that set *HIS* apart from competition and have contributed to the success of *HIS* emissions reduction products.

The American Society of Mechanical Engineers

Reprinted From
Proceedings of the First International Pipeline Conference
Editors: M. Yoon, M. Mensik, and M. Mohitpour
Book No. H1048B – 1996

CONTROL OF INDUSTRIAL ENGINE AND GAS TURBINE EXHAUST EMISSIONS TO MEET PRESENT AND FUTURE CLEAN AIR REGULATIONS

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and
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HOUSTON INDUSTRIAL SILENCING
Emissions Reduction Systems Division
Houston, Texas

ABSTRACT

Increasingly stringent regulations by the EPA and state air quality agencies in the U.S., as well as new regulations by Environment Canada, are making the reduction of exhaust emissions from industrial engines and gas turbines ever more important for their operators. Not only are these regulations getting increasingly strict with time, but there will be both substantial fines and possible criminal penalties for non-compliance in the future.

This presentation describes how harmful exhaust emissions are formed during the combustion process, what the current regulations are in various areas of North America and where they are probably headed in the foreseeable future. It then discusses possible emission reduction strategies in two broad categories, combustion modification and post-combustion treatment, using catalytic converters.

The three types of catalyst substrates are discussed, with the advantages and disadvantages of each, as well as the relative advantages and disadvantages of the four possible catalyst locations.

HOW ENGINE EXHAUST EMISSIONS ARE FORMED

When combustion takes place in a confined space under pressure, such as in the combustion chamber of a reciprocating engine or gas turbine, the resulting pressure and temperature cause some reactions which create compounds that have been judged to be harmful to the environment. Under high temperature, high pressure combustion (Fig.1) some of the nitrogen in the air combines with oxygen and creates oxides of nitrogen, principally NO and NO_2, which are commonly referred to as NO_x. Also, some of the carbon in the hydrocarbons does not completely oxidize and forms carbon monoxide (CO). In addition, some of the fuel does not completely oxidize and carries through in an unburned state. These unburned hydrocarbons are sometimes referred to as volatile organic compounds (VOC), reactive organic gasses (ROG), or non-methane hydrocarbons (NMHC) by various regulatory agencies. They all mean essentially the same thing and, for simplicity, will be referred to in this presentation as C_xH_y.

It has been determined that NO_x assists in the formation of ozone, which is toxic, as is CO, and C_xH_y is a factor in the creation of smog. As a result, the Environmental Protection Agency (EPA) and Environment Canada have mandated that all three of these exhaust emissions must be reduced if we are to enjoy an improved environment.

EMISSIONS REGULATIONS

In the Clean Air Act Amendments of 1990, the United States was divided into attainment areas and non-attainment areas by the EPA. The emission requirements are stricter in the the non-attainment areas. These regulations are rather complicated and vary from state to state, but, in general, in the attainment areas exhaust emissions are required to meet the following values for engines of 500 horsepower and above:

NO_x	2.0 gms/bhp/hr
CO	3.0 gms/bhp/hr
C_xH_y	1.0 gms/bhp/hr

In the non-attainment areas, the levels are the same except that they apply to engines of 150 horsepower and above.

In the South Coast Air Quality Management District (SCAQMD) of southern California, the requirements are somewhat stricter, and apply to engines of 50 horsepower and above, as follows:

	1994	1995
NO_x	0.30 gms/bhp/hr	0.15 gms/bhp/hr
CO	0.50 gms/bhp/hr	0.50 gms/bhp/hr
C_xH_y	0.60 gms/bhp/hr	0.30 gms/bhp/hr

In 1995 the SCAQMD reduced the allowable NOx and C_xH_y values to half those previously allowed.

Some jurisdictions limit tons per year, rather than grams per horsepower hour. There has been a trend in the heavily populated northeastern portion of the United States to tighten the restrictions to somewhat more stringent than the rest of the country.

Environment Canada issued a guideline in 1994 calling for the following exhaust emissions for gas engines of 600kW or greater:

NO_x	6.0 gms/kW/hr
CO	3.5 gms/kW/hr
C_xH_y	2.0 gms/kW/hr

The regulations for gas turbines are a moving target at present, due to the rapid advances being made in NOx control by the turbine manufacturers. These technologies will be covered later in this presentation. Environment Canada has an innovative approach in this area in that they have a higher allowance for turbines that have waste heat recovery, to account for the fact that this saves the pollution from additional fuel being burned elsewhere.

It is evident that as various governmental bodies become more environmentally aware, there are going to be increasing restrictions on exhaust emissions. It is important for an engine or turbine operator to look ahead and select a reduction scheme that not only meets present requirements, but is capable of being upgraded to meet more stringent future regulations.

EMISSIONS REDUCTION STRATEGIES

Reduction of exhaust emissions falls into one of two basic categories, the first being internal modifications to reduce the formation of emissions during the combustion process and the second is post-combustion treatment, which involves the use of catalytic converters in the exhaust. Following is a listing of the various types of gas and diesel engines, as well as gas turbines, and the applicable reduction strategies for each.

RICH BURN (STOICHIOMETRIC) GAS ENGINES

Non Selective (Three Way) Catalytic Converters.

The basic and most widely used catalytic converter technology is the three way catalytic converter, which simultaneously reduces NO_x, CO, and C_xH_y. A three way catalytic converter requires that the air/fuel ratio be slightly rich of stoichiometric, where the quantity of CO and NO_x are equal, (Fig.1). The CO acts as a reducing agent for the NO_x in the following reaction:

$$NO_x + CO \text{ -------> } N_2 + CO_2$$

The small amount of oxygen remaining in the exhaust oxidizes the C_xH_y in the following reaction:

$$C_xH_y + O_2 \text{ ------> } CO_2 + H_2O$$

N_2, CO_2 and H_2O are all non-toxic. This is a very simple and cost effective emission reduction strategy and is used on all automotive gasoline, propane and CNG fueled engines being built today.

Two Stage Catalytic Converters

In southern California, and other critical areas, the emission reduction requirements are somewhat more stringent than can be met with a standard three way catalytic converter. In these instances a two stage catalytic converter is employed, in which a larger first catalyst is used, for a more thorough conversion of the NO_x, producing the following reaction:

$$NO_x + CO \text{ -----> } N_2 + CO_2 + CO \text{ (excess)}$$

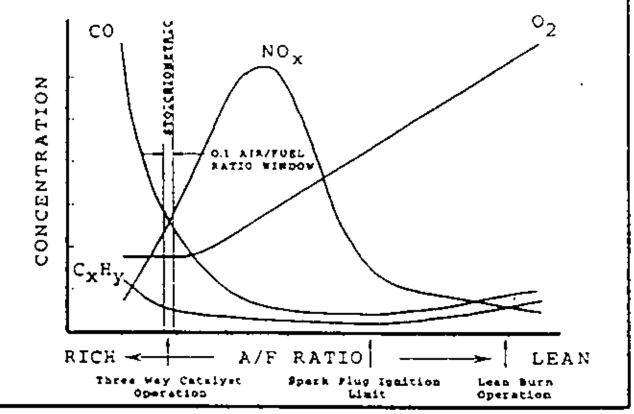
Air is sometimes introduced down stream of this catalyst to provide a leaner mixture going into a second oxidation catalyst producing the following reaction:

$$CO + C_xH_y + O_2 \text{ -----> } CO_2 + H_2O$$

Because of the two catalysts required, this is more expensive than a three way catalytic converter, but will produce emissions reductions that meet all current and foreseeable future requirements. Also, it's possible to design a catalytic converter to initially employ a three way catalyst, with space available for the later addition of a second catalyst, should it be necessary to meet a somewhat stricter emission requirement in the future.

EMISSIONS VS. AIR/FUEL RATIO

FIG. 1



Air/Fuel Ratio Controller

Exhaust emission control of rich burn gas engines is dependent on an engine air/fuel ratio that maintains equal quantities of NO_x and CO (Fig.1). Under steady state operating conditions the engine can be adjusted to the proper air/fuel ratio manually, however as conditions change the air/fuel ratio deviates from the manual set point. This can be caused by a change in the fuel composition, engine load, speed or ambient air temperature. A normal carburetor cannot hold a constant air/fuel ratio under these changing conditions. For this reason, best conversion efficiency can only be achieved with an automatic air/fuel ratio controller.

Air/fuel ratio controllers are driven by an oxygen sensor installed in the exhaust stream of the engine, upstream of the catalyst. This sensor sends an electrical signal to a computer in the controller. This signal varies from 0 millivolts at full lean to 1,000 millivolts at full rich, with the ideal set point for a three way catalytic converter being somewhere in the neighborhood of 700 to 800 millivolts, as determined by exhaust gas analysis. The computer then either varies the fuel flow or pressure to the carburetor, or adds trim fuel, to maintain the proper air/fuel ratio.

TWO-CYCLE AND LEAN BURN FOUR-CYCLE GAS ENGINES

In general, gas engines that run with an extremely lean air/fuel ratio produce lower emissions than engines that run at a stoichiometric mixture, in which the fuel and air are theoretically correct for complete combustion (Fig.1). This is true for both lean burn four-cycle gas engines and two-cycle gas engines, which cannot be run stoichiometrically and always have some excess oxygen in the exhaust due to the scavenging air required. The additional air in lean operation causes more thorough combustion of the fuel, thereby reducing the levels of CO and C_xH_y in the exhaust, up to a point. The cooler combustion also reduces the formation of NO_x as well, but as the mixture becomes very lean, the CO and C_xH_y begin to increase again, due to the cooler combustion. In order to reach the low emissions produced by these engines, the excess air causes the air/fuel ratio to exceed the lean ignition limit by a normal spark plug and it has to be ignited by some other means. There are several strategies for doing this, as follows:

1. The cylinder head can be manufactured with a pre-chamber combustor, which contains the spark plug. Additional fuel is introduced into this chamber to enrich the mixture to near stoichiometric. The spark plug then ignites this richer mixture, sending a flame into the combustion chamber to ignite the lean mixture there.

2. There are after market pre-chambers available that are designed to screw into the existing spark plug hole, to save the expense of purchasing new heads when converting an older engine to lean burn.

3. Ignition systems have recently been introduced which produce multiple sparks over several degrees of crank angle to improve the ignition of lean mixtures.

4. "Plasma" ignition systems have recently come on the market which produce a hot, long duration, arc at the electrodes for improved ignition of lean mixtures.

Excess Air for Lean Burn Engines

In addition to more reliable ignition for lean mixtures, lean burn engines also require substantially more air than rich burn (stoichiometric) engines. There are several strategies for providing this additional air, as follows:

1. New Engines - All new lean burn engines are turbocharged and are designed with high capacity turbochargers which provide excess air over and above normal requirements. In addition, these engines are generally built with the pre-chamber ignition system described above, as well as more sophisticated engine controls to maintain the air/fuel ratio and ignition timing at optimum for lowest emission levels. For this reason, lean burn engines are generally somewhat more expensive than their rich burn counterparts of the same horsepower.

2. Retrofit of Turbocharged Engines - When an older turbocharged rich burn engine is converted to lean burn operation it occasionally is possible to modify the existing turbocharger for higher capacity, but in most cases it is necessary to replace the existing turbocharger with a new higher efficiency, higher capacity unit. In addition the turbocharger after cooler must be replaced with a higher capacity unit and additional cooling water flow has to be provided to adequately cool the higher volume of air. Also it is imperative that the ignition system be improved by one of the methods described above. Of course the engine must still have very sophisticated engine controls. These retrofits can be very expensive.

3. Retrofit of Naturally Aspirated Engines - In an effort to retrofit naturally aspirated gas engines to some form of lean burn operation, a number of different schemes have been tried with varying degrees of success, as follows:

a. Deration - In cases where the full original design power of the engine is not required, it is sometimes possible to lean the air/fuel ratio by readjusting the carburetor, or inducting air downstream of the throttle valve, so that the engine burns less fuel with the same amount of air it was originally designed for. This can derate the engine 35% or more. It is generally necessary to improve the ignition somewhat to prevent misfiring at this lighter load, which can be expensive.

b. Turbocharging - the deration described above can sometimes be avoided by turbocharging a naturally aspirated engine during the conversion to lean burn operation. Not only is the new turbocharger rather expensive, but it generally is necessary to cool the air between the turbocharger and the engine, which involves not only the additional expense of an after cooler but the additional cooling water capacity involved. In some cases it also is necessary to replace the existing water cooled exhaust manifold with an insulated exhaust manifold, to provide more heat energy to the turbocharger, in addition to the added expense of more powerful ignition and better engine controls.

Many of the above lean burn combustion schemes will reduce NO_x emissions to the 2.0 gms/hp/hr required in most of the United States and Canada and some will even go lower than that, however none of them will come anywhere close to meeting either the 0.15 gms/hp/hr required currently in Southern California or the stricter standards being proposed for the northeastern United States. Since requirements are beginning to tighten up, anyone contemplating new lean burn engines or a lean burn conversion on their existing engines needs to seriously consider whether the results achieved will meet the probable stricter future requirements in their area.

Oxidation Catalysts

As was noted earlier, the reduction of NO_x emissions during lean burn combustion is often accompanied by increases in the formulation of CO and C_xH_y due to the cooler combustion (Fig.1). The levels of the CO and C_xH_y can be reduced by the installation of an oxidation catalyst in the exhaust to oxidize these pollutants into carbon dioxide and water. This reaction is the same as was explained above in the two stage catalytic reduction for rich burn engines.

Selective Catalytic Reduction (SCR)

In an oxygen rich exhaust, such as is produced by a lean burn four cycle engine or two cycle engine, it is not currently possible to significantly reduce NO_x with a catalyst alone. In this situation the NO_x can be reduced by introducing ammonia (NH_3) in some form into the exhaust upstream of an SCR catalyst. A reaction between the NO_x and NH_3 takes place in the catalyst producing the following reaction:

$$NO_x + NH_3 \text{ -----> } N_2 + H_2O$$

In a premium SCR system, the addition of an oxidation catalyst downstream will cause the CO and C_xH_y to react with the excess oxygen to produce the following reaction:

$$C_xH_y + CO + O_2 \text{ -----> } CO_2 + H_2O$$

This currently is the only effective way to reduce these three emissions in an oxygen rich exhaust. At present three different methods are being used to introduce ammonia into the exhaust stream:

1. The most cost effective way to provide ammonia in the exhaust is by the injection of anhydrous ammonia. Even though farmers have been handling anydrous ammonia and injecting it directly into their fields as fertilizer for many years, with a good safety record, many engine operators feel that there is a potential for problems should this pressurized gas escape into the atmosphere and are reluctant to use it. It has been classified as a toxic gas by OSHA and there might be some potential liability problems in this area.

2. Most of the problems associated with anhydrous ammonia can be overcome by the use of aqueous ammo-

nia, which is a solution of 25%-30% anhydrous ammonia into mineral free water. This water needs to be of very good quality to avoid depositing mineral scale on the catalyst when the water evaporates in the exhaust. This aqueous ammonia, also called ammonium hydroxide, can be purchased premixed from several suppliers in North America and is available delivered from their tank trucks. This solution can be stored at atmospheric pressure in closed tanks, which are arranged to prevent escape of any fumes into the atmosphere. This arrangement is being successfully employed at a number of installations in North America. The net ammonia delivered to the engine exhaust with this scheme is more expensive than with anhydrous ammonia, due to the expense of mixing and transporting the ammonia water solution.

3. The safest, and many people feel the most satisfactory, system is the injection of a solution of urea and water into the exhaust. Urea (ammonium nitrate) is a commonly and widely used fertilizer readily available all over the world. It is crystalline in form and granular, similar to rock salt. It is available in plastic or paper bags sized for handling by one person. It is non-toxic and is even used as a feed supplement for cattle and other livestock. It can be either purchased in its granular form and mixed by the user at the jobsite with demineralized water, or is available from several suppliers around North America as a premixed solution delivered in liquid form to the users storage tank. In either case, there is no vapor pressure problem or irritating fumes associated with the solution. Depending on the concentration, there can be some crystallization problems at very low temperatures, which can be solved either by heating the storage tank during these low temperature periods or using some additives that are available to retard this crystallization.

When the aqueous urea solution is injected into the engine exhaust the water is vaporized and the urea is transformed into ammonia by the exhaust heat. The resulting ammonia then reacts with the NOx as described previously. The net ammonia delivered to the exhaust is more expensive than with either aqueous ammonia or anhydrous ammonia, but most operators feel that the added safety is worth the additional cost.

In all of the above schemes, either a variable speed pump or a fixed volume pump with a variable bypass valve can be used to regulate the flow to the exhaust system according to the engine load, so that adequate, but not excessive, ammonia is injected into the system. Excessive flow not only wastes ammonia but causes "ammonia slip" thereby introducing another toxic substance into the atmosphere. This can be prevented with proper controls.

DIESEL ENGINES

Unlike four cycle gas engines, diesel engines operate with an open throttle and, in the case of a naturally aspirated diesel, the air flow is strictly a function of the speed of the engine. In turbocharged diesels there is additional air that is a function of the exhaust energy available to the turbocharger. The power output of the engine is controlled by the amount of diesel fuel injected on each power stroke. Because of this, the exhaust of a diesel is always oxygen rich, even at full load, and it is impossible to operate a diesel at the stoichiometric point. For this reason a three way catalytic converter will not work on a diesel engine and the methods employed to reduce exhaust emissions are similar to those used on a lean burn four cycle or two cycle gas engine, both of which also have an oxygen rich exhaust. Some of the techniques for doing this are as follows.

<u>Combustion Modification</u>

In modern diesels the formation of NO_x during the combustion process can be reduced by varying the fuel injection timing, injection pressure and injection duration to lower the combustion temperature and minimize the combining of nitrogen and oxygen in the air to form NO_x. In some instances exhaust gas recirculation is also employed to reduce NO_x formation. This reduced combustion temperature also increases the level of CO and C_xH_y in the exhaust.

<u>Oxidation Catalysts</u>

As is the case with lean burn gas engines, the CO and C_xH_y in diesel exhaust can be significantly reduced by employing an oxidation catalyst to complete the combustion process of these two emissions, using the excess air already present in the exhaust. Depending on the exhaust temperature available, it is not uncommon to get a 95 to 99 percent reduction in CO and 80 to 85 percent reduction in C_xH_y with an oxidation catalyst.

Another benefit of an oxidation catalyst in diesel exhaust is that both the diesel odor and visible smoke are significantly reduced to make the diesel engine more acceptable to the nearby community. The odor normally associated with diesel engines comes from the C_xH_y in the exhaust and, by significantly reducing these elements, the diesel odor that many people find objectionable is significantly reduced as well. Also the reaction between CO and C_xH_y in the catalyst is exothermic. This high temperature causes the black soot particles in the exhaust to either completely incinerate or further oxidize into white particles, causing the exhaust to become very translucent, in fact essentially transparent.

The initial puff of smoke at start-up only lasts for a few seconds with an oxidation catalyst in place, and even this brief time can be reduced by electrically pre-heating the catalyst prior to start-up.

The use of an oxidation catalyst in conjunction with residential or hospital grade silencing has made many diesel engines much more acceptable in densely populated areas.

Selective Catalytic Reduction (SCR)

In cases where the NO_x reduction by combustion modification is not adequate for the local air quality agency, the NO_x can be further reduced by SCR, employing the use of ammonia injection, as described in the section on lean burn gas engines.

CATALYST SUBSTRATES

The catalyst in a catalytic converter consists of precious metals coated onto a substrate, which supports the catalyst and provides a flow path for the exhaust gas. These precious metals cause the necessary catalytic reactions. Several different substrates have evolved over the years.

In early converters the catalyst was in the form of ceramic beads containing the precious metals, which were then packed into a basket through which the exhaust gas flowed and contacted the catalyst. The disadvantage of this scheme was that pulsation in the exhaust caused the beads to rub against each other, reducing the volume of catalyst by abrasion.

This problem was solved by substituting a ceramic honeycomb structure for the beads. The catalyst was then coated onto the surface of this honeycomb. The disadvantage of using this substrate on industrial engines is that the pulsating flow in the exhaust causes fatigue cracking in the catalyst module. Also, ceramic substrates are very vulnerable to destruction by engine backfire.

To overcome this problem, some catalytic converter manufacturers are now using metal substrates. In a metallic substrate a foil of stainless steel is crimped to prevent its nesting, then either wound into a roll, or folded back and forth, to form a catalyst module which allows axial flow of the exhaust gas. The catalyst is coated onto the metal foil. These metallic substrates have proven to be more durable in operation on industrial engines, due to their better resilience and greater strength.

LOCATION OF CATALYST

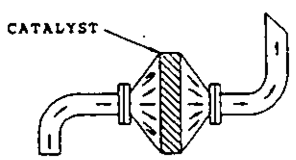
There are four possible locations for the catalyst in a reciprocating engine exhaust (Fig.2). The advantages and disadvantages of each are as follows:

1. Catalytic Converters With No Exhaust Silencer - (Fig. 2a) This arrangement has the advantage of minimal exhaust back pressure to the engine, but the sound attenuation within the catalytic converter is also minimal and not adequate for most applications. The catalyst is also subject to damage by exhaust pulsation or backfires.

2. Catalytic Converter Located Upstream of the Exhaust Silencer - (Fig. 2b) This arrangement has the advantage of providing maximum exhaust temperature at the catalyst, which provides good catalytic conversion. In

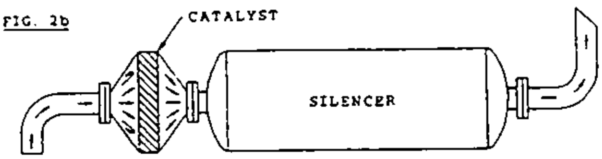
ALTERNATE CATALYST LOCATIONS

FIG. 2a



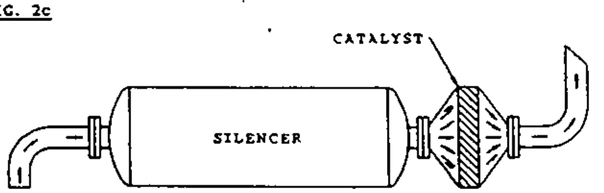
CONVERTER WITH NO SILENCER

FIG. 2b



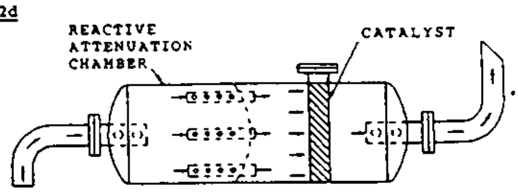
CONVERTER LOCATED UPSTREAM OF SILENCER

FIG. 2c



CONVERTER LOCATED DOWNSTREAM OF SILENCER

FIG. 2d



COMBINATION CONVERTER/SILENCER
(U.S. PATENT NO. 4,601,168)

CONVERTER LOCATED WITHIN SILENCER

general, the higher the temperature, the better the catalyst operates, up to a point. The disadvantage of this arrangement is that it subjects the catalyst to full pulsation of the engine exhaust, which can cause fatigue damage and eventual deterioration of the catalyst module, as well as possible backfire damage.

3. Catalytic Converter Located Downstream of the Exhaust Silencer - (Fig. 2c) This arrangement has the advantage of protecting the catalyst module from exhaust pulsation and backfire damage. It has the disadvantage that a lot of heat is radiated from the exhaust silencer, resulting in the exhaust temperature being reduced to a point where the catalyst is less effective.

4. Catalyst Located Within the Exhaust Silencer - (Fig. 2d) This is the optimum location. The first reactive chamber of the silencer greatly reduces the exhaust pulsation, for minimal fatigue damage to the catalyst module, and provides good backfire protection, yet the exhaust is still very hot at this point and will give a good catalytic reaction. This has the further advantage that the exhaust gas is flow conditioned by the first chamber so that not only is there less pulsation in the exhaust, but the exhaust is distributed more evenly across the entire face of the catalyst for maximum catalytic reduction. This arrangement can be designed for a lower total pressure drop than a separate converter and silencer in series, resulting in less exhaust back pressure to the engine for cooler, more economical engine operation.

GAS TURBINES

All gas turbines have an oxygen rich exhaust, due to the large quantities of dilution air that must flow through the turbine in order to keep the temperature to the first stage turbine blades at a low enough level to prevent failure of the blades. For this reason, the exhaust emission reduction schemes are similar to those used in lean burn gas engines and diesel engines. Some of these techniques are as follows:

Combustion Modification

The preferred and most cost effective way to reduce NO_x in gas turbine exhaust is to reduce its formation in the first place. In the earlier days of gas turbines, combustion in the burner cans, or combustors, took place as a near stoichiometric combustion in the center of the can, which gave very good flame stability, with the necessary dilution air being added after the combustion took place. This gave a very hot flame in the center of the can, which generated large amounts of NO_x due to the high temperature. The key to lowering the formation of NO_x was to lower this temperature of combustion. The combustion modification schemes fall into one of two categories, as follows:

1. **Water or Steam Injection** - The earliest attempts to accomplish this was to add either high quality deionized water or steam to the combustion air as it entered the combustor. The presence of this water or steam lowered the combustion temperature and reduced the formation of NO_x. This scheme was satisfactory in combined cycle plants where the exhaust heat was being used to generate steam for a steam turbine, as the high quality injection water had to be produced for the steam boiler anyway and it was not that difficult or expensive to produce additional deionized water for the gas turbine as well. This was not as satisfactory in pure mechanical drive turbines, as the deionized water or steam had to be made from scratch at a significant expense. Also water is scarce and expensive in many parts of the world. The quality of this water is critical because the presence of any minerals in the water will result in deposits in the combustors and on the turbine blades.

2. **Dry Low NO_x Combustors** - Because of the problems above, most gas turbine manufactures are now concentrating their development efforts on the design of dry low NO_x combustors, which do not require water or steam. In a dry low NO_x combustor the fuel and most of the air are premixed as they enter the combustor to provide a very lean homogeneous mixture. The flame stability of such a lean mixture would normally be very poor, however this is overcome by a very small, near stoichiometric, pilot flame in the center of the combustor to maintain flame stability. Of course some NO_x is formed in this pilot flame but this pilot fuel is held to the bare minimum, generally somewhat less than 5% of the total, so that the overall mixture generates very low NO_x. Additional dilution air is added near the exit of the combustor to reduce the exit temperature to the necessary level for the first stage turbine blades. The key to making this scheme work is very careful control of the air/fuel ratio and mixing under a wide range of operating conditions to prevent flame out.

Dry low NO_x combustors generally have been able to obtain lower NO_x levels with gaseous fuel than with liquid fuel, due to the fact that it is easier to get a homogeneous mixture between gas and air than with liquids. Even sub micron size liquid particles have a high combustion temperature in the vicinity of the particle, which encourages NO_x formation. Most base load turbines run on gaseous fuels anyway, with liquid fueling available as a standby in case of interruption of the gas supply.

Oxidation Catalysts

In some cases the combustion modification used to control NO_x formation does not adequately control the formation of CO and C_xH_y due to the lower combustion temperature. In this instance an oxidation catalyst can be added to the exhaust system to reduce these emissions as well, similar to the technology used on lean burn gas engines and diesel engines. These oxidation catalysts will also reduce the exhaust odor in the case of liquid fueled turbines.

Selective Catalytic Reduction (SCR)

In instances where combustion modification will not adequately reduce the NO_x emissions in a gas turbine, SCR can be used to further reduce NO_x levels, as described previously.

CONCLUSION

Hopefully this information will assist engine and turbine operators in choosing the exhaust emissions scheme best suited for their particular situation. It is important to keep in mind that the historic trend of emissions regulations have been for them to get increasingly strict as time goes by. Because of this, it is important that the operator select an emission control system that will not only meet the current requirements, but also have the capability of being upgraded to meet stricter requirements which seem to be inevitable in the future.

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ADVANCES IN ENGINE EMISSIONS CONTROL TECHNOLOGY

presented at

THE TWELFTH ANNUAL
ENERGY-SOURCES TECHNOLOGY
CONFERENCE AND EXHIBITION
HOUSTON, TEXAS
JANUARY 22–25, 1989

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THE S.I. NATURAL GAS ENGINE EXHAUST AND THE CONVERTER/SILENCER AS A SYSTEM

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ABSTRACT

The Clean Air Act impacted the internal combustion engine and most other power sources. The catalytic converter, adopted from the automotive industry, overshadowed earlier OSHA-imposed noise standards and negated the dynamics of the engine exhaust system. The automotive industry, in early developmental stages, recognized that the converter and muffler should be combined. Materials, economics, and manufacturing techniques have delayed that, even with present day capabilities and technology. The gas engine exhaust, treated as a system, and introduction of a low pressure drop, reactive (multi-chamber) silencer containing the catalytic converter, fit the engine exhaust with a single vessel, reducing emissions and exhaust noise to any required sound quality.

THE CATALYTIC CONVERTER AND ENGINE EXHAUST SYSTEM

Passage of the Clean Air Act in 1970, and the continuing escalation of air quality regulations has compromised the engine exhaust, which makes it a logical place to look for improved efficiency.

This discussion is not about redesign of any part of the engine. The references to silencer or muffler design and application are applicable to all engines. Specifically, the engine of interest is the spark-ignited, carbureted, natural gas fueled engine we know as the "rich-burn" gas engine.

The exhaust manifold is designed to reduce exhaust gas pressure. The exhaust gas cannot escape as fast as it enters and backpressure is the result of high pressure at the exhaust valves working against restricted manifold passages, exhaust piping and muffler.

Possibly the greatest influence on the exhaust system was the "sticker shock," or cost of the catalytic converter, apparently drawing attention from the engine exhaust to the impact of emissions control and the added accessory cost.

The engine exhaust must be viewed as a system to efficiently remove exhaust gasses at low pressure drop for proper engine scavenging. The engine exhaust generally includes the piping, expansion joint, the exhaust silencer or muffler, an explosion relief port, and often, a catalytic converter. This is the engine exhaust system.

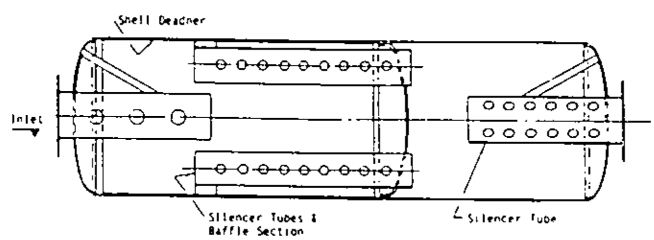


Fig. 1 The muffler or exhaust silencer representative of "Residential" quality.

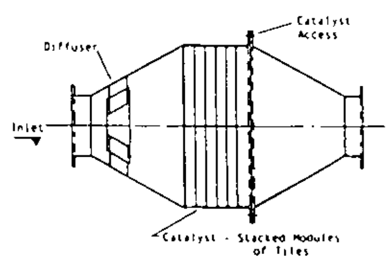


Fig. 2 The catalytic converter (typical for ceramic "honeycomb" converter)

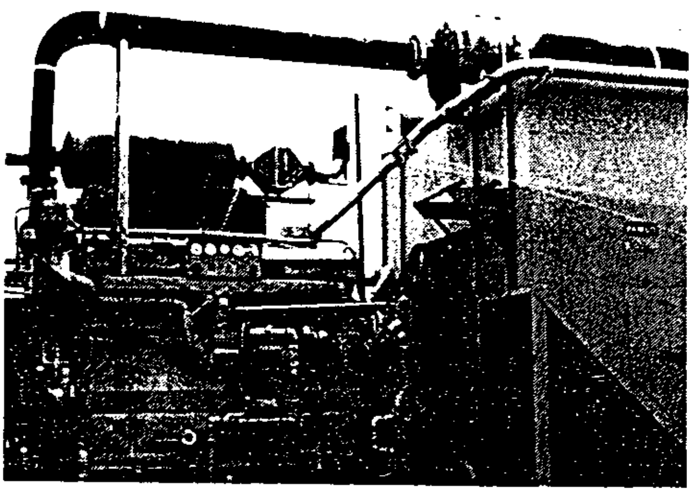


Fig. 3 Catalytic converter shown installed either before or after the muffler in the exhaust system (typical of separate converter & muffler)

The two examples illustrated in Fig. 3, show the catalytic converter on the outlet end of the muffler and also show the converter on the inlet end of the muffler. In the first application, it is apparent that the converter on the outlet end of the muffler is protected from exhaust gas pulsation, while the converter located on the inlet side of the muffler is subject to the pulsation from the engine exhaust.

The catalytic converter was the industry's first attempt at the control of exhaust emissions from the automobile engine. Early automobile converters were filled with platinum pellets for CO and HC reduction. Later, ceramic substrates (honeycomb) coated with platinum, palladium, and rhodium (three-way catalyst) for NOx, CO and HC reduction, dominated the automobile converter market. The advantage of this new substrate design was that the converter would be built smaller and installed closer to the engine manifold for quicker "light-off" or faster operation.

Opinions differed about how these new converters should be constructed, and it was decided that the converter would be made of stainless steel. Many of the automotive engineers thought it necessary to keep the converter separate from the muffler in the exhaust pipe.

The automotive OE muffler industry was reluctant to manufacture the catalytic converter built into the muffler because their experience had been with carbon steel, and, later, aluminized steel. Stainless alloys and manufacturing techniques had not developed to make it economically feasible to add the cost of a stainless steel exhaust system to the price of the automobile.

The ceramic "honeycomb" converter that dominated the automotive market was adapted to the natural gas fueled engine we now know as the rich-burn engine.

Naturally, the greater exhaust mass flow from the rich-burn gas engine required a much larger converter than for the automobile, and larger cross-sectional flow area to accommodate required catalyst volume.

In some catalytic converters, ceramic tiles are arranged and framed in a square configuration, the stacked-in depth to obtain catalyst volume for a specific exhaust gas flow. This is the non-selective catalytic converter (NSCR) illustrated in Fig. 2.

Emissions reduction with precious metal catalysts operating with the rich-burn gas engine is proven technology, and for that reason we will not go into any explanation of that process except for the purpose of illustrating some of the reactions in the printed versions of this paper.

Reaction

The noble metal catalyst, offered for simultaneous conversion of NOx and oxidation of CO and NMHC, performs optimally when the engine is running "fuel rich," a condition that results in sufficient reducing agents being present in the exhaust to reduce NOx to N2. Placement of a proper catalyst in the exhaust stream will result in the extraction of oxygen from the NO molecule when oxidizable materials (CO, HC, NH3, etc.) are present, changing the NOx molecule into harmless nitrogen. Since virtually all of the NOx in the exhaust is initially present as NO, there are several reactions that govern the reduction phenomenon:

1. $4\ NO + CH_4$ -- $2N_2 + 2H_2 + CO_2$

2. $2\ NO + 2\ CO$ -- $N_2 + 2CO_2$

3. $2\ NO + 2\ H_2$ -- $N_2 + 2H_2O$

4. $6\ NO + 4\ NH_3$ -- $5N_2 + 6H_2O$

Any NO_2 in the exhaust is reduced by the following reactions.

5. $4\ NO_2 + 2\ CH_4$ -- $2N_2 + 2CO_2 + 4H_2O$

6. $2\ NO_2 + 4\ H_2$ -- $N_2 + 4CO_2$

7. $2\ NO_2 + 4\ H_2$ -- $N_2 + 4H_2O$

8. $6\ NO_2 + 8\ NH_3$ -- $7N_2 + 12\ H_2O$

The Occupational Safety and Health Act and the Walsh-Healy Act legislated prior to 1970, had less impact on the engine exhaust system than the Clean Air Act simply as many of the major oil and petro- chemical companies had established noise control policies for personnel protection stricter than those imposed by OSHA.

One of the predominate and inherent features of operation of the IC engine is exhaust noise. The exhaust gas has mass and elasticity set into motion at the completion of the power stroke. The dynamics of this motion is like a spring that, upon sudden release, overruns by stretching itself far beyond the normal length. Oscillating freely, it sometimes pulls into resonance in its travel through the exhaust pipe to atmosphere. Noise is accentuated not so much as the result of the amplitude or the pressure change, but it is, rather, the abruptness of the pressure change or release to atmosphere that causes the "snap" at the end of the tailpipe. This is exhaust gas pulsation that is audible.

If this phenomenon is taking on the character description of pulsation in a gas compression system, consider the similarity. Pulsation in the compression system is inaudible noise, and in the closed system, pulsation energy is sometimes manifested as piping vibration. The exhaust silencer is the "pulsation damper" of the exhaust system.

In generic terms, we can rate silencing quality categorically by "Commercial," "Standard," "Residential," and "Hospital/Critical." These definitions describe the relative size of the silencer. The "Commercial" silencer being the smallest and the "Hospital/Critical" the largest.

For all but the most critical locations, the selection of the "generic" quality of silencer may be acceptable. By specification or environment, silencer application should be made by site survey for ambient (background) noise level and impact on public relations and unsilenced noise level of the engine itself. Analysis of this data will contribute to the desired end performance.

The exhaust system or muffler illus-trated in Fig. 1 is the reactive, multi-chamber type and is somewhat dependent on area discontinuity (area change) for sound reduction and the dissipative effect of perforated tubes for broad band, low frequency noise attenuation. Acoustic performance is a function of diameter, relative volume, and internal design.

Performance of the expansion chambers depends on the ratio of the inlet pipe cross-sectional area to silencer body cross-sectional area and a dimensionless parameter K1.

The dimensionless parameter can be expressed as

$$K1 = \frac{2\pi F}{C}\, l$$

Where: F = frequency of interest in hertz
C = speed of sound in the medium in feet per second
l = chamber length in feet

The maximum transmission loss occurs for a value of K1 and 1.57 and intergral whole number multiples of this number.

Perforated tubes provide for a transmission loss in the lower frequency portion of the spectrum because of the ability to act as a high pass filter.

Transmission loss for an element of this type can be expressed by:

$$TL = 10\log_{10}\left[1 + \left(\frac{CO}{2KS}\right)^{2}\right]$$

Where: TL = transmissions loss in decibels
S = tube cross-sectional area in square feet
K = wave number

$$\frac{2\pi F}{C} \quad \text{per cubic foot}$$

CO = orifice conductivity in feet

This element is used primarily as a low frequency device. These factors take the silencer dimensionally from "Commercial" through "Critical" quality of silencing.

Consider that one inch of water column pressure drop is valued at 20 BTU per horsepower hour. Reduction of 4 inches water column of pressure drop in the exhaust system of a 1000 HP gas engine can be a saving of as much as 7008 MCF per year in fuel/gas or $1,401.60 at $2.00 per 1 MCF.

The one item left for expression is pressure drop. The internal velocity is selected between 5000 feet per minute to 8000 feet per minute to hold pressure drop to 6 inches of water maximum.

$$P = C \times \left(\frac{V}{4005}\right)^{2} \times \frac{530}{460 + {}^{\circ}F} = H_2O$$

Where: P = pressure drop in inches H_2O
C = converter/silencer coefficient (in this case, 4.2)
V = velocity, Fpm

Pressure drop is critical to the oper-ation of the engine and in excess can cause oil blowby, burn valves, and cause improper scavenging, and contribute to overall inefficiency. It was at an early ASME meeting that I heard a distinguished speaker, commenting on a paper, describe pressure drop as serving no good purpose, besides..."it constipates the engine."

One step toward improved efficiency in the engine exhaust system is the coupling of the catalytic converter and the exhaust silencer in a single vessel and one pressure drop equivalent to that of the exhaust silencer or total pressure drop no more than 7.0 inches of water column flange to flange. See Fig. 4.

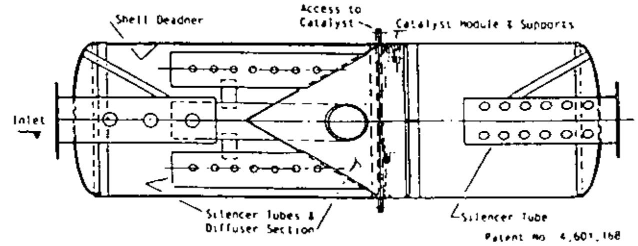


Fig. 4. Converter/silencer combination for "Residential" quality silencing

Evolution of the metallic substrate has added another dimension to catalytic converter configuration, a cylindrical shape. For this substrate, a special stainless steel foil was developed for high temperature operation. It is probable that Mercedes-Benz was the first to use this metallic substrate as a diesel particulate trap.

This metallic foil is formed to a corrugated/chevron shape before the catalyst formulation for three-way operation is applied. This three-way catalyst is a composition of platinum, palladium, and rhodium, the percent of which is proprietary. However, one automotive catalyst manufacturer has stated that the precious metals are combined in various ratios such as five parts platinum, one part palladium, and one part rhodium, with the coating being about 25 grams per cubic foot of volume of substrate.

Now, the stainless foil having been shaped and coated, the foil can be wound to a given diameter for the catalyst volume required. Catalyst volume is determined by the following method:

$$\text{Catalyst Volume} = \frac{\text{Exhaust Gas Flow - SCFH}}{\text{100,000 (Space Velocity)}}$$

Example:

$$\text{1000HP} = \frac{\text{100,000SCFHExhaustGas=One}^3\text{Catalyst}}{\text{100,000 (Space Velocity)}}$$

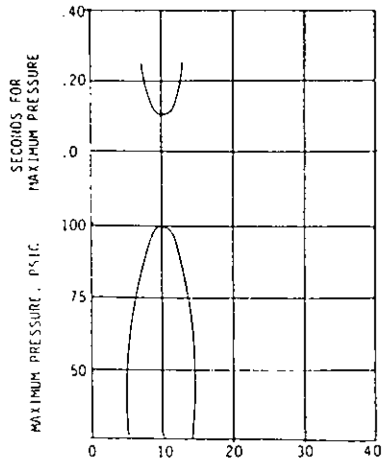
Having calculated the catalyst volume and winding the substrate material, the corrugated shape forming the "honeycomb," or parallel passages, the diameter of the substrate will equal the volume calculated for the space velocity. Diameter, giving the monolith volume, leaves pressure drop a calculation constant regardless of exhaust mass flow rate. For area in cross-section, it is 90 percent to 95 percent.

In the application of the combination converter/silencer where reduced gas velocity and lower pressure drop results in larger silencing tubes, it is economically feasible and becomes a very small percentage of the overall cost of the emissions reduction system.

The combination converter/silencer is built inherently like a pressure vessel. Overall, the material thicknesses, dished heads and continuous welding, design working pressure ranges as high as 125 psig.

At times, when backfire or exhaust pipe explosion occurs on a failed start attempt, the instantaneous pressure peak is very high. The catalytic converter module will not be destroyed by the explosion or backfire if the cells are open for free flow of the pressure wave. The catalyst module is supported and contained to have a safety factor as much as 5:1 greater than the peak pressure.

It would seem that a backfire relief port could not react fast enough to relieve this peak pressure in a tenth of a second.



Reference: Bureau of Mines,
U.S. Department of Interior

Fig. 5 Explosion time and pressure for percent mixture of methane and air

Figure 5 illustrates the maximum pressure reached with various percent mixtures of methane and air related to time in tenths of a second to reach maximum pressure.

Installation and operation of this converter silencer combination on an I.C. rich-burn gas engine calls for the operating company to obtain an operating permit from the local air quality management authority.

One such installation was made in the State of Louisiana on an Ingersoll-Rand 48KVG engine to 5.9 lbs/hr of NOx, 9.7 lbs/hr of CO, and 0.43 lbs/hr of hydrocarbons. The permit required that NOx emissions ratio be corrected to Reference Ambient Conditions (RAC) according to the formula published by the EPA in 40CFR 60, Subpart FF (proposed).

Initially, a series of air fuel ratio settings for various CO levels was made to establish a test matric. This is illustrated in Fig 6, where the NOx mass emissions are correlated to air fuel ratios as a function of exhaust CO concentration upstream of the catalyst.

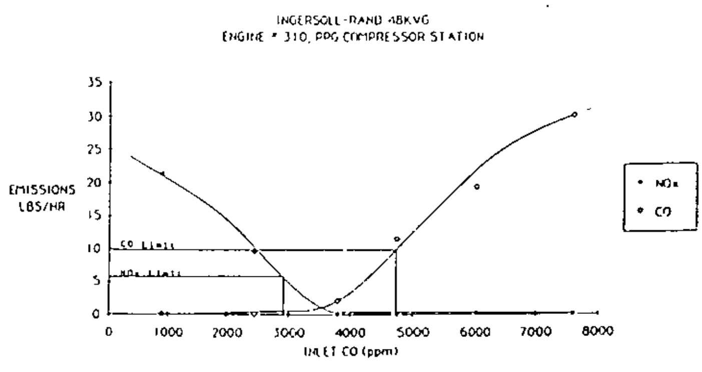


Fig. 6 Exhaust emissions at various A/F ratios.

Ingersoll-Rand 48KVG Engine #310

Data By Test Run	1	2	3	4	5	6
Engine Data						
Intake Manifold Pressure (in. Hg)	-8	-8	-8	-8	-8	-8
Suction Gas Pressure (psig)	230	230	230	230	230	230
Discharge Gas Pressure (psig)	450	450	450	450	450	450
Engine/Compressor speed (rpm)	331	331	330	330	330	330
Fuel Gas Pressure (in. water)	5.5	5.5	5.5	5.5	5.5	5.5
Fuel Flow (MMSCFD)	0.1914	0.1898	0.1863	0.1861	0.1875	0.1860
Suction Gas Flow (MMSCFD)	17.9	17.5	17.9	17.6	17.6	17.7
Suction Gas Temperature (°F)	66.7	68	73.4	73.9	74.9	77.1
Ambient Conditions						
Temperature Wet Bulb (°F)	58	59	60	63	62	67
Temperature Dry Bulb (°F)	72	68.5	73	76	75	76
Humidity (gr./lbs dry air)	59	59	58	65	62	84
Atmospheric Pressure (in Hg)	30.22	30.22	30.22	30.22	30.22	30.22
RAC Factor	1.127	1.173	1.112	1.092	1.100	1.148
Catalyst Inlet CO (ppm)	7650	6000	4900	3675	2450	900
Measured Emissions						
NOx (ppm)	26	32	28	13	1150	2525
CO (ppm)	5780	3750	2250	440	22	20
CO2 (%)	11.55	11.62	11.70	12.70	11.85	11.65
THC (ppm)	325	325	300	280	245	230
O2 (%)	0.05	0.05	0.05	0.06	0.09	0.27
Actual Mass Emissions						
NOx (lbs/hr)	0.24	0.27	0.24	0.11	9.7	21.4
CO (lbs/hr)	30.3	19.5	11.6	2.2	0.11	0.10
VOC (lbs/hr)	0.011	0.011	0.010	0.010	0.008	0.008
Reference Ambient Emissions						
NOx (lbs/hr)	0.31	0.38	0.31	0.12	10.7	24.6

Fig. 7 Ingersoll-Rand 48KVG Engine #310

Figure 7 is a graphic presentation of the engine and illustrates the range of catalyst CO concentrations required to allow the catalyst to efficiently release the NOx and CO to permit limits.

Noise limit specifications for this installation were for 85 DBA. Pressure drop limits were set at 3.5 inches of water column. Noise specifications called for a silenced level to be 9.0 DBA at a distance 3 feet horizontal and 3 feet upward from the exhaust outlet.

CONCLUSION

It can be concluded that progress has been made in emissions reduction for the internal combustion engine by combining the converter and the exhaust silencer and considering the engine exhaust as a system, that engine efficiency can be improved by reduced pressure drop, exhaust gas flow conditioning, and provision for noise control of any quality.

APPLICATION DATA SHEET

Name: ______________________________

Company: ______________________________ PHONE: ____________

Address: ______________________________ FAX: ____________

____

Engine: Make ____________________ Model ____________

HP or KW rating ______________________________

Exhaust gas flow and temperature ______________________________

Raw emissions data (if available) (NOx, CO, NMHC) ____________

____

____

Required emissions levels and % of reduction or gm/hp/hr for NOx, CO & NMHC

____

____

____

____

Installation: Original _____ or Retrofit _____

Describe any space limitations, noise quality restrictions (commercial, semi-residential, residential, hospital/critical): ______________________________

____

____

____

____

Mail to: *HIS* Emissions Reduction Systems
9837 Whithorn Drive
Houston, Texas 77095

or call: (713) 463-8883
FAX: (713) 463-8951

HIS Emissions Reduction Systems

Thanks, MIRATECH

Thanks, JOHNSON-MATTHEY

Thank, WPI

Thanks, MECHANICAL EQUIPMENT

Thanks for recognizing that the *HIS* DeNOx Silencer has set the industry standard for engine exhaust emissions with the combination catalytic converter/silencer.

Thanks again for the compliments, imitation is the most genuine form of flattery.

Sincerely,

HIS Emissions Reduction Systems

Harold L. Harris
President

9837 Whithorn Drive · Houston, Texas 77095 · 281-463-8883
P.O. Box 1639 · Cypress, Texas 77410 · Fax 281-463-8951

HISCORP

APPENDIX C

TANKS 4.0 EMISSIONS REPORT – DETAIL FORMAT
FOR FUEL OIL STORAGE TANK

TANKS 4.0
Emissions Report - Detail Format
Tank Identification and Physical Characteristics

Identification

User Identification:	COL PEAK TANK
City:	Lakeland
State:	Florida
Company:	Lakeland Electric
Type of Tank:	Vertical Fixed Roof Tank
Description:	294,000 GALLON FUEL OIL STORAGE TANK

Tank Dimensions

Shell Height (ft):	31.00
Diameter (ft):	40.50
Liquid Height (ft):	30.50
Avg. Liquid Height (ft):	28.00
Volume (gallons):	294,000.00
Turnovers:	26.26
Net Throughput (gal/yr):	7,721,000.00
Is Tank Heated (y/n):	N

Paint Characteristics

Shell Color/Shade:	Gray/Light
Shell Condition:	Good
Roof Color/Shade:	Gray/Light
Roof Condition:	Good

Roof Characteristics

Type:	Dome
Height (ft):	1.00
Radius (ft) (Dome Roof):	40.50

Breather Vent Settings

Vacuum Settings (psig):	-0.03
Pressure Settings (psig):	0.03

Meteorological Data used in Emissions Calculations: Orlando, Florida (Avg Atmospheric Pressure = 14.75 psia)

TANKS 4.0
Emissions Report - Detail Format
Liquid Contents of Storage Tank

Mixture/Component	Month	Daily Liquid Surf. Temperatures (deg F) Avg.	Min.	Max.	Liquid Bulk Temp. (deg F)	Vapor Pressures (psia) Avg	Min.	Max.	Vapor Mol. Weight	Liquid Mass Fract.	Vapor Mass Fract.	Mol. Weight	Basis for Vapor Pressure Calculations
Distillate fuel oil no. 2	All	79 91	70.58	89.24	74.56	0 0122	0 0091	0 0162	130.0000			188.00	Option 5: A=12.101, B=8907

TANKS 4.0
Emissions Report - Detail Format
Detail Calculations (AP-42)

Annual Emission Calculations	
Standing Losses (lb):	29.5000
Vapor Space Volume (cu ft):	4,509.3963
Vapor Density (lb/cu ft):	0.0003
Vapor Space Expansion Factor.	0.0656
Vented Vapor Saturation Factor	0.9977
Tank Vapor Space Volume	
Vapor Space Volume (cu ft)	4,509.3963
Tank Diameter (ft):	40.5000
Vapor Space Outage (ft).	3.5004
Tank Shell Height (ft):	31.0000
Average Liquid Height (ft):	28.0000
Roof Outage (ft):	0.5004
Roof Outage (Dome Roof)	
Roof Outage (ft):	0 5004
Dome Radius (ft):	40.5000
Shell Radius (ft):	20.2500
Vapor Density	
Vapor Density (lb/cu ft):	0 0003
Vapor Molecular Weight (lb/lb-mole):	130.0000
Vapor Pressure at Daily Average Liquid Surface Temperature (psia):	0.0122
Daily Avg. Liquid Surface Temp (deg R):	539.5832
Daily Average Ambient Temp. (deg. F):	72 3167
Ideal Gas Constant R (psia cuft / (lb-mol-deg R)):	10.731
Liquid Bulk Temperature (deg. R):	534.2267
Tank Paint Solar Absorptance (Shell):	0 5400
Tank Paint Solar Absorptance (Roof)	0.5400
Daily Total Solar Insulation Factor (Btu/sqft day)	1,486.6667
Vapor Space Expansion Factor	
Vapor Space Expansion Factor:	0.0656
Daily Vapor Temperature Range (deg. R):	37.3224
Daily Vapor Pressure Range (psia).	0 0070
Breather Vent Press. Setting Range(psia)	0.0600
Vapor Pressure at Daily Average Liquid Surface Temperature (psia).	0.0122
Vapor Pressure at Daily Minimum Liquid Surface Temperature (psia):	0 0091
Vapor Pressure at Daily Maximum Liquid Surface Temperature (psia):	0 0162
Daily Avg. Liquid Surface Temp. (deg R):	539 5832
Daily Min. Liquid Surface Temp. (deg R):	530.2526
Daily Max. Liquid Surface Temp. (deg R):	548.9138
Daily Ambient Temp. Range (deg. R):	20.6167
Vented Vapor Saturation Factor	
Vented Vapor Saturation Factor:	0.9977
Vapor Pressure at Daily Average Liquid Surface Temperature (psia):	0.0122
Vapor Space Outage (ft)	3.5004

TANKS 4.0
Emissions Report - Detail Format
Detail Calculations (AP-42)- (Continued)

Working Losses (lb):	291.5986
Vapor Molecular Weight (lb/lb-mole):	130.0000
Vapor Pressure at Daily Average Liquid Surface Temperature (psia):	0.0122
Annual Net Throughput (gal/yr.):	7,721,000.000 0
Annual Turnovers:	26.2619
Turnover Factor:	1.0000
Maximum Liquid Volume (gal):	294,000.0000
Maximum Liquid Height (ft):	30.5000
Tank Diameter (ft):	40.5000
Working Loss Product Factor:	1.0000
Total Losses (lb):	321.0986

TANKS 4.0
Emissions Report - Detail Format
Individual Tank Emission Totals

Annual Emissions Report

	Losses(lbs)		
Components	Working Loss	Breathing Loss	Total Emissions
Distillate fuel oil no. 2	291.60	29.50	321.10