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ENVVEST
Semiannual Progress Report

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1.0 INTRODUCTION

On 16 March 1995, President Clinton and Vice President Gore announced an initiative titled *Reinventing Environmental Regulation,* which proposed ten principles on regulatory reform and directed U.S. Environmental Protection Agency (U.S. EPA) to implement twenty-five high priority actions. One of the twenty-five actions was aimed at achieving regulatory reform within the Department of Defense (DoD) through a program called ENVVEST (Environmental Investment).

On 2 November 1995, the DoD and the U.S. EPA signed a Memorandum of Agreement (MOA) on Regulatory Reinvention Pilot Projects, which formally indoctrinated the ENVVEST program. The MOA established a framework for developing pilot programs at approximately three to five selected DoD facilities. Vandenberg Air Force Base (AFB) has been selected as the prototype facility to pilot the ENVVEST program and implement common sense and cost effective environmental protection. The ENVVEST program emphasizes regulatory compliance through pollution prevention and provides an alternative strategy from prescriptive command-and-control regulatory requirements with a performance based environmental management system designed to attain greater environmental results.

On 3 November 1997, Vandenberg AFB, U.S. EPA, and the Santa Barbara County Air Pollution Control District (SBCAPCD) signed the first ENVVEST Final Project Agreement (FPA) within the DoD. The FPA states the intentions of the aforementioned parties to carry out a pilot project pursuant to the 1995 MOA by testing innovative approaches to environmental protection. Under the FPA, the Vandenberg AFB Air Quality Project XL/ENVVEST Initiative is aimed at improving air quality beyond that achieved through federal, state, and local permit programs. This multi-year implementation strategy is aimed at generating a reduction of ozone precursors, i.e., oxides of nitrogen (NOx) and volatile organic compounds (VOCs), by 10 tons or more by 30 November 2002.

The FPA describes the implementation of the ENVVEST initiatives and sets project milestones. Vandenberg AFB plans to implement a phased program to achieve the designated emission reduction goals. Project milestones pertaining to this phase of the program are:

- Thirty percent of ENVVEST Candidate boilers identified in the Boiler Emission Reduction Implementation & Cost Feasibility (Boiler ERI & CF) study shall be retrofitted or replaced by 30 April 1999.

- Two tons per year of emission reductions shall have been accomplished by 30 April 2000.

2.0 BOILER EMISSION REDUCTION IMPLEMENTATION PLAN

The Plan presents an overview of the subject boilers and their associated uncontrolled NO_x emissions. In this case a boiler is defined as an external combustion source that produces steam or hot water. In most cases the steam or hot water is used for space heating or hot water at the facilities.

The boilers at Vandenberg AFB span a broad range of equipment designs and heat input capacities. This Plan focuses on boilers with a heat-input range of 2.0 to 5.0 MMBtu/hr. The

feasibility of retrofitting the burner or replacing a boiler is dependent on heat transfer configuration, furnace size, burner configuration, heat input capacity, fuel type, fuel train configuration, age, and overall condition. In addition to the hardware and equipment specifications, there are space and facility constraints that need to be considered when evaluating the feasibility of each burner retrofit or boiler replacement. Coupled with the complexity of the boiler design are the similar variations in estimating the uncontrolled NO_x emissions. Uncontrolled NO_x emissions may vary significantly among the various boiler design types.

2.1 SITE SURVEY PROCESS

Site survey efforts were performed in three phases. The first effort identified Vandenberg AFB boilers that have a heat input rating of 2.0 to 5.0 MMBtu/hr. During this effort, the building number, facility description, building square footage, tenant organization, facility manager/point of contact (POC), POC phone number, and access constraints were identified. Additionally, the sources were identified for potential impact (scheduled for replacement or eliminated) by other capital improvement projects through the year 2001. This effort involved contacting the Civil Engineer's Capital Improvement Program and examining the 30th Space Wing Space Track Plan.

The second phase of the site survey verified the boiler manufacturer, model, serial number, and heat input rating and identified the boiler and burner type, fuel type, and approximate age of the boiler. In addition, the boiler design and logistical configuration were identified. The fuel train and boiler configurations with respect to the boiler room orientation were also documented.

The third phase of the site survey effort identified the emission measurement sampling location and facility fuel meters when present. Sample ports were identified and located in accordance with U.S. EPA Method 1 and the ENVVEST Emission Measurement Protocol. The fuel meter type (e.g., turbine, rotary, or diaphragm meter) along with meter function (e.g., dedicated boiler meter or facility meter servicing other combustion sources) and the meter readout resolution were also documented during this effort.

2.2 SITE SURVEY RESULTS

Vandenberg's Wing Environmental Services contractor, Tetra Tech, Inc., was initially given an original listing of the boilers that were believed to have a heat input rating between 2.0 and 5.0 MMBtu/hr. Using a Draft submittal of the 1996 Comprehensive Emission Inventory Update, it was discovered that some of the boilers had been left off the original listing; therefore, additional boilers were added to the list and verified during site visits. Initially, 45 boilers were evaluated during the site visit. The site visit revealed that 11 boilers were replaced and four boilers were being replaced. In one case, the heat input rating was incorrectly documented in the original information and found to be outside the initial target 2.0 to 5.0 MMBtu/hr range. Through the site survey process, it was determined that 44 boilers between 2.0 and 5.0 MMBtu/hr remain in the pool that shall be considered in this phase of the program. This pool of boilers shall be referred to as the Vandenberg AFB ENVVEST Baseline boilers. A detailed profile for these boilers is presented in Table 2.2-1.

During the site visit, it was discovered that many of the Vandenberg AFB ENVVEST Baseline boilers were replaced or being replaced. In order to categorize the boilers and develop a pool of candidate boilers that would benefit the most from low NO_x technology under the ENVVEST program, the following categories were developed:

ENVVEST BOILER REFERENCE NUMBER	TID	BUILDIN	FACILITY DESCRIPTION	BUILDING SQUARE FOOTAGE	FACILITY TYPE	FACILITY OCCUPANT
100	974	433			Warehouse	Lockheed Martin
101						
102						
103						
200	984	719	MST SUPPORT	5440	Payload Processing	Lockheed Martin
300	985	719	MST SUPPORT	5440	Payload Processing	Lockheed Martin
400	986	719	MST SUPPORT	5440	Payload Processing	Lockheed Martin
500	988	719	MST SUPPORT	5440	Payload Processing	Lockheed Martin
600	989	719	MST SUPPORT	5440	Payload Processing	Lockheed Martin
700	NA	731		21460	Office	Lockheed Martin
800	NA	731		21460	Office	Lockheed Martin
801						
802						
803						
900	1009	836		55271	Office	NASA
1000		836		55271	Office	NASA
1100	NA	875	MAINTENANCE SHOP	21933	Warehouse	Paracyne
1200	1023	960	SRM STORAGE	8758	Warehouse	NASA
1300	1024	980	STORAGE	12975	Warehouse	United Technologies
1400	951	1800	MISSILE MAINT FACILITY	18640	Warehouse	576 Test Squadron
1500	NA	1819	MISSILE ASSEMBLY BLD.	179050	Warehouse	Detachment 9 Material Comma
1600	1035	3000	MSL/SPACE RSCH TST	74347	Warehouse	Lockheed Martin
1700	NA	3000	MSL/SPACE RSCH TST	74347	Warehouse	Lockheed Martin
1800	1038	5500	RSCH EQUIP STOR	172577	Warehouse	30th Transportation Squadron
1900	1041	6523	MSL/SPACE RSCH ENG	35078	Office	Various Government Tenants
2000	1043	6601	MSL OPS BLD	44300	Office	30th Mission Support Squadron
2100	1052	7425	MSL/SPACE RSCH ENG	38600	Office	30th Mission Support Squadron
2200	1062	8310	MSL/SPACE RSCH ENG	142654	Office	4th Space Launch Squadron
2201		8310			Office	4th Space Launch Squadron
2202		8310			Office	4th Space Launch Squadron
2203		8310			Office	4th Space Launch Squadron
2204		8310			Office	4th Space Launch Squadron
2300	1065	8314	AUDIO-VIS FCLTY	40738	Office	30th Communication Squadron
2400	1068	8401	RSCH EQUIP STOR	118900	Office	Lockheed Martin
2500	1071	8401	RSCH EQUIP STOR	118900	Office	Lockheed Martin
2600	1072	8401	RSCH EQUIP STOR	118900	Office	Lockheed Martin
2700	1074	8500	MSL SPACE RSCH ENG	115603	Office	Detachment 9 Space and Missi
2701		8500			Office	Detachment 9 Space and Missi
2702		8500			Office	Detachment 9 Space and Missi
2703		8500			Office	Detachment 9 Space and Missi
2800	1076	8510	MSL SPACE RSCH ENG	45223	Office	Lockheed Martin
2900	1079	9005	GYMNASIUM	23369	Warehouse	Gymnasium
3000	1088	9320	MSL/SPACE RSCH TST	40400	Warehouse	ITT Federal Services
3100	1091	9340	PHOTO LAB BSE	35447	Office	30th CES
3200	1090	9340	PHOTO LAB BSE	35447	Office	30th CES
3300	1093	10145	SWIM POOL WTR TRMT	NA	Swimming pool	Various users
3400	1096	10252	OPEN MESS NCO	40035	Restaurant	NCO Club/Eating Facility
3500	1100	10577	HQ NUMBERED AF	92482	Office	Base Headquarter
3600	1108	11070	OPEN MESS OFF.	28325	Office	Officers Club
3601						
3700	1109	11439	BE MAINT. SHOP	52924	Office	30th CES
3800	1122	13123	DORM	1562	Dormitory	Air Force personnel
3801		13123			Dormitory	Air Force personnel
3802		13123			Dormitory	Air Force personnel
3803		13123			Dormitory	Air Force personnel
3900	1121	13321	DORM	11413	Dormitory	Air Force personnel
4000	1123	13323	DORM	11413	Dormitory	Air Force personnel
4100	1125	13330	DH ADM	14969	Administration and Mess Hall for Dormitory	Air Force personnel
4200	1128	13607	ACAD LECT. HALL	13406	Lecture Hall	Air Force personnel
4201		13607			Lecture Hall	Air Force personnel
4202		13607			Lecture Hall	Air Force personnel
4300	1153	23225	TRACKING STATION	11054	Office	Detachment 1, 750 SPG (Track
4400	1154	23225	TRACKING STATION	11054	Office	Detachment 1, 750 SPG (Track

"C" Boilers that are currently being retrofitted or replaced;

"E" Boilers that are not scheduled for retrofit or replacement and are within the desired heat input rating; also known and referred to as the ENVVEST Pre-selected Candidate boilers;

"N" Boilers that do not meet the heat input rating criteria or the facility that housed the boiler is no longer in operation;

"R" Boilers that were replaced; and

These categories were applied to the pool of Vandenberg AFB ENVVEST Baseline boilers to determine the ENVVEST Pre-selected Candidate boilers. Results from this effort are summarized in the following discussions and tables and are presented in detail in Table 2.2-2.

2.2.1 Summary of Vandenberg AFB ENVVEST Baseline Boilers and ENVVEST Pre-selected Candidate Boilers

Boilers with a heat input rating of less than 10 MMBtu/hr are generally classified as commercial/institutional units; this includes the boilers at Vandenberg AFB. An important method of classifying boilers is by burner type and heat transfer configuration. Boilers are equipped with two types of burner configurations, atmospheric and power. The basic difference between the two is that atmospheric burners draw in surrounding ambient air to be used for combusting the specific fuel, whereas power burners are fan-assisted systems. In general, a boiler equipped with a power burner tends to be more efficient with respect to complete combustion, (operating near stoichiometric conditions) and therefore has lower NO_x emissions. Only two types of heat transfer are used at Vandenberg AFB, watertube and firetube configurations. In a watertube boiler, combustion heat is transferred to water flowing through tubes lining the furnace chamber, creating convective heat transfer. In a firetube boiler, the hot combustion gases flow through hollow tubes and water flows around the tubes to absorb heat transferred from the hot gas. In either case, the heat is carried by water, then exchanged with ambient air through a radiator to heat the surrounding space. Water is pumped back to the boiler and reheated to complete the cycle.

Forty-four boilers are in the Vandenberg AFB ENVVEST Baseline boiler category. The boilers in this category are predominately manufactured by Ajax (9 boilers), Cleaver Brooks (9 boilers) and Kewanee (7 boilers). The Vandenberg AFB Baseline boilers are summarized by manufacturer and type in Table 2.2-3.

Table 2.2-2
ENVVEST Pre-selected Candidate Boilers

ENVVEST Pre-selected Candidate Boiler Reference Number	Building	Operating Facility/Description	Zone	Access	Class	Boiler Function	Boiler Manufacturer	Boiler Model Number	Boiler Serial Number	Heat Input Rating (MMBtu/hr)	Boiler Type (Fire or Water Tube)	Burner Type (Power or Atmospheric)	Fuel Type	Year Installed	Age
200	719	SLC 4 (LM)/Temperature Control to SLC	2	Restricted	E	Environmental	Cleaver Brooks	M4S-2000	4G017684	2.000	WATER TUBE	POWER	NG	Jan-88	9
300	719	SLC 4 (LM)/Temperature Control to SLC	2	Restricted	E	Environmental	Cleaver Brooks	M4S-2000	4G017685	2.000	WATER TUBE	POWER	NG	Jan-88	9
400	719	SLC 4 (LM)/Temperature Control to SLC	2	Restricted	E	Environmental	Cleaver Brooks	M4S-3000	4G017686	3.000	WATER TUBE	POWER	NG	Jan-88	9
500	719	SLC 4 (LM)/Temperature Control to SLC	2	Restricted	E	Environmental	Cleaver Brooks	M4S-3000	46017687	3.000	WATER TUBE	POWER	NG	Jan-88	9
600	719	SLC 4 (LM)/Temperature Control to SLC	2	Restricted	E	Environmental	Cleaver Brooks	M4S-3000	46017688	3.000	WATER TUBE	POWER	NG	Jan-88	9
1000	836	NASA/Environmental/Secondary Boiler	2	General	E	Environmental	Kewanee	L3W80G	95844	3.348	WATER TUBE	POWER	NG/P	Aug-90	7
1100	875	GSA/Comfort Heat	2	General	E	Heating	Kewanee	M-175-KG	98247	2.188	FIRE TUBE	POWER	NG	Jan-95	2
1300	980	4 SLS/Comfort Heat	2	General	E	Heating	Ajax	WGFN-2500	92-44183	2.500	WATER TUBE	POWER	P	Jan-91	6
1400	1800	30MS/LGMHE/Comfort Heat	1	General	E	Hot Water	Kewanee	M-250-KGD	R6161	2.050	FIRE TUBE	POWER	P	Jan-94	3
1500	1819	DET9/ENF661/Comfort Heat	1	General	E	Heating	Industrial Boiler	PFDL50GAS	55094	2.100	FIRE TUBE	POWER	P	Jan-92	5
1800	5500	30 TRAN/Comfort Heat	3	General	E	Heating	Ajax	WG0FD-4250	87-39279	4.250	WATER TUBE	POWER	NG	Jun-91	16
1900	6523		3	General	E	Heating	Kewanee	M-335-KG	97975	3.350	FIRE TUBE	POWER	NG	Aug-93	4
2000	6601	30MS/Comfort Heat	3	General	E	Heating	Ajax	WGB-2000	83088	2.000	WATER TUBE	ATMOSPHERIC	NG	Jan-93	4
2100	7425	30 MSS/Comfort Heat	3	General	E	Heating	Ajax	WGB-2250D	AC-81-33744	2.250	WATER TUBE	ATMOSPHERIC	NG	Jan-81	16
2300	8314	30 CS/SCVS 740/Comfort Heat	3	General	E	Heating	Cleaver Brooks	M4W-3000	G-12517-M4	3.000	WATER TUBE	POWER	NG	Jan-79	18
2400	8401	LM/Comfort Heat	3	Restricted	E	Environmental	Thermific	CRNK136451234	CC47-89-0882	2.060	WATER TUBE	POWER	NG	Jan-91	6
2500	8401	LM/Comfort Heat	3	Restricted	E	Environmental	Thermific	CRNK136451234	CC47-89-0883	2.060	WATER TUBE	POWER	NG	Jan-91	6
2600	8401	LM/Comfort Heat	3	Restricted	E	Environmental	Thermific	CRNK136451234	CC47-89-0885	2.060	WATER TUBE	POWER	NG	Jan-91	6
2800	8510	4 SLS/DMF 770/Comfort Heat	3	Restricted	E		Cleaver Brooks	M4S-2500	AG016483	2.500	WATER TUBE	POWER	NG		
2900	9005	30 SVS/Fitness Center/Comfort Heat	3	General	E	Heating	Pacific Boilers	84-25F	1167N1562	2.500	WATER TUBE	ATMOSPHERIC	NG	Jan-84	13
3000	9320	FSC/Comfort Heat	3	General	E	Heating	Kewanee	M-265-KDO	R3433	3.313	FIRE TUBE	POWER	NG	Jan-81	16
3100	9340	30CS/Hot Water	3	General	E	Hot Water	Ajax	WGB-4250	AC-87-39483	4.250	WATER TUBE	ATMOSPHERIC	NG	Jan-87	10
3200	9340	30CS/Hot Water	3	General	E	Hot Water	Ajax	WGB-4250	AC-87-39484	4.250	WATER TUBE	ATMOSPHERIC	NG	Jan-87	10
3300	10145	30 CES/Swimming Pool/Water Heater	3	General	E	Heat Swimming Pool	Ray Pak, Inc	P-3001A-BEDRDGA	1291117683	3.000	WATER TUBE	ATMOSPHERIC	NG	Jan-87	10
3500	10577	30 SW/Comfort Heat	3	General	E	Heating	Ajax	WGB-3750	73-26890	3.750	WATER TUBE	ATMOSPHERIC	NG	Aug-75	22
3700	11439	30 CES/CEOI900/Comfort Heat	3	General	E	Heating	Kewanee	L2S100-G	P-2763	4.185	FIRE TUBE	POWER	NG	Jan-81	16
4200	13330	30 SVS/Comfort Heat	3	General	E	Heating	Kewanee	H35-100KG	10527	4.185	FIRE TUBE	POWER	NG	Nov-92	5
4300	23225	250 SG/Maintain Heat to Control Room	1	Restricted	E	Environmental	Ajax	WGGFD-4250	92-43822	4.250	FIRE TUBE	POWER	NG	Jun-92	5
4400	23225	250 SG/Maintain Heat to Control Room	1	Restricted	E	Environmental	Ajax	WGGFD-4250	92-43808	4.250	FIRE TUBE	POWER	NG	Jun-92	5

Table 2.2-3
Summary of Vandenberg AFB Baseline Boilers

Manufacturer	Number of Units	Heat Input Rating (MMBtu/hr)	Boiler Type	Burner Type
Ajax	6	2.000 to 4.250	Water Tube	Atmospheric
Ajax	2	2.500 to 4.250	Water Tube	Power
Ajax	2	4.250	Fire Tube	Power
American Standard	1	3.120	unknown	unknown
Avco	1	2.188	Fire Tube	Power
Cleaver Brooks	11	2.000 to 3.000	Water Tube	Power
Industrial	1	2.100	Fire Tube	Power
Kewanee	3	3.313 to 4.500	Water Tube	Power
Kewanee	9	2.050 to 4.185	Fire Tube	Power
Kewanee	1	3.875	Water Tube	Atmospheric
Pacific Boilers	1	2.500	Water Tube	Atmospheric
Ray Pak	1	3.000	Water Tube	Atmospheric
Rite Engineering	2	2.250 to 3.000	Water Tube	Atmospheric
Thermific	3	2.060	Water Tube	Power
Total	**44**			

Twenty-nine boilers have qualified as a category "E" for the Vandenberg ENVVEST Pre-selected Candidate boiler pool. These boilers are also predominately manufactured by Ajax, Cleaver Brooks, and Kewanee. This pool of boilers contains 20 watertubes and 9 firetubes, and predominately equipped with power burners, 22 units to be exact. The Vandenberg AFB ENVVEST Pre-selected Candidate boilers are summarized by manufacturer and type in Table 2.2-4.

Table 2.2-4
Summary of ENVVEST Pre-selected Candidate Boilers

Manufacturer	Number of Units	Heat Input Rating (MMBtu/hr)	Boiler Type	Burner Type
Ajax	5	2.000 to 4.250	Water Tube	Atmospheric
Ajax	2	2.500 to 4.250	Water Tube	Power
Ajax	2	4.250	Fire Tube	Power
Cleaver Brooks	7	2.000 to 3.000	Water Tube	Power
Industrial Boiler	1	2.100	Fire Tube	Power
Kewanee	1	3.348	Water Tube	Power
Kewanee	6	2.150 to 4.185	Fire Tube	Power
Pacific Boilers	1	2.500	Water Tube	Atmospheric
Ray Pak	1	3.000	Water Tube	Atmospheric
Thermific	3	2.060	Water Tube	Power
Total	29			

2.2.2 Boiler Function, Fuel Type and Operation

The boilers at Vandenberg AFB are used in various applications; mostly they provide heating to facilities, and in a few cases provide heating for hot water and a swimming pool. Two types of fuel are used in the Vandenberg boilers, natural gas and propane. In some cases the boiler can be

fired on either fuel. All diesel-fired units have been converted to clean fuels being either natural gas or propane.

When evaluating boiler operations, the following factors were taken into consideration:

- Facility function versus boiler operation.
- Fuel use and boiler capacity.
- Boiler functional use versus boiler operating hours.

2.2.3 Fuel Use and Boiler Capacity

During June through August 1997, all ENVVEST Pre-selected Candidate boilers had fuel meters installed, excluding any pre-existing meters. Actual fuel use data has been compiled since the start of this period to document each boiler's monthly and annual fuel usage. The fuel use for each boiler is monitored in accordance with the ENVVEST Fuel Measurement Protocol.

Regardless of the facility function, it was observed that the heat input and output required for many of the facilities were over sized at the time the boiler was originally installed at the facility. This was confirmed by evaluating monthly and annual fuel data that many of the boilers seldom operate at or near their rated maximum heat input capacity.

2.2.3.1 Boiler Functional Use v. Boiler Operation

The boilers evaluated in this study have many functional uses. In order to correlate the facility function with the boiler function and operation, the boilers were categorized into seven functional use categories. They are as follows: space heating, hot water, steam, steam/heating, environmental-general climate control, environmental-process oriented climate control, and swimming pool heating. Boiler use for providing space heating, hot water, steam, steam/heating, and swimming pool heating are standard heating applications and definitions for these functional use categories are not necessary. However, in the case of the environmental-general climate control, and environmental-process oriented climate control, these functions are not as common, therefore brief descriptions for these categories are provided. Boilers classified as "environmental-general climate control" are used to provide heating to a building so that a "set" temperature for sensitive equipment is maintained on a 24-hour basis. Boilers classified as "environmental-process oriented climate control" are used to provide heat during launch related processes. The boiler operation is dependent on the launching frequency as well as the duration of the process. In most cases, boilers that provide either general or process oriented climate control are considered "mission critical" and before they are retrofitted or replaced, the operation of the boiler must be closely coordinated with all parties involved with the facility.

Site survey results showed that a majority of the boilers in this study provided heating and are located in general access facilities. Results also show that the boilers at restricted facilities primarily provide heating for climate controlled areas and that only one boiler was found to provide steam. The boiler function and number of boilers providing the function for the Vandenberg AFB Baseline and ENVVEST Pre-selected Candidate boilers are summarized in Table 2.2-5.

Table 2.2-5
Summary of Vandenberg AFB ENVVEST Baseline and Pre-selected Candidate Boiler Functions

Building Access	Boiler Functional Use	ENVVEST Baseline Boilers	ENVVEST Pre-selected Candidate Boilers
General	Swimming Pool Heating	1	1
General	Space-Heating	19	12
General	Hot Water	3	3
General	Steam/Heating	1	0
General	Environmental-General Climate Control	2	1
Restricted	Environmental-General Climate Control	10	6
Restricted	Environmental-Process Oriented Climate Control	5	5
Restricted	Environmental-General Climate Control & Steam	1	1
Restricted	Space Heating	2	0
Total		44	29

The functional use is better determined by separating the boilers by building access. During the site survey, it was observed that the boilers located in general access areas (e.g., areas without a controlled access point) are operated as the primary boiler for the facility. Additionally, the boilers located in "restricted" access areas (e.g., facilities with a controlled access point) typically operated on a continual basis.

2.2.4 Boiler Baseline Emissions

2.2.4.1 NO_x Formation

NO_x is the high-temperature byproduct from the combustion of fuel and air. When fuel is burned with air, nitric oxide (NO, the primary form of NO_x), is formed from the high temperature reaction of atmospheric nitrogen and oxygen (thermal NO) and from the reaction of organically bound nitrogen in the fuel with oxygen (fuel NO). A third and less important reaction that forms NO is "prompt NO," in which the rapid reaction of the atmospheric nitrogen with hydrocarbon radicals forms NO_x precursors that are rapidly oxidized to NO at lower temperatures. Prompt NO generation is generally minor compared to the overall quantity of NO generated from combustion. Nitric oxide formed from combustion is further oxidized with oxygen to form nitrogen dioxide (NO_2). Nitric oxide and nitrogen dioxide are generally combined and called oxides of nitrogen (NO_x) in combustion chemistry. However, as NO_x emissions are reduced to extremely low limits, the contribution of prompt NO becomes more important.

The mechanism of NO_x formation in combustion is complex. Most of the NO_x formed from combustion of natural gas is attributed to thermal NO_x, which is an exponential dependence of temperature. The control of thermal NO_x is achieved by reducing the combustion temperature. Fuel NO_x results from the oxidation of the fuel bound nitrogen and is typically proportional to the amount of nitrogen in the fuel.

In addition to the physical and chemical characteristics of the fuels, boiler design and operating parameters influence the formation of NO_x. Peak flame temperatures, fuel to air mixing rates,

and oxygen concentrations are just a few of the design and operating parameters affecting the NO_x concentration.

2.2.4.2 Emission Factor Determination

NO_x emission factors for each boiler will be measured in accordance with the ENVVEST Emission Measurement Protocol for both pre- and post-retrofit or replacement (R&R) conditions. The following sections describe the procedures for calculating boiler-specific emission factors.

2.2.4.2.1 Baseline Emission Measurement Results

Pre-R&R NO_x emission measurement and combustion efficiency results will be an average of test runs conducted in accordance with section 2.5, Test Duration and Data Collection, of the ENVVEST Emission Measurement Protocol.

The baseline emission factors have been determined for each ENVVEST Pre-selected Candidate boiler. The emission factor results are summarized in Table 2.2-6.

2.2.4.2.2 NO_x Emission Factor Calculation

Boiler specific NO_x emission factors will be calculated using equation 1.0:

Equation 1.0 $$E_{NOx} = C_d F_d \left[20.9 / \left(20.9 - O_{2d}\right)\right]$$

Where:

E_{NOx} = NO_x emission factor, pounds per million British thermal units, lb/MMBtu

C_d = pollutant concentration, pounds per standard cubic foot, lb/scf (conversion for parts per million [ppm NO_x] to lb/scf is 1.194×10^{-7})[1]

F_d = EPA Method 19 for various fuels (natural gas), 8,710 dry standard cubic feet per million British thermal units (dscf/MMBtu)[2]

O_{2d} = oxygen concentration in flue gas (dry basis), percent

The ENVVEST Pre-selected Candidate boiler baseline emission factors along with actual fuel usage will be used to evaluate the emission reduction potential remaining within the pool of boilers rated at 2 to 5 MMBtu/hr. The application and calculations to derive the overall baseline is addressed in the ENVVEST Baseline Protocol.

[1] Code of Federal Regulations, Part 60, Appendix A, Method 19.
[2] Oxygen based F factor for natural gas will be used for either natural gas or propane.

Table 2.2-6 Summary of ENVVEST Boiler Emission Measurement Testing Data

ENVVEST Boiler Reference Number	Building	Manufacturer	Model	Serial Number	Heat Input (MMBtu/hr)	Test Date	Average NOx @ 3% oxygen, ppm (+/- 2STDEV)	Representative Testing for ENVVEST Boiler Number	Burner Type (power or atmospheric)	Average Combustion Efficiency (%)	Notes
2000	6601	Ajax	WGB-2000	83088	2.0000	9 Apr-98	107.08		atmospheric	56.66	
2100	7425	Ajax	WGB-2250D	AC-81-33744	2.2500	7-Jan-98	109.45		atmospheric	68.66	
2900	9005	Pacific Boilers	84 25F	1167N1562	2.5000	25-Feb-98	118.80		atmospheric	73.93	
3200	9340	Ajax	WGB-4250	AC-87-39484	4.2500	23-Jan-98	115.98	3100	atmospheric	73.99	
3300	10145	Ray Pak Inc.	P-3001A-DEDR	1291117683	3.0000	23-Jan-98	145.58		atmospheric	75.87	
3500	10577	Ajax	WGB-3750	73-26890	3.7500	15-Apr-98	136.76		atmospheric	62.75	
						Average	122.27		Average	68.64	

ENVVEST Boiler Reference Number	Building	Manufacturer	Model	Serial Number	Heat Input (MMBtu/hr)	Test Date	Average NOx @ 3% oxygen, ppm (+/- 2STDEV)	Representative Testing for ENVVEST Boiler Number	Burner Type (power or atmospheric)	Average Combustion Efficiency (%)	Notes
200	719	Cleaver Brooks	M4S-2000	4G017684	2.0000	12-Dec-97	73.79	300	power	76.25	
400	719	Cleaver Brooks	M4S-3000	4G017686	3.0000	11-Dec-97	81.30	500, 600	power	70.99	
1000	836	Kewanee	L3W80G	95844	3.3480	8-Dec-97	82.82		power	82.61	
1100	875	Kewanee	M-175-KG	98247	2.1880	17-Dec-97	68.87		power	75.78	
1400	1860	Kewanee	M-250-KGO	R6161	2.0500	16-Jan-98	95.70		power	78.77	
1700	3000	Clever Brooks	M4S 3000	G-13946-M4	3.0000	19-Jun-97	82.55	1600	power	77.81	
1800	5500	Ajax	WG0FD-4250	87-39279	4.2500	6-Jan-98	60.91		power	72.10	
1900	6523	Kewanee	M-335-KG	97975	3.3500	6-Jan-98	79.94		power	80.78	
2300	8314	Cleaver Brooks	M4W-3000	G-12517-M4	3.0000	23-Jan 98	60.80		power	76.90	
2800	8510	Cleaver Brooks	M4S-2500	AG018483	2.5000	26-Jan-98	83.88		power	69.47	
3000	9320	Kewanee	M-265-KDO	R3433	3.3130	7-Jan 98	57.02		power	76.14	
3700	11439	Kewanee	L2S100-G	P-2783	4.1850	19-Dec-97	69.88		power	77.47	
4100	13330	Kewanee	H3S-100KG	10527	4.1850	6-Jan-98	70.35		power	73.45	
						Average	74.45		Average	76.04	

ENVVEST Boiler Reference Number	Building	Manufacturer	Model	Serial Number	Heat Input (MMBtu/hr)	Test Date	Average NOx @ 3% oxygen, ppm (+/- 2STDEV)	Representative Testing for ENVVEST Boiler Number	Burner Type (power or atmospheric)	Average Combustion Efficiency (%)	Notes
1300	980	Ajax	WGFN-2500	92-44183	2.5000	26-Jan-98	47.57		power	74.56	This AJAX boiler is equipped with a low NOx NOVA combustion system with a manufacturer's emission concentration rating of 24 ppm.
1500	1819	Industrial Boiler	PFDL50 Gas	S 5094	2.1000	16-Jan-98	54.36		power	83.63	Power burner is designated as a low NOx burner. The manufacturer's emission concentration rating is unknown at this time.
4400	23225	Ajax	WGGFD 4250	92-43808	4.2500	18-Dec-97	18.83	4300	power	73.56	This AJAX boiler is equipped with a low NOx NOVA combustion system with a manufacturer's emission concentration rating of 24 ppm.
						Average	40.25		Average	77.25	
1200	960	Ajax	WGFN-2500	92-44183	2.5000		n/a		power	n/a	Boiler not yet tested.

2.3 ENVVEST CANDIDATE BOILER DETERMINATION

The retrofit and replacement decision for each boiler is based on the estimated emission reductions, cost of retrofit or replacement, age of boiler, available technology, experience factor, potential mission impact, and environmental benefits. Candidate determinations are made consistent with Air Force Instruction 32-7001 and based on Air Force requirements. The ranking criteria in section 2.3.1 were designed to determine the applicability and feasibility for each ENVVEST Pre-selected Candidate boiler to be a candidate for retrofit or replacement.

Budgetary constraints exist for the ENVVEST program. In order to achieve the program milestones, a ranking system to qualify the final selection for boiler projects was required. This ranking and scoring system is used to evaluate the potential benefit to the ENVVEST program during its various phases. Each criterion involved in determining whether a boiler is selected for maximum reduction of NO_x emissions was given a weighed numerical value. For each boiler evaluated, the values from each criterion are multiplied by a weight factor based on its importance. Then, the values are summed and ranked to prioritize the order of project selection. Details of the criteria used for ranking are presented in the following sections.

The numbers assigned to each criterion range from 0 to 10; the lower the number for each criterion, the less likely the option would meet the goals for the ENVVEST program. Any source that scores a "zero" in any criteria is considered for omission from the ENVVEST program. The ranking of values for scoring initiatives are shown in Table 2.3-1 and Table 2.3-2. In summary, there are five categories for evaluating each ENVVEST Pre-selected Candidate boiler: estimated emission reduction, age of boiler, programmatic impacts, proposed available control technology, and cost per MMBTU/hr.

2.3.1 ENVVEST Boiler Ranking System

As previously mentioned, a total of 44 boilers are selected as ENVVEST Baseline boilers. Of these, 29 boilers were selected as ENVVEST Pre-selected Candidate boilers. Since fuel consumption is the most predominate factor to accurately assess retrofit or replacement feasibility, twelve (12) consecutive months of fuel usage will be compiled for each ENVVEST Pre-selected Candidate boilers prior to completing this analysis. Other information based on boiler age, operating conditions, and boiler historical maintenance activities have already been compiled. Two categories for the program objectives and operational limitations include boilers recommended for replacement and boilers recommended for retrofit. For the two categories, the ranking system for the ENVVEST Pre-selected Candidate boilers was developed based on the following criteria. Each criterion is weighted differently according to its relative importance to the program. The criteria are:

- NO_x Emission Rate (lbs/yr) - weight factor 4;
- Estimated NO_x Emission Reduction (lbs/yr) - weight factor 3;
- Cost per Heat Input ($/MMBtu/hr) - weight factor 2; and
- Age of boilers (yrs) - weight factor 1. (Criteria used for retrofit projects only.)

Table 2.3-1
Ranking and Scoring Guidelines for ENVVEST Pre-selected Candidate Boilers (Replacement)

Criteria	Ranking	Weight Factor	Description
Emission Rate[1]	8-10	4	Emission rate is >500 lbs
	5-7	4	Emission rate is >400</=500 lbs
	2-4	4	Emission rate is >300</=400 lbs
	1	4	Emission rate is >200</=300 lbs
	0	4	Emission rate is </=200 lbs
Emission Reduction[2]	8-10	3	Emission reduction is >400 lbs
	5-7	3	Emission reduction is >350</=400 lbs
	2-4	3	Emission reduction is >300</=350 lbs
	1	3	Emission reduction is >250</=300 lbs
	0	3	Emission reduction is </=250 lbs or is unknown
Cost per heat input ($/MMBtu/hr)[2]	8-10	2	Cost per heat input is<$12K
	5-7	2	Cost per heat input is >$12K</=$14K
	2-4	2	Cost per heat input is >$14K</=$22K
	1	2	Cost per heat input is >$22K</=$24K
	0	2	Cost per heat input is >$24K

Notes: 1 - Emission reduction based on boiler replacement NO_X emission concentration of 20 ppm.
2 - Cost per heat input based on actual bids to replace boilers located at Buildings 9005, 9320, 10145, 10577, 13330, and 8510.

Table 2.3-2
Ranking and Scoring Guidelines for ENVVEST Pre-selected Candidate Boilers (Retrofit)

Criteria	Ranking	Weight Factor	Description
Emission Rate[1]	8-10	4	Emission rate is >500 lbs
	5-7	4	Emission rate is >400</=500 lbs
	2-4	4	Emission rate is >300</=400 lbs
	1	4	Emission rate is >200</=300 lbs
	0	4	Emission rate is </=200 lbs
Emission Reduction[1]	8-10	3	Emission reduction is >400 lbs
	5-7	3	Emission reduction is >350</=400 lbs
	2-4	3	Emission reduction is >300</=350 lbs
	1	3	Emission reduction is >250</=300 lbs
	0	3	Emission reduction is </=250 lbs or is unknown
Cost per heat input[2] ($/MMBtu/hr)	8-10	2	Cost per heat input is<$5K
	5-7	2	Cost per heat input is >$5K</=$10K
	2-4	2	Cost per heat input is >$10K</=$15K
	1	2	Cost per heat input is >$15K</=$20K
	0	2	Cost per heat input is >$20K
Age of Boiler	8-10	1	Boiler age is </=2 years old
	5-7	1	Boiler age is >2</=4 years old
	2-4	1	Boiler age is >4</=6 years old
	1	1	Boiler age is >6</=10 years old
	0	1	Boiler age is >10 years old

Notes: 1 - Emission reduction based on burner retrofit NO_x emission concentration of 20 ppm.
2 - Cost per heat input based on actual bids to retrofit burners on boilers located at Buildings 875, 1800, 1819, and 23225.

Under each criterion, five rankings (0, 1, 2-4, 5-7, and 8-10) ranging from zero to 10 points are used to evaluate each boiler. Weight factors from 1 to 4 are used to highlight the relative importance of each criterion and its potential impact on the program.

The ranking and scoring guidelines for ENVVEST Pre-selected Candidate Boilers replacement projects are shown in Table 2.3-1. The ranking and scoring guidelines for ENVVEST Pre-selected Candidate boiler retrofit projects are shown in Table 2.3-2.

It is important to note that until actual emission and fuel measurement data for the Pre-selected Candidate boilers are compiled, the R&R feasibility assessment cannot be completed. This information is essential to calculate total emissions and the emission reduction potential based on actual emissions and fuel measurement data. Each boiler R&R evaluation will be completed by October 1998. At that point, the final ENVVEST Candidate boiler list will be identified, ranked, and selected for R&R.

In order to meet ENVVEST program milestones specified in the Final Project Agreement, Vandenberg AFB has prematurely begun R&R projects on ENVVEST Pre-selected Candidate boilers. The status of these projects is discussed in the following section.

3.0 STATUS OF ENVVEST R&R BOILER PROJECTS

Vandenberg AFB has optimized mechanisms already existing for conducting public participation in ENVVEST through environmental advisory boards which already consider air quality issues as they pertain to Vandenberg AFB or the entire County. These existing boards have been asked to place the program on their agendas when requested at each regular meeting for updates and any necessary action.

On base, the Community Advisory Board (CAB) chosen by the community three years ago through a non-military community public process has been asked to expand its scope beyond consideration of the Installation Restoration Program to include the ENVVEST program. CAB members include residents in the towns around the base with no affiliation to it, Air Force officials, and state and county regulators including the SBCAPCD. It is co-chaired by a townsperson, Mr Jack Dougherty, and the 30th Space Wing Commander. The status of the following projects was recently briefed to members of the CAB on 5 June 1998.

3.1 GYM & FITNESS CENTER (BUILDING 9005)

This ENVVEST project included replacing a 2.5 MMBtu/hr atmospheric burner water tube boiler, manufactured by Pacific Boilers in 1984, with a 2.500 MMBtu/hr power burner water tube boiler, manufactured by PVI Industries, Inc. The boiler installation was completed on 18 March 1998. The boiler is equipped with a Pyromat Radiation Stabilized Burner (RSB) designed by Alzeta, Inc. This specially designed burner incorporates cylindrical burner surfaces that control heat flux uniformity, which will allow the system to achieve less than 9 parts per million (ppm) oxides of nitrogen (NOx) and less than 50 ppm carbon monoxide (CO). A field demonstration and emission testing in accordance with the ENVVEST Emission Measurement Protocol was successfully completed for both pre and post R&R. Results show that the new boiler system delivered a 92 percent reduction in NOx concentration. The average combustion efficiency was observed at 79.5 percent, a 7 percent increase in combustion efficiency and proportional savings in fuel consumption. In addition to achieving low emissions, the manufacturers of this boiler package have set an additional goal for this project to obtain system certification from

Underwriters Laboratory (UL). Currently, PVI and Alzeta are pursuing UL certification and anticipate package approval before January 1999.

3.2 BREAKERS DINING HALL (BUILDING 13330)

This ENVVEST project includes retrofitting a 4.185 MMBtu/hr power burner fire tube boiler, manufactured by Kewanee Boiler in 1992, with a 2.500 MMBtu/hr power burner, designed and patented by the by the Institute of Gas Technology (IGT). Field-testing determined the maximum firing range for this boiler is 0.4 to 3.5 MMBtu/hr, and that the normal operating firing range is 0.4 to 1.7 MMBtu/hr. Therefore, the firing rate will be de-rated from 3.5 to 2.5 MMBtu/hr to optimize the boiler efficiency for its application.

The unique combustion system design, formally known as a forced internal recirculation (FIR) burner combines two-stage combustion with premixed first stage gases and forced internal recirculation of products of partial combustion to reduce formation of "thermal" and "prompt" NOx. A conceptual design of the FIR burner is presented in Figure 1. A natural gas/primary combustion air mixture is utilized for the first stage and enters via a plenum. The velocity of the natural gas/air mixture through several nozzles is sufficient to create a reduced pressure, which induces flow from the exit of the primary zone. Inside the recirculation insert, the products of partial combustion flow back to the root of the flame (as indicated by the curved arrows). These combustion products contain hydrogen, which improves combustion stability in the primary zone allowing combustion at relatively low stoichiometric ratios. Combustion at a low stoichiometric ratio (fuel rich) produces less NOx emissions than complete combustion. Secondary air is injected through a pipe, which is located at the center of the burner to burn out hydrogen, carbon monoxide, and unburned hydrocarbons. Mixing of the secondary air with the combustion products from the primary zone is critical to the design of the low NOx burner. The recirculation insert radiates heat to the cold walls and allows products of partial combustion to cool before flowing to the secondary combustion zone and back to the root of the flame cooling and stabilizing point. The current schedule for installation and field testing of this burner is set to occur 1 August through 31 December 1998.

3.3 BASE SWIMMING POOL (BUILDING 10145)

This ENVVEST project included replacing a 3.0 MMBtu/hr atmospheric burner, water tube boiler, manufactured by Ray Pak, Inc. in 1987, with a two 1.440MMBtu/hr atmospheric burner, water tube boilers, manufactured by Lochinvar Boiler. Replacement was chosen do to the poor condition of the Ray Pak boiler and its associated historical maintenance problems. By replacing the single boiler, with two boilers operating on a lead-lag system, each boiler operates on an as needed basis, hence increasing the boiler efficiency, resulting in an tailored heating system that optimizes boiler operations to meet pool heating requirements. Manufacturer specifications document each boiler at 84 percent combustion efficiency with a NOx emission concentration rating at less than 10 ppmvd at 3 percent oxygen. Installation of the new Lochinvar boilers was completed on 2 April 1998. Preliminary test results show manufacturer efficiency and pollutant concentration will be met. Emission testing in accordance with the ENVVEST Emission Measurement Protocol is scheduled for completion before 31 July 1998.

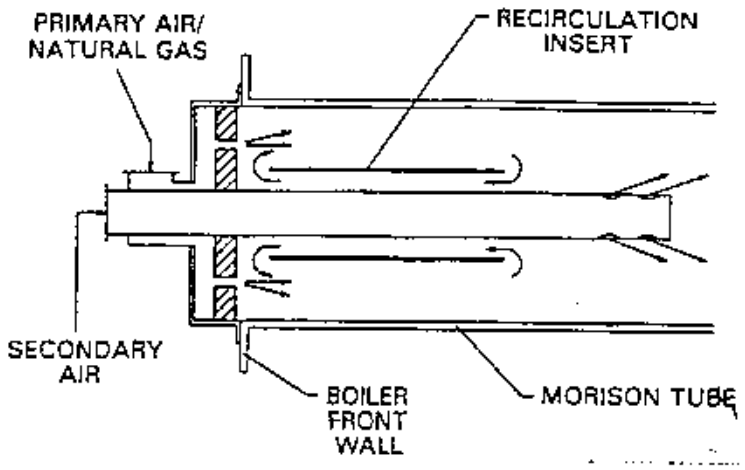

Figure 1. CONCEPTUAL DESIGN OF THE TWO-STAGE FIR BURNER

3.4 576TH FLIGHT TEST SQUARDON FACILITY (BUILDING 6601)

This ENVVEST project included retrofitting a 2.0 MMBtu/hr atmospheric burner water tube boiler, manufactured by Ajax Boiler in 1993, with a 2.0 MMBtu/hr atmospheric burner retrofit package, manufactured by Parker Boiler Company. This retrofit project included installing a Maxon premixer blower and Burner Systems International/Furigas metal fiber burner system. Air for combustion is drawn in through the ratio valve where the air to fuel ratio is throttled down to create optimum combustion conditions. Because of the special perforation in the metal fiber burner system, the pressure drop across the burner is minimal, therefore, creating a stable combustion zone. Preliminary results show a 91 percent decrease in NOx emissions and a 26 percent increase in combustion efficiency. Emission testing in accordance with the ENVVEST Emission Measurement Protocol is scheduled for completion before 31 July 1998.