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IMPLEMENTATION OF EMERGING TECHNOLOGIES FOR NO_X REDUCTIONS

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ABSTRACT

The U. S. manufacturing sector uses more energy for steam generation than for any other single purpose. In 2002, steam accounted for 31% of total U. S. manufacturing energy consumption. This high-energy demand in part reflects the reliance on an aging U. S. industrial boiler population employing designs that conceptually vary little from those used at the end of the 19th century. As such, new developments are limited and have offered only incremental gains in operational efficiency. The U. S. manufacturing sector utilizes more than 33,000 boilers with capacities greater than 10 million Btu/hr. Of these, more than 80% were purchased prior to 1978, with the largest share purchased in the 1960's. However, an important window of opportunity to reduce steam generation energy use will open to U. S. manufacturers as they begin to replace their aging stock of existing industrial boilers nearing retirement.

Researchers are working to develop new, breakthrough steam generation technologies that could potentially save U. S. industry billions of dollars per year in operating costs and substantially lower associated environmental impacts. By utilizing a unique boiler geometry incorporating a two-stage fire tube design and heat recovery system that are both compact and highly efficient (>94% HHV efficiency), First

Generation Super Boilers will offer up to 25% increases in steam generation efficiency and occupy substantially reduced footprints relative to their conventional counterparts. Efficiency gains alone could result in total U. S. manufacturing energy cost savings of approximately $6 billion per year. Reduced footprints also enable new opportunities for boiler modularization. **In addition, the First Generation Super Boilers will integrate several novel technologies to achieve extraordinarily low emissions NO<5 ppmv, aiding in compliance with the stringent emissions regulations.**

During the past three decades, several research efforts have been directed to find solutions for NOx reductions. The major NOx emission sources are from vehicles and industrial boilers. Power plant smokestacks are a significant source of dangerous

pollutants, including nitrogen oxides (NOx), sulfur dioxide (SO2), and sooty particles that cause unhealthy ozone and particulate pollution in communities across the nations. Industrial boilers account for 25% of NOx that is emitted worldwide. National emission of NOx over past few years has increased by about 20% whereas all other pollutants have decreased since the implementation of Clean Air Act of 1970 which is a United States Federal law that requires the Environmental Protection Agency (EPA) to develop and enforce regulations to protect the general public from exposure to airborne pollutants that are known to be hazardous to human health.

The Industrial Technologies Program (ITP) of the U. S. Department of Energy (DOE) has developed several energy efficient programs such as Best Practices Tools and Energy Efficient Technologies including NOx and Energy Assessment Tools, which help manufacturers to implement, assess and analyze NOx emissions, and energy efficiency improvements. With the help of these tools we can compare how various technology applications and efficiency measures affect overall costs and reduction of NOx and also select the best method for reducing NOx in a system.

In this paper, an application of NOx and Energy assessment tools to a natural gas boiler is discussed. NOx reduction analysis using current generation low NOx burner, Next generation ultra NOx burner, and Selective catalytic reduction is performed and results are compared. The details of the application to NxEAT and its advantages like reduction of NOx emissions in the environment are discussed.

INTRODUCTION

A boiler is used to produce steam or hot water to meet process applications or building heat requirements. Boilers vary in size depending upon residential or industrial applications for production of steam or hot water and consume millions of Btu/hr. In between these two extremes are many different sizes used to meet all types of commercial and industrial applications. Commercial boilers are used for space heating or in process heating applications. Industrial boilers are used for providing process heat or for space heating. The boilers are classified as:

- Fire tube boilers
- Water tube boilers
- Tubeless boilers

The characteristics of Fire tube boilers are as follows:

- Used for space heating and smaller industrial processes
- Range from 600,000 to 50 Million Btu/hr
- Not suitable for high pressure steam generation or high capacity
- Low cost, Easy to maintain
- Can handle sudden load variations
- Typically operate at 150 psig, 700 Bhp with gasses @ 1700°F

The characteristics of Water tube boilers are as follows:

- Range from 700,000 lbm/hr of hot water to several million pounds per hour of steam
- High pressure can be obtained
- Can reach high temperatures 1000 F
- Scale is built outside the boiler so difficult to clean
- Operate from 150 psig to 600 psig

The characteristics of tubeless boilers are as follows:

- Ranges in size from 20,000 Btu/hr to 4 million Btu/hr

- Upper pressure limit is 300 psig
- Long term cost effectiveness
- Exceptional reliability and minimum level of maintenance

All of them discharge NOxs, CO_2, and SO_2, and other pollutants to the atmosphere resulting in Acid Rain and Global Warming. This paper discusses an approach to reduce these pollutants with the purpose of finding solutions to the problems caused by Acid Rain and Global Warming.

BACKGROUND

The NO Molecule

The NO molecule was first discovered by Joseph Priestly in 1772, the same person who previously had discovered the oxygen molecule.(1)* Under atmospheric conditions, NO appears as a clear, colorless gas. NO is present in the atmosphere as a result of human activities such as the emission of waste gas from combustion processes using fossil fuels, burning biomass, but also from natural sources like soil emissions. NO plays an important role in the formation of photochemical smog and acid rain.

NO is not only a dangerous pollutant, but it is also an essential molecule for living species. NO is produced in nature by animal and plant cells from the amino acid. In 1992, NO was named molecule of the year by the Journal of Science and in 1998, the Nobel Prize in Medicine was awarded for the discovery of the effects of NO in living organisms. Due to its small dimensions, the molecule is able to pass through cell membranes and it can serve as a signaling agent. For example, in mammals, NO helps to maintain blood pressure within certain limits by dilating blood vessels and it plays a role in the regulation of the immune system. It also plays a role in controlling the penile erection, by taking part in the enzymatic pathway responsible for the relaxation of blood vessels. As a matter of fact, Viagra™ amplifies the NO effect in this process. Inside the brain, NO can contribute to the formation of memory and it plays a role in the communication between neurons. Recently, it has been discovered that NO is able to block a protein involved in Parkinson's disease providing new pathways for treatment methodologies(2).

Environmental impact of NOx

The nitrogen monoxide molecule belongs to the family of NOx compounds, which include nitrogen dioxide (NO_2) and nitrous oxide (N_2O). NOx can cause severe health problems and have strong environmental impacts. The main effects are:

- formation of ground-level ozone;
- formation of acid aerosols;
- formation of acid rain;
- deterioration of water quality;
- formation of toxic chemicals;
- global warming.

Below 100 $\mu g/m^3$, plants and vegetable growth are not negatively affected by NO. For human beings, the critical short-term exposure level (24 hours) to NO is around 75 $\mu g/m^3$. For long-term exposure (one year), the critical level is around 30 $\mu g/m^3$ (1).

NOx emissions in the environment cause acid rain, smog and depletion of ozone. Boilers and Power plants are major source of emitters in the environment. They almost emit like 4 million tons every year. So government has taken tough measures like enacting EPA Clean Air Act of 1970. This act has helped to control emissions of CO_2 but NOx still remains a problem. The Government implemented another EPA Clean Air Act, which requires control of NOx emissions.

The NOx emissions in a boiler can be reduced by using current generation low NOx Burner, Next generation ultra NOx burner and Selective catalytic reduction. By using technical parameters and operating conditions NxEAT can determine the most effective method of NOx reduction in boilers (2-5).

NOx and Energy Assessment Tool (NxEAT)

The U. S. Department of Energy's NOx and Energy Assessment Tool (NxEAT) is available at no charge to help industries develop a cost-effective, plant-wide strategy for NOx reduction and energy efficiency improvements.

*Numbers in parentheses refer to the reference numbers

NxEAT allows the user to inventory existing equipment and study several cost-effective NOx reduction methods and energy-efficient best practices. The user starts this analysis by selecting options from a list of standard NOx-reducing methods that relate to specific types of equipment, such as fired systems, utility distribution systems, and other energy-consuming systems including pumps, blowers, and compressors. Next, energy-saving options are selected for each section of the plant and, with the help of the NxEAT database, the tool uses this information to calculate NOx reduction, energy savings, and costs. The tool can then be used to generate several detailed reports that provide the annual amount of NOx reduction, the cost of the NOx-reducing options, energy savings, and comparisons of the options that were analyzed. (6)

Figure 1: Opening NxEAT screen, which shows user choices such as NOx reduction analysis, energy savings analysis, reports, and data options.

Tool Description

NxEAT provides a systematic approach to estimate NOx emissions and analyze NOx and energy reduction methods and technologies. The tool targets specific systems (e.g., fired heaters, boilers, gas turbines, and reciprocating engines) to help identify the NOx and energy savings potential associated with each option. This tool also provides useful calculators that aid in the analysis. Outputs from the tool include:

- Profile of a plant's current NOx emissions, energy use, and annual energy cost for NOx-generating equipment.
- Calculations and comparisons of NOx emission and capital reduction for each analysis.
- Energy savings analysis
- Additional features
  - Tables and charts of NOx and energy savings.
  - Import data from NxEAT database.
  - Export data to the existing NxEAT database.

NxEAT was developed jointly by the U.S. Department of Energy (DOE), Oak Ridge National Laboratory, E3M, Inc., and Texas Industries of the Future. Project participants also include: AZTEC Engineering and the Texas Commission on Environmental Quality Pollution Prevention and Industry Assistance Division, and an advisory committee consisting of members from the chemical and petroleum refining industries.

NxEAT can be downloaded from the DOE's website: www.eere.energy.gov/industry/bestpractices and can be used free of charge. (6)

Case Study

This case study was done by applying the NxEAT tool to boilers at Holmes Hall Bradley University, which are used to meet the Heating, Ventilation and Air Conditioning needs of the University. Three boilers are installed in the facility; two of them are water tube boilers and one is fire tube boiler. These boilers operate on a seasonal shift basis, the fire tube boiler is used in summer and water tube during winter.

Fire Tube Boiler:

Fired tube boiler has a Clever Brooks forced draft natural gas burner. This High-pressure boiler is 30 years old and supplies 30000 pounds/hr steam equivalent to 900 Bhp. This boiler is mainly used for hot water supply and heating purposes.

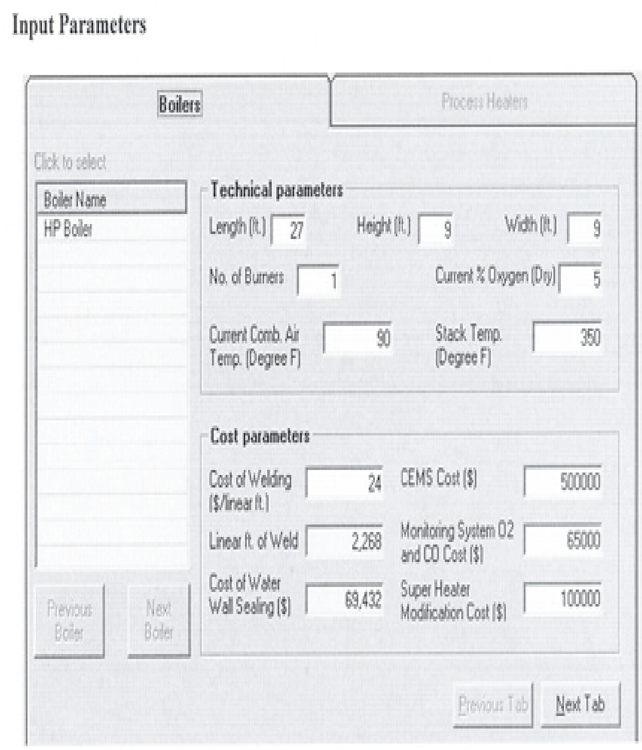
Below are the specifications of the Fire Tube Boiler:

Manufacturer: Cleaver Brooks
Model: 700-700
Length: 27 ft.
Width: 9 ft.
Height: 9 ft.
Current% of Oxygen Dry: 3%
Stack Temperature: 340°F

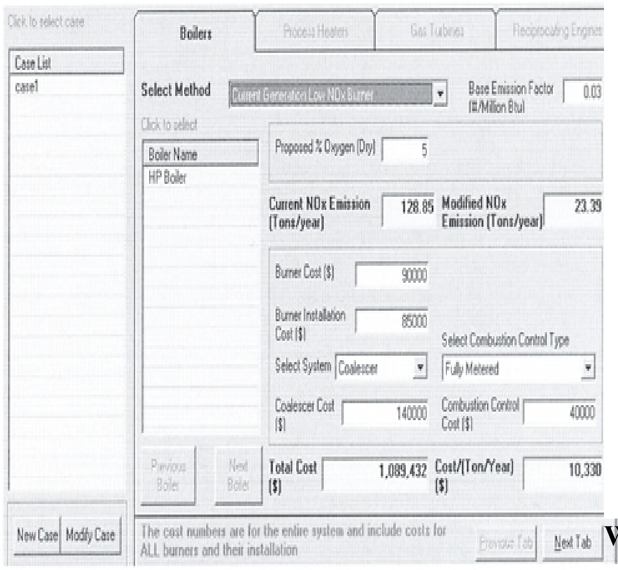
Application of NxEAT

Taking all the parameters into consideration, it was found that if technology of Current Generation Low NOx burner is used, the modified emissions would be 18.05 tons/year. The total cost which includes burner cost and installation charges would be $1,089,432 or cost ton/year would be $9,832. If the Next Generation Ultra Low NOx burner is used, the modified emission would be 11.67 tons/year. The total cost which includes burner cost and installation charges would be $1,184,432, and the cost ton/year would be $10,110. If the Selective Catalyst Reduction is used, the modified emissions would be 12.70 tons/year. The total cost which includes burner cost and installation charges would be $3,764,240, and the cost ton/year would be $32,408.

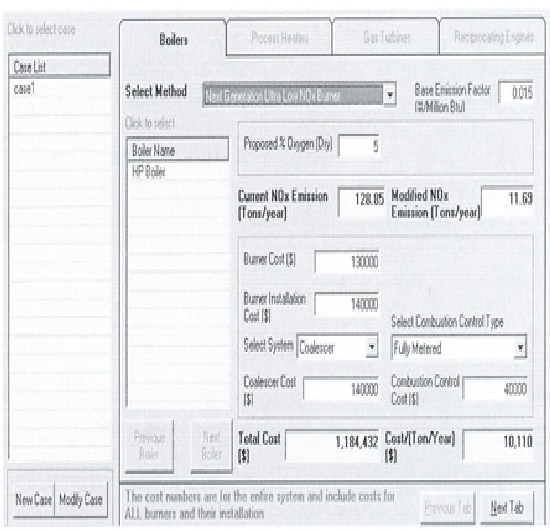
NxEATTool



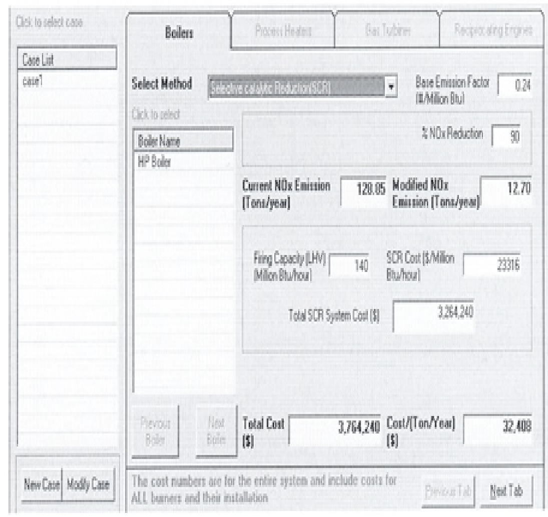
Current Generation Low NOx Readings



Next Generation Ultra Low Nox Burner Readings



Selective Catalyst Reduction Readings



Water Tube Boiler:

There are two water tube boilers out of which one is of Murray Iron Works and the other is Trane Murray.

One Water Tube Boiler supplies 32,000 Pound/hr of steam and its make is Murray Iron Works. It is a High Pressure Boiler. This boiler is used for hot water supply and heating purpose. Second Water Tube Boiler supplies 46,000 pounds/hr. The boiler is used for hot water supply and heating purposes.

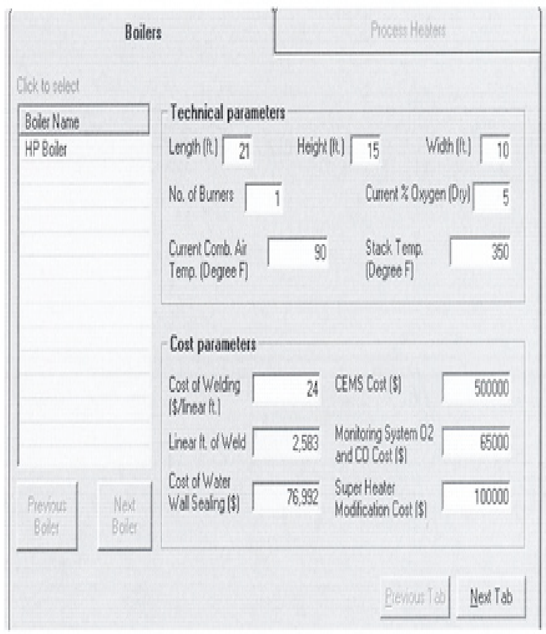
Below are the specifications of the Water Tube Boilers:

Manufacturer: Murray Iron Works
Length: 21 ft
Width: 10 ft
Height: 15 ft
Current % of Oxygen Dry: 3%
Stack Temperature: 350°F

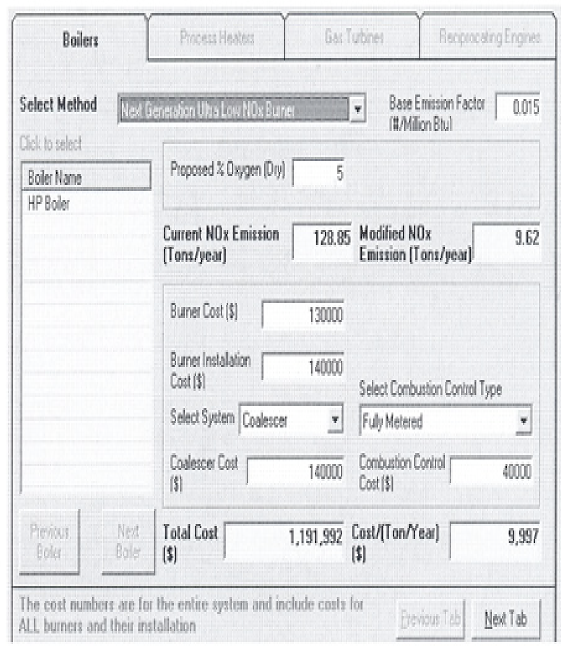
Manufacturer: Trane Murray
Length: 21 ft
Height: 15 ft
Width: 10 ft
Current % of Oxygen Dry: 3%
Stack Temperature: 360°F

NxEAT Tool

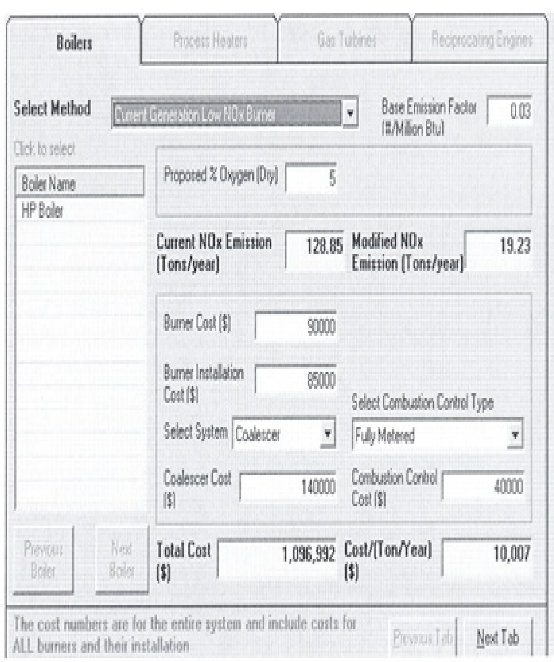
Input Parameters



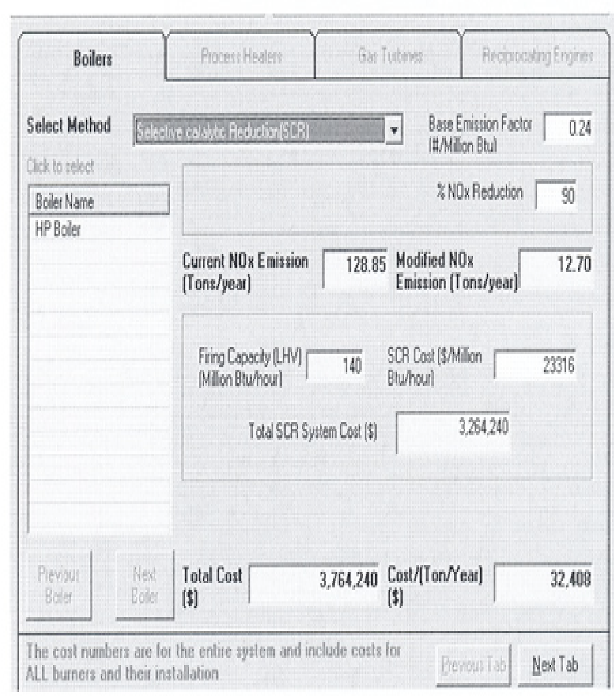
Next Generation Ultra Low Nox Burner Readings



Current Generation Low Nox Readings



Selective Catalyst Reduction Readings



NxEAT Results

Taking all the parameters into consideration, it was found that if technology of current generation low NOx burner is used, the modified emissions would be 19.23 tons/year. The total cost which includes burner cost and installation charges would be $1,096,992 and cost ton/year would be $10,007. If we use the Next Generation Ultra Low NOx Burner the modified emission would be 9.62 ton/year. The total cost which, includes burner cost and installation charges would be $1,191,992 and the cost ton/year would be $9,997. If we use the Selective Catalyst Reduction, the modified emissions would be 12.70 tons/year. The total cost, which includes burner cost and installation charges would be $3,764,240 and the cost ton/year would be $32,408.

Recommendations

In order to reduce NOx emissions from the boilers the burners need to be changed to Current Generation Low NOx Burner, since this burner is best suited for HVAC load requirements. Some of the common other maintenance tasks that have to be done to increase the life of the boilers are to Check Pump System, Low Water-Fuel Cut off, Burner Operations and Gage Glass which are to be done on a daily basis. Vent Louvers and Hot Water Heaters need maintenance on a monthly basis. Fans and Blower Motors and Motor Controls are to be checked on an annual basis.

Conclusions

In fire tube boiler the present burner has NOx emissions in the amount of 128.85 tons/year and by using the current generation burner the NOx emissions can be reduced to 18.05 tons/year.

In Water tube boiler the present burner has NOx emissions in the amount of 128.8 tons/year and by using the current generation burner the NOx emissions can be reduced to 19.23 tons/year.

For this type of low range industries and HVAC applications the current generation low NOx burner is recommended. Whereas the Next generation low NOx burner should be used for Mid Range Industries and Selective Catalyst Reduction should be used for industries like Power Stations.

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