

## ENVIRONMENTAL AND ECONOMIC BENEFITS OF SOME OF AIR POLLUTANTS CONTROL, CASE STUDY: EMISSIONS FROM A BOILER OF A FACTORY

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### ABSTRACT

Excess air is very important factor to increase combustion efficiency, and decrease pollutants emission. In this thesis, we provide that development plans and environmental conservation go in one direction, where we can decrease environmental pollution with economic benefits in the same time. By monitoring the emissions from four stacks (two boilers in petrochemical sector and two boilers in food sector) all are working using natural gas as a fuel. Changing in excess air to increase the combustion efficiency, which means fuel saving, and decrease pollutants concentration. There is a relationship between the cost, combustion, stack heat loss, fuel saving and environment.

By using portable stack gas analyzer combustion efficiency and emitted pollutants through the stacks were measured before and after maintenance and changing air ratio mixed with the fuel. In boiler 1 of the petrochemical sector CO changed from 2222 mg/m<sup>3</sup> to 21 mg/m<sup>3</sup>. In boiler two CO changed from 4695.3 mg/m<sup>3</sup> to 5.5 mg/m<sup>3</sup>. Efficiency of boiler1 and 2 improved from 75.5% to 92.1 %, and from 71.5 to 93.1 respectively. In boiler 1 of food sector CO changed from 2200 mg/m<sup>3</sup> to 45 mg/m<sup>3</sup>. In boiler 2 CO changed from 1900 mg/m<sup>3</sup> to 59 mg/m<sup>3</sup>. Efficiency of boiler1 and 2 improved from 69.8 % to 91.4 %, and from 76.5 to 91.1 respectively. The cost reduction per year in petrochemical sector were 8469.1 \$ in boiler 1 and 11692.8 \$ in boiler 2, while 11624.4 \$ and 12168.2 \$ in boiler 1 and 2 of food sector.

### الملخص

فائض الهواء هو عامل مهم جدا لزيادة كفاءة الاحتراق، وخفض الملوثات الانبعاثات. في هذه الأطروحة، نحن نقدم أن خطط التنمية والحفاظ على البيئة في اتجاه واحد، حيث يمكننا تقليل التلوث البيئي مع الفوائد الاقتصادية في نفس الوقت. ومن خلال رصد الانبعاثات من أربعة أكوام) اثنان من المراجل في قطاع البتروكيماويات واثنين من المراجل في قطاع الأغذية (تعمل جميعها باستخدام الغاز الطبيعي كوقود. تغيير الهواء الزائد لزيادة كفاءة الاحتراق، مما يعني توفير الوقود، وتقليل تركيز الملوثات. هناك علاقة بين التكلفة، الاحتراق، كومة فقدان الحرارة، توفير الوقود والبيئة.

باستخدام المحمولة كومة الغاز محلل كفاءة الاحتراق والملوثات المنبعثة من خلال مداخن تم قياس قبل وبعد الصيانة وتغيير نسبة الهواء مختلطة مع الوقود. في المرجل 1 من قطاع البتروكيماويات كو تغيرت من 2222 ملغ / م<sup>3</sup> إلى 21 ملغ / م<sup>3</sup>. في المرجل 2 من قطاع البتروكيماويات كو تغيرت من 4695.3 ملغ / م<sup>3</sup> إلى 5.5 ملغ / م<sup>3</sup>. كفاءة المرجل 1 و 2 تحسنت من 75.5% إلى 92.1%، ومن 71.5% إلى 93.1% على التوالي. في المرجل 1 من قطاع الأغذية كو تغيرت من 2200 ملغ / م<sup>3</sup> إلى 45 ملغ / م<sup>3</sup>. في المرجل 2 كو تغيرت من 1900 ملغ / م<sup>3</sup> إلى 59 ملغ / م<sup>3</sup>. كفاءة المرجل 1 و 2 تحسنت من 69.8% إلى 91.4%، ومن 76.5% إلى 91.1% على التوالي. وبلغت التكلفة في

السنة في قطاع البتروكيماويات ١٨٤٦٩,١ \$ في المرجل ١ و ١١٦٩٢,٨ \$ في المرجل ٢، في حين ٤,٤ ١١٦٢٤ \$ و ١٢١٦٨,٢ \$ في المرجل ١ و ٢ من قطاع الأغذية.

## 1. INTRODUCTION

A survey of measurements of various types of air pollution inside boiler in two types of industrial sectors (petrochemical and food sectors). On the other hand, calculation of fuel saving, cost reduction, and impact on the public health and thesis organization will be discussed. Types of Air Pollutants according to boiler emission include Nitrogen dioxide, Sulphur Oxides, Carbon Monoxides.

Energy Is defined as the ability of a material or system to perform labor (Dincer and C.

Zamfirescum, 2011)<sup>(1)</sup>. *Fuels are* the fuel is any substance that can be burned to give off heat.

(Boiler plant system, 1980)<sup>(2)</sup>. *Combustion Is the combining of fuel and air in a burning process to produce heat energy* (TSI in corporated (2004)<sup>(3)</sup>.

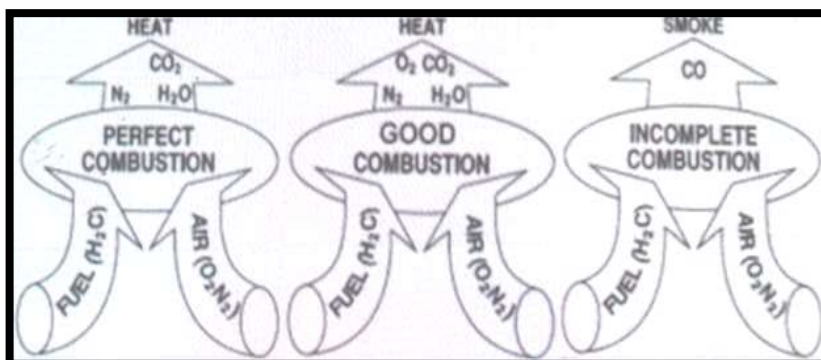


figure 1 Perfect, good and incomplete combustion

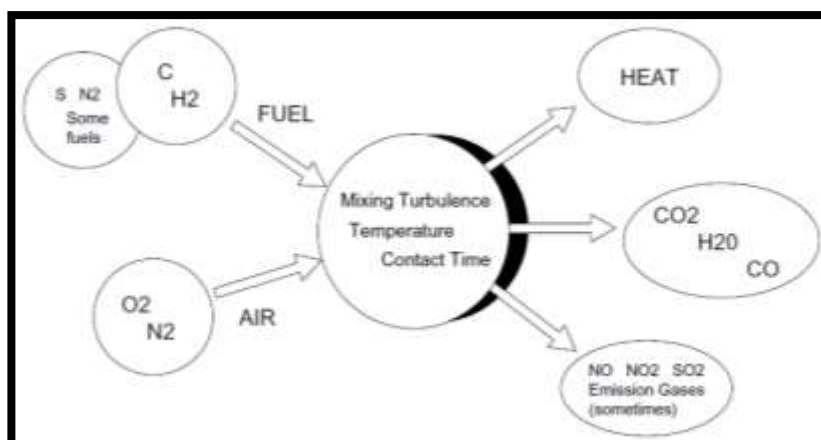


Figure 2 . Combustion Diagram<sup>(3)</sup>

The theoretical air required for the combustion reaction depends on fuel composition and the rate at which the fuel is used (TSI in corporated (2004)<sup>(3)</sup>. The combustion process must be

supplied with more than the stoichiometric volume of oxygen. This additional amount of combustion air is called excess air.

$$\% \text{ excess air} = \frac{\% O_2}{20.9 - \% O_2} \times 100 \quad \text{eq. 1}$$

If the CO concentration is very high, it may also be included in the excess air calculation. This is shown in the following equation.

$$\% \text{ excess air} = \frac{\% O_2 - \frac{\% CO}{2}}{20.9 - (\% O_2 - \frac{\% CO}{2})} \times 100 \quad \text{eq. 2}$$

Adding additional excess air is often done to reduce the CO concentration. Too much excess air can actually have the reverse effect of increasing CO. This results when fuel and air no longer mix properly in the burner, reducing the time of contact between oxygen and fuel and inhibiting a complete reaction.

Combustion efficiency is a measure of how effectively energy from the fuel is converted into useful energy (e.g. to create steam). (TSI incorporated (2004)<sup>(3)</sup>).

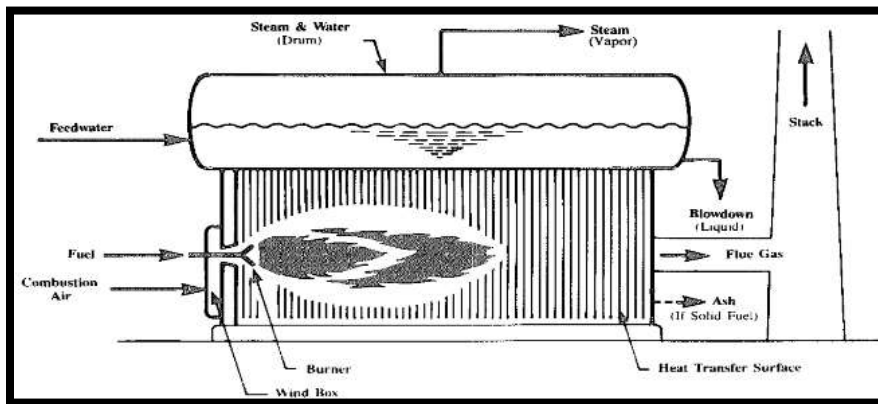
$$\% \text{ com. eff.} = 100 \% - \left( \frac{SHL}{FHV} \times 100 \right) \quad \text{eq. 4}$$

The energy content of a fuel is typically given in Btus per pound of fuel. Stack heat losses heat leaving the exhaust flue with the hot gases is not transferred to do useful work.

Combustion efficiency, determined from combustion analysis, is a cost-effective way to improve equipment operation and reduce fuel expense (TSI incorporated (2004)<sup>(3)</sup>).

**Boilers:**

used to generate steam or hot water. The basic components of the boiler can be shown schematically (Fig 3) kuprianov I.V(2004)<sup>(4)</sup>.



**Figure 3 Basic components of the boiler**

**Environmental Impact of Energy Generation and Utilization:**

The environmental impact of energy use is reduced by increasing the efficiency of energy-resource utilization (often referred to as energy conservation), and by substituting more environmentally benign energy resources for damaging ones.

Objectives of Paper

The objectives of this work are to establish a system for Environmental and Economic Benefits of Some of Air Pollutants Control Emitted from a Boiler of a Factory

## 2. MATERIALS AND METHODS

Stack gases emissions were measured using SENSONIC 2000 portable analyzer, which is a microprocessor controlled environment with pre-calibrated electrochemical cells and temperature sensor for the optimum adjustment of boilers, furnace, kilns, and the monitoring of industrial emissions. The equipment measured the combustion efficiency in addition to stack gases concentration. Combustion efficiency was used in calculation of stack heat loss, fuel saving, and cost reduction through the following equations:

### EQUATION OF CALCULATION:

#### - *Stack heat loss*

% combustion efficiency =  $100 - (\text{stack heat loss}/\text{fuel heating value}) \times 100$  (TSI incorporated (2004)<sup>(17)</sup>, Combustion efficiency optimization<sup>(6)</sup>).

#### - *Fuel saving*

Estimated fuel savings =  $((\text{Improved efficiency} - \text{original efficiency}) / \text{Improved efficiency}) \times 100$ <sup>(7)</sup>

#### - *Cost reduction*

Diff. in eff. Imp. =  $\% \text{Eff}_{af} - \% \text{Eff}_{bef}$   
(Savings/hour) =  $(\text{Diff. in eff. Imp.} \times (\text{Fuel cost/hour}) \times 100$   
Monthly Saving =  $(\text{Savings/Hour}) \times 24 \times (365/12)$   
Annual savings =  $\text{monthly saving} \times 12$

### EFFICIENCY AND PAYBACK TIME:

#### Efficiency

The **payback time** of an energy-saving solution is a measure of how cost-effective it  
Payback time (years) =  $\text{cost of installation (£)} \div \text{savings per year in fuel costs (£)}$

## 4. RESULTS AND DISCUSSION:

This part includes the results and discussion of:

**1- The measurements of different parameters** such as CO, NO, NO<sub>2</sub>, NO<sub>x</sub>, SO<sub>2</sub>, O<sub>2</sub>, CO<sub>2</sub>, Flue Temperature, Ambient Temperature, and efficiency which emitted from boilers in different industrial sectors (Food and petrochemical sectors). On the other hands, different equations will be used to have a new data such as

**2- Stack heat loss,**

$$Com. Eff. = 100 - \left( \frac{SHL}{FHV} \right) \times 100$$

**3- Fuel saving:**

$$EST. F.S = \frac{Imp.Eff.-Org.Eff.}{Imp.Eff.} \times 100 \quad (6)$$

**4- Cost reduction and Payback:**

$$Diff.in Eff. Imp. = Eff.af - Eff.bef$$

$$S.per Hr = Diff.in Eff.Imp. \times F.C.per Hr \times 100$$

$$Mon.S. = S.per Hr. \times 24 \times \left( \frac{365}{12} \right)$$

$$Ann.S. = Mon.S. \times 12$$

#### **4.1 MEASURING DATA FROM BOILERS IN PETROCHEMICAL AND FOOD SECTOR:**

The concentrations of the Carbon monoxide (CO mg/m<sup>3</sup>) were measured in two boilers inside petrochemical sector and recorded levels higher than AQL and all parameters such as (NO, NO<sub>2</sub>, NO<sub>x</sub>, SO<sub>2</sub>) were lower than AQL but it seems to be improved. By the way, the O<sub>2</sub> and CO<sub>2</sub> were not adjusted so this situation makes trouble in the combustion and make it uncompleted. After that we put action plan through corrective action, maintenance has been done, and the measurements were done again and give a good result as follows.

##### **4-1-1 IN PETROCHEMICAL SECTOR**

The measurement of different parameters such as (CO, NO, NO<sub>2</sub>, NO<sub>x</sub>, SO<sub>2</sub> O<sub>2</sub>, CO<sub>2</sub>, Flue Temperature, Ambient Temperature, and efficiency have been measured different time before and after corrective action (Perform the necessary maintenance, ensure that the boiler is operated in a normal manner and adjustments to the combustion process and the excess air-maintenance ratio).

##### **4-1-1-1 IMPROVEMENT PERCENTAGE FOR CO IN BOILER 1**

Carbone monoxide reaches to 2222 mg/m<sup>3</sup> before any action that is mean it increased 8.9 times of AQL. So this value reaches to 888.4 % of AQL. On the other hands the concentration of CO after the corrective action (maintenance) reach to 21 mg/m<sup>3</sup> So the percentage of this value after the maintenance reach to 8.4 % the improvement of this action = 888.8 – 8.4 = 880.4 % as shown in the table (1).

##### **4-1-1-2 Improvement Percentage for CO in boiler 2**

Carbone monoxide reaches to 4695.3 mg/m<sup>3</sup> before any action that's mean it increased 18.7 times of AQL. So this value reaches to 1878.12 % of AQL. On the other hands, the concentration

of CO after the corrective action (maintenance) reach to 5.5 mg/m<sup>3</sup> So the percentage of this value after the maintenance reach to 2.2 % the improvement of this action =  $1878.12 - 2.2 = 1875.92$  % as shown in the table (1).

**Table 1: Emission of the different pollutants from the stack of Boiler at a Company in the petrochemical sector, Alexandria City, 2015.**

Parameters	FT <sup>00</sup> C	AT °C	O <sub>2</sub> %	CO <sub>2</sub> %	CO mg/m <sup>3</sup>	NO mg/m <sup>3</sup>	NO <sub>2</sub> mg/m <sup>3</sup>	NO <sub>x</sub> mg/m <sup>3</sup>	SO <sub>2</sub> mg/m <sup>3</sup>	Efficiency %
AQL					250			300	1600	
<b>Fuel Type: Natural Gas (Petrochemical sector)</b>										
Boiler 1 Before	242	33	14.22	3.76	2222	24.2	0	24.2	7.98	75.5
% according to AQL					888.8			8.07	0.49	
Boiler1 After	340	36	8.9	4.6	21	20.1	0	20.1	4.6	92.1
% according to AQL					8.4			6.7	0.28	
% of improvement					880.4			1.37	0.21	16.6
Boiler 2 Before	236	33	0.65	11.34	4695.3	64.2	0	64.2	61.18	71.4
% according to AQL					1878.12			21.4	3.86	
Boiler 2 After	312	34	9.2	5.1	5.5	19.2	0	19.2	3.1	93.1
% according to AQL					2.2			6.4	0.19	
% of improvement					1875.92			15	3.6	

#### **4-1-1-3 IMPROVEMENT PERCENTAGE FOR NOX IN BOILER 1**

Nitrogen oxides are within the limit in both cases before and after maintenance, but its concentration decrease from 24.2 mg/m<sup>3</sup> to 21.1 mg/m<sup>3</sup> after the corrective action (maintenance). The percentage of improvement is 1.37 % as shown in table (1)

#### **4-1-1-4 IMPROVEMENT PERCENTAGE FOR NOX IN BOILER 2**

Nitrogen oxides are within the limit in both cases before and after maintenance, but its concentration decrease from 64.2 mg/m<sup>3</sup> to 19.2 mg/m<sup>3</sup> after the corrective action (maintenance). The percentage of improvement is 15 % as shown in the table (1).

#### **4-1-1-5 IMPROVEMENT PERCENTAGE FOR SO<sub>2</sub> IN BOILER 1**

Sulfur oxides are within the limit in both cases before and after maintenance, but its concentration decrease from 7.98 mg/m<sup>3</sup> to 4.6 mg/m<sup>3</sup> after the corrective action (maintenance). The percentage of improvement is 0.21 % as shown in table (1)

#### **4-1-1-6 IMPROVEMENT PERCENTAGE FOR SO<sub>2</sub> IN BOILER 2**

Nitrogen oxides are within the limit in both cases before and after maintenance, but its concentration decrease from 61.18 mg/m<sup>3</sup> to 3.1 mg/m<sup>3</sup> after the corrective action (maintenance). The percentage of improvement is 3.6 % as shown in the table (1).

#### **4-1-1-7 IMPROVEMENT PERCENTAGE FOR EFFICIENCY IN BOILER 1 AND BOILER 2 IN THE PETROCHEMICAL SECTOR**

According to the improvement of all parameters such as CO, NO<sub>x</sub>, and SO<sub>2</sub> the efficiency for boiler1 and boiler 2 improved from 75.5% to 92.1 % , and from 71.5 to 93.1 respectively. So all these improvements help the company to save fuel, increase the life time of the boiler, and decrease the emission which impact on the public health as shown in table (1).

#### **4-1-1-8 IMPROVEMENT THE FLOW TEMPERATURE INSIDE BOILER 1 AND BOILER 2 IN THE PETROCHEMICAL SECTOR**

The flue temperature (FT) is one of the very important parameters, which plays an essential role for complete combustion. The change in the temperature boiler1 and boiler2 improved from 242<sup>0</sup>C to 340<sup>0</sup>C and from 236<sup>0</sup>C to 312<sup>0</sup>C respectively. This increase 98<sup>0</sup>C and 76<sup>0</sup>C according to the maintenance of the burning system which helps the boiler to complete all ignited fuel (complete combustion) and this by indirect way help the company to save fuel, and increase the life time of the boiler, and decrease the emission which impact on the public health as shown in Table (1)

#### **4-1-1-9 IMPROVEMENT O<sub>2</sub> % INSIDE BOILER 1 AND BOILER 2 IN THE PETROCHEMICAL SECTOR**

The percentage of O<sub>2</sub> is one of the very important parameters which play an essential role for complete combustion. The change in the O<sub>2</sub> inside boiler1 and boiler 2 improved from 14.22% to 8.9% and from 0,65% to 9.2% respectively, according to this change by increasing and decreasing the efficiency for burning in boiler1 and boiler 2 improved and reach to the suitable ration for O<sub>2</sub>. On the other hands the CO<sub>2</sub> play the same roles and the percentage of it changed from 3.76% to 9.2% and from 11.34% to 5.1% in boiler 1 and boiler 2 respectively. All these adjustments for the ratio of O<sub>2</sub> and CO<sub>2</sub> indirect ways help the company to save fuel, and increase the life time of the boiler, and decrease the emission which impact on the public health as shown in Table (1)

#### **4-1-2 In Food Sector**

The measurement of different parameters such as (CO, NO, NO<sub>2</sub>, NO<sub>x</sub>, SO<sub>2</sub> O<sub>2</sub>, CO<sub>2</sub>, Flow Temperature, Ambient Temperature, and efficiency have been measured different time before and after action plan.

#### 4-1-1-1 IMPROVEMENT PERCENTAGE FOR CO IN BOILER 1

Carbone monoxide reaches to 2200 mg/m<sup>3</sup> before any action that's mean it increased 8.8 times of AQL. So this value reaches to 88% of AQL. On the other hands the concentration of CO after corrective action (maintenance) reach to 45 mg/m<sup>3</sup> So the percentage of this value after the maintenance reach to 8.4 % the improvement of this action =  $88 - 8.4 = 79.6\%$  as shown in table (2)

#### 4-1-1-2 IMPROVEMENT PERCENTAGE FOR CO IN BOILER 2

Carbone monoxide reaches to 1900 mg/m<sup>3</sup> before any action that's mean it increased 7.6 times of AQL. So this value reaches to 760.0 % of AQL. On the other hands, the concentration of CO after the corrective action (maintenance) reach to 23.6 mg/m<sup>3</sup> So the percentage of this value after the maintenance reach to 30.0 % the improvement of this action =  $760.0 - 23.6 = 736.4\%$  as shown in the table (2).

### 2: Emission of the different pollutants from the stack of Boiler at a Company in Food sector, Alexandria City, 2015.

Parameters	FT °C	AT °C	O <sub>2</sub> %	CO <sub>2</sub> %	CO mg/m <sup>3</sup>	NO mg/m <sup>3</sup>	NO <sub>2</sub> mg/m <sup>3</sup>	NO <sub>x</sub> mg/m <sup>3</sup>	SO <sub>2</sub> mg/m <sup>3</sup>	Efficiency %
<b>AQL</b>					<b>250</b>			<b>300</b>	<b>1600</b>	
<b>Fuel Type: Natural Gas Food sector</b>										
<b>Boiler 1 before</b>	234	30	12.2	2.76	2200	700	0	700	36.20	69.8
<b>% according to AQL</b>					880			233.33	5.71	
<b>Boiler1 after</b>	243	30	5.4	6.3	45	47	0	47	2.7	91.40
<b>% according to AQL</b>					18.0			15.67	0.39	
<b>% of improvement</b>					<b>862</b>			<b>217.66</b>	<b>5.32</b>	
<b>Boiler 2 before</b>	234	31	2.1	10.4	1900	550	0	550	24.3	76.5
<b>% according to AQL</b>					760.0			183.33	3.47	
<b>Boiler 2 After</b>	243	31	4.6	7.3	59	90	0	90	4.8	91.1
<b>% according to AQL</b>					23.6			30.0	0.69	
<b>% of improvement</b>					<b>736.4</b>			<b>153.33</b>	<b>2.78</b>	

#### 4-1-1-3 IMPROVEMENT PERCENTAGE FOR NOX IN BOILER 1

Nitrogen oxides were higher than AQL and reach to 700 mg/m<sup>3</sup> before any action that's mean it increase 2.33 times of AQL. So this value reaches to 233.33 % of AQL. On the other hands, the concentration of NO<sub>x</sub> after the corrective action (maintenance) reach to 47.0 mg/m<sup>3</sup> So the percentage of this value after the maintenance reach to 15.67 % the improvement of this action =  $233.33 - 15.67 = 217.66\%$  as shown in the table (2).



#### **4-1-1-4 IMPROVEMENT PERCENTAGE FOR NOX IN BOILER 2**

Nitrogen oxides were higher than AQL and reach to 550 mg/m<sup>3</sup> before any action that's mean it increase 1.83 times of AQL. So this value reaches to 183.33 % of AQL. On the other hands, the concentration of NO<sub>x</sub> after the corrective action (maintenance) reach to 90.0 mg/m<sup>3</sup> So the percentage of this value after the maintenance reach to 30.0 % the improvement of this action = 183.33-30.0 = 153.33 % as shown in the table (2).

#### **4-1-1-5 IMPROVEMENT PERCENTAGE FOR SO<sub>2</sub> IN BOILER 1**

Sulfur oxides are within the limit in both cases before and after maintenance, but its concentration decrease from 36.20 mg/m<sup>3</sup> to 2.7 mg/m<sup>3</sup> after the corrective action (maintenance). The percentage of improvement was 5.32% as shown in the table (2).

#### **4-1-1-6 IMPROVEMENT PERCENTAGE FOR SO<sub>2</sub> IN BOILER 2**

Nitrogen oxides are within the limit in both cases before and after maintenance, but its concentration decrease from 24.3 mg/m<sup>3</sup> to 4.8 mg/m<sup>3</sup> after the corrective action (maintenance). The percentage of improvement is 2.78 % as shown in the table (2).

#### **4-1-1-7 IMPROVEMENT PERCENTAGE FOR EFFICIENCY IN BOILER 1 AND BOILER 2 IN THE FOOD SECTOR**

According to the improvement of all parameters such as CO, NO<sub>x</sub>, and SO<sub>2</sub> the efficiency for boiler1 and boiler 2 improved from 69.8 % to 91.4 %, and from 76.5 to 91.1 respectively. So all these improvements help the company to save fuel, increase the life time of the boiler, and decrease the emission which impact on the public health as shown in table (2).

#### **4-1-1-8 IMPROVEMENT THE FLOW TEMPERATURE INSIDE BOILER 1 AND BOILER 2 IN THE FOOD SECTOR**

The flue temperature (FT) is one of the very important parameters, which plays an essential role for complete combustion. The change in the temperature boiler1 and boiler 2 improved from 234<sup>o</sup>C to 243<sup>o</sup>C and from 234<sup>o</sup>C to 243<sup>o</sup>C respectively. This increase 234<sup>o</sup>C and 243<sup>o</sup>C according to the maintenance of the burning system which helps the boiler to complete all ignited fuel (complete combustion) and this by indirect way help the company to save fuel, and increase the life time of the boiler, and decrease the emission which impact on the public health as shown in Table (2)

#### **4-1-1-9 IMPROVEMENT THE PERCENTAGE OF O<sub>2</sub> INSIDE BOILER 1 AND BOILER 2 IN THE PETROCHEMICAL SECTOR**

The percentage of O<sub>2</sub> is one of the very important parameters, which play an essential role for complete combustion. The change in the O<sub>2</sub> inside boiler1 and boiler 2 improved from 12.2% to 3.4% and from 2.1% to 4.8% respectively, according to these change by increasing and decreasing the efficiency for burning in boiler1 and boiler 2 improved and reach to the suitable ration for O<sub>2</sub>. On the other hands the CO<sub>2</sub> play the same roles and the percentage of it changed from 2.76% to 6.3% and from 10.4% to 7.3% in boiler 1 and boiler 2 respectively. All these adjustments for the

ratio of O<sub>2</sub> and CO<sub>2</sub> indirect ways help the company to save fuel, and increase the life time of the boiler, and decrease the emission which impact on the public health as shown in table (2).

#### 4-2 STACK HEAT LOSS

Calculation of stack heat loss from combustion efficiency, and fuel heat value, which can be known from guideline of inspection of power generation units by EEAA.

$$Com. Eff. = 100 - \left( \frac{SHL}{FHV} \right) \times 100$$

According to the Guideline of inspection of power generation units by EEAA <sup>(8)</sup> as follows

**Table 3: The Calorific value for different types of fuel in Egypt <sup>(8)</sup>**

Fuel	Components weight (percentage)		Calorific value Kj/kg						
	Carbon	Hydrogen	Sulfur	Nitrogen	Oxygen	Ash	Water	Net Calorific Value	Gross Calorific value
Natural gas	70.0	20.0	---	---	---	---	---	50300	59830
LPG	82.4	17.6	---	---	---	---	---	46860	43285
Kerosene	86.0	13.7	0.07	---	---	---	---	45900	43030
Solar	86.3	12.5	1.0	0.05	0.05	0.1	---	44570	41900
Crude Oil	86.0	10.5	3.0	0.05	0.05	0.2	0.2	43250	41080
Cane waste	24.7	2.7	0.1	0.4	20.6	1.5	50	9473	7796

**ble 4: Calculation of stack heat loss <sup>(3)</sup>**

Case studies		Petroleum sector				Food Sector			
parameters	Unit	Boiler 1 before	Boiler 1 after	Boiler 2 before	Boiler 2 after	Boiler 1 before	Boiler 1 after	Boiler 2 before	Boiler 2 after
Difference in efficiency improvement	%	75.5	92.1	71.4	93.1	69.8	91.4	76.5	91.1
Calorific Value (natural gas)	kJ/kg	49830	49830	49830	49830	49830	49830	49830	49830
Stack heat loss/day	Kj	12210000	3936570	14251380	3438270	15048660	4285380	11710050	4434870
Stack heat loss/day	MMBTU	11.57	3.73	14.25	3.44	15.1	4.3	11.7	4.4
Cost of heat loss/day	\$ / day	34.73	11.19	42.8	10.32	45.2	12.9	35.1	13.3
Cost of heat loss/month	\$ / month	1041.6	335.8	1284	309.6	1354.4	385.7	1053.9	399.1
Cost of heat	\$ / annual	12498.7	4029.6	15408	3715.2	16252.6	4628.2	12646.85	478.66
Cost reduction/year	\$ / annual	8469.1		11692.8		11624.4		12168.2	

**4-3- FUEL SAVIN**

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Calculation of estimated fuel saving from measured combustion efficiency improvement in boilers according to the following equation.

$$EST.F.S = \frac{Imp.Eff.-Org.Eff.}{Imp.Eff.} \times 100 \text{ (6)}$$

**Table 5: Shows the fuel saving in four boilers at petrochemical and food sectors**

Sector	Boiler	% of Efficiency before	% of Efficiency after	Difference	% of Fuel saving
Petrochemical	Boiler 1	75.5	92.1	16.6	18.02
	Boiler 2	71.4	93.1	21.7	23.31
Food	Boiler 1	69.8	91.4	21.6	23.63
	Boiler 2	76.5	91.1	14.6	16.03

**4-4- COST REDUCTION AND PAYBACK**

**4-4-1 COST REDUCTION**

Estimated fuel savings = ((Improved efficiency-original efficiency)/Improved efficiency) x 100 <sup>(6)</sup>  
 In the case of that the annual cost of fuel for the company = 100000 \$ so:

**Table 6: the annual saving cost (\$)**

	Boiler	% of Efficiency before	% of Efficiency after	Difference	% of Fuel saving	Saving Cost \$	Saving Cost L.E.
Petroche	Boiler 1	75.5	92.1	16.6	18.02	19565.69	358052.1
	Boiler 2	71.4	93.1	21.7	23.31	25037.59	458188
Food	Boiler 1	69.8	91.4	21.6	23.63	25853.39	473117.1
	Boiler 2	76.5	91.1	14.6	16.03	17596.05	322007.7

**IV-5- IMPACT ON THE PUBLIC HEALTH**

The effects of several selected air pollutants to human health are discussed as follows.

**IV-5-2 Sulphur Dioxide**

Sulfur dioxide is an acute air pollutant to human health, again with the lungs being the target organ. These include irritation and restriction of air passages. There is reduced mucous clearance from the restricted air passages and chest tightness. Otherwise healthy individuals may also experience

sore throats, coughing, and breathing difficulties in addition to noticeable odors at concentrations approaching 0.5 ppm. There are some indications of an increased sensitivity to sunlight due to acute exposure <sup>(9)</sup>.

As for chronic effects, sulfur dioxide is responsible for immune system suppression and increased probabilities of bronchitis. The latter is of particular concern for individuals with emphysema. There are some indications that chronic exposures to sulfur dioxide may also act as a cancer promoter, in addition to being an immune system suppressor. It should be emphasized that the effect of sulfur dioxide on human health can be strengthened by soot particles <sup>(9)</sup>.

#### **4-5-3 NITROGEN DIOXIDE**

In addition to participating in the formation of photochemical ozone at ground level, nitrogen dioxide has its own particular health effects.

Of the two oxides of nitrogen that are included in NON, NO<sub>2</sub> has much the higher toxicity. Nitrogen dioxide has lower solubility than Sulphur dioxide so that a much higher proportion penetrates into the deep lung. There are direct effects on the respiratory system, including increased airway resistance, increased incidence of respiratory illness and damage to lung tissue. Therefore, the acute effects of nitrogen dioxide are both direct and indirect. The direct effects are damages to the membranes in the lung tissues as well as constriction of the airway passage. Asthmatics are in particular affected by these acute effects. The indirect effects are that nitrogen dioxide causes edema or a filling of the intercellular with fluid, which develops into local areas of infection.

Among the chronic effects of the long-term exposures to nitrogen dioxide is necrosis, a term for direct cell death. In addition, there is evidence of nitrogen dioxide causing a thickening of the alveolar walls of the lungs, which interfere with efficient oxygen and carbon dioxide exchange across those cell walls. Short- duration exposure to nitrogen dioxide has also been shown to increase lung reactivity to other pollutants <sup>(9)</sup>.

#### **4-5-4 CARBON MONOXIDE**

Carbon monoxide combines with blood hemoglobin 200 times more readily than oxygen. Since hemoglobin is the oxygen- carrying protein which is responsible for the oxygen and carbon dioxide exchanges necessary for life, it is clear that at a high level of carbon monoxide, the potentially exists asphyxiation. The formation of carboxyl-haemoglobin molecules can no longer transport oxygen from the lungs around the body, and hence the oxygen supply to the brain and other organs is reduced <sup>(9)</sup>.

### **5- CONCLUSIONS:**

1- Carbon monoxide emitted from the boilers was higher than AQL of law 4 for 1994 which modified to law 9 for 2009 before applying the maintenance and corrective action plan for the boilers in petrochemical and food sectors.

- 2- Nitrogen oxides recorded concentration within the limit in the petrochemical sector but were higher than AQL in food sector applied the maintenance and corrective action plan for the boilers in petrochemical and food sectors.
- 3- Also, the Sulphur dioxide was within limit before and after applying the maintenance and corrective action plan for the boilers in petrochemical and food sectors. but it decreases after applied the action plan.
- 4- The efficiency of the burning improved after applied the maintenance and corrective action plan for the boilers in petrochemical and food sectors.
- 5- Oxygen and Carbon dioxide change to the best ration applied the maintenance and corrective action plan for the boilers in petrochemical and food sectors.
- 6- Flue Temperature increase after applied the maintenance and corrective action plan for the boilers in petrochemical and food sectors.
- 7- All parameters such as (CO, NO<sub>x</sub>, and SO<sub>2</sub>) give Improvement Percentage for Efficiency of the boiler after applied the maintenance and corrective action plan for the boilers in petrochemical and food sectors.
- 8- Fuel saving reaches to 18.2, 23.31, 23.63, and 16.03 for the boiler1 petrochemical sector, boiler 2 petrochemical sector, boiler1 food sector, boiler2 food sector respectively.
- 9- Applied to the maintenance and corrective action plan in the boilers of petrochemical and food sector already help the two companies in the two sectors in cost reduction.
- 10- According to the improvement which already happened in the boilers of petrochemical and food sectors after applied the maintenance and corrective action plan all these will help as a positive impact on the public health by indirect way inside the working environment and ecosystem as all.

## **6- RECOMMENDATIONS:**

- 1- Air flow should vary with the fuel flow in order to keep a fixed ratio of air flow to fuel flow. A good controller should be able to keep this ratio steady within 1% to 2% of an operating set point.
- 2- Periodic measurements (Air flow can be controlled much more precisely by using measured exhausted O<sub>2</sub> concentration, where Exhaust O<sub>2</sub> is a direct indicator of the actual air flow relative to the theoretically required amount)
- 3- Put an annual program for training such as:
  - Operation. Boiler operation is energy intensive, making efficient operation an important cost reduction activity.
  - Maintenance.(If the equipment is properly maintained, losses such as those from steam leaks are minimal. Convection and radiation losses are often small also, and usually unavoidable)
  - Follow up and adjusting the combustion conditions.
  - Contingency plan especially for boiler department.
  - Emergency plan.
  - Calculate the Stack heat loss
  - Calibration the stack such as Analyzer Principle Measures NDIR: Non-Dispersive Infrared - Carbon Monoxide - Sulfur Dioxide - Carbon Dioxide Chemiluminescent - Nitric Oxide - Nitrogen Dioxide - Total NO<sub>x</sub> FID (Flame Ionization Detector) • Methane - Propane - Total Hydrocarbons Paramagnetic - Oxygen

- Using high and environmental technology in the boiler system

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