Waste Heat Recovery Boiler (WHRB) at Nimra Textile Ltd. Faisalabad

1 Executive Summary

Installation and operation of Waste Heat Recovery Boiler (WHRB) at Nimra Textile Limited, Faisalabad is one of the pilot projects under SCI-Pak project. Nimra Textile Limited has installed Waste Heat Recovery Boiler (WHRB) at its facility to produce steam by utilizing waste energy of the flue gases of its Power House Generators. The steam generated from waste heat is being used in the process. This project has results in fuel savings and reduction in green house gases emissions.

2 Project Purpose

The purpose of the project was to recover waste heat from the flue gases of captive power plant of accumulative rated capacity of 1,250 kW. This was done by installing a Waste Heat Recovery Boiler of capacity 1.5 tons per hour. This intervention resulted in estimated fuel saving of 51m^3/hr which can yield an annual financial benefit of Rs. 4.6 million for next 20 years.

3 Previous Process

Waste heat is the energy associated with the waste streams of air. Exhaust gases, and/ or liquids that leave the boundaries of a plant or building and enter the environment. There are many such waste streams in a process plant. The potential for economic waste-heat recovery, however, does not depend as much on the quantity available as it does on whether its quality fits the requirements of the potential heating load which much be supplied and whether the waste heat is available at the times when it is required.

Figure 1: Captive Power Plant at Nimra Textile Ltd.

Captive power plants are a common utility in textile processing. It is estimated that the 25~30% of thermal energy supplied for power generation to internal combustion engines leaves as waste heat through stack. Main source of electricity in the Nimra is the captive power. There are two natural gas fuel based electricity generators in the mill with the total capacity of 1,250 kW or 1.25 MW (900 kW & 350 kW). The combustion process in these generators produces flue gases at a very high temperature of about 390°C. Previously these energy extensive flue gases were allowed to emit in the atmosphere without any heat recovery. The estimated amount of energy being wasted was 1,583 MJ per hour (About 56 m^3 natural gas/hr).

4 Improved Process

Nimra installed this WHRB in December 2010 to recover this energy to produce process steam.

Figure 2: Waste Heat Recovery Boiler at Nimra Textile Ltd.

WHRB is a package type boiler with design capacity of **1.5 ton steam per hour** (242 m^2 heating surface area). It is designed on the basis that the flue gas stream of each generator uses its own path independently. So there are two separate flue gas paths in the boiler for each generator. Flue gases from both the generators are introduced into the WHRB separately at a temperature of about **390°C**. There are also **two economizers** (bundled into one body) installed at the exhaust of flue gases from the boiler to preheat the boiler feed water. This economizer has also separate arrangement for each stream of flue gas (**Duplex Exchanger**).

The exhaust gases from the boiler at about 140°C temperature are introduced into the economizer to preheat the incoming reverse osmosis treated boiler feed water up to 90°C temperature. This water remains in circulation in the economizer till its temperature reaches to 90°C. The flue gases at a temperature about 130°C from the economizer are then ultimately wasted into the atmosphere. **Boiler blow down** is about 3% of the total steam produced from the boiler. The overall **boiler efficiency** 91% (for details see annex I).

Expected life of the boiler is 20 years.

Figure 3: Waste Heat Channels from Generators to WHRB

Water flow meter is installed at the inlet of boiler feed water. Steam quantity is estimated through boiler feed water consumption quantity. The temperature and pressure gauges are installed at the flue gases lines, boiler, economizers and boiler feed water tank.

5 Project Financing

- Project Cost: **Rs. 5.3 Million**
- The project was financed by Nimra Textile Ltd. from its internal equity. No bank financing was obtained.

6 Project Vendor

The project was executed by:

INDUSTRIAL BOILERS (PVT) LTD
10-km.G.T.Road, More Eminabad,
Gujranwala-Pakistan.
Tel: 055-3263700
Contact Person: Mian Maqsood Ahmad

7 Saving Calculations

7.1 Savings in steam:

Capacity of WHB (Designed)	**1.5 t/hr**
Quantity of water used per day	13 ton
Blow down per day	0.39 ton (@3% of total steam produced)
Steam produced per day	12.61 ton
Steam produced per hour	0.52 ton
Enthalpy at 100 psig	2761177 j/kg (@110psia)

Steam energy per day	0.52 x 1000 x 2761177
	1,435,812,378 j/hr
Gas consumed to produce this much energy	1,435,812,378/35,359,380
40.60 m^3/hr (100% efficiency) or 50.75 m^3/hr (80% efficiency) where calorific value of natural gas is 35,359,380 j/m^3	
Or 50.75 x 24 x 300 x 12.50[1]	**Rs. 4,568,205/year**

7.2 Payback Calculations

Capital cost of Pilot Plant	**5,300,000 Rs**
O & M Cost	3,200 per day
	960,000 Rs/year
Net profit	Steam saving – O&M cost
	4,568,205 – 960,000
	3,608,205 Rs/year
Pay back	(Capital cost / Net profit) x 12
	(5,300,000 / 3, 608, 205) x 12
	17.60 month

[1] Assumptions:
Boiler Efficiency: 80%
Cost of Natural Gas: Rs. 12.50/m^3
Working Days: 300

8 Financial Performance of the Project:

Year	1	2	3	4	5	6	7	8	9	10	11
Cash Flows from operating Activities:											
Capital Expenditure	(5,300,000)										
Revenue from Savings		3,608,205	3,608,205	3,608,205	3,608,205	3,608,205	3,608,205	3,608,205	3,608,205	3,608,205	3,608,205
Depreciation		(265,000)	(265,000)	(265,000)	(265,000)	(265,000)	(265,000)	(265,000)	(265,000)	(265,000)	(265,000)
Recurring Cost		(960,000)	(960,000)	(960,000)	(960,000)	(960,000)	(960,000)	(960,000)	(960,000)	(960,000)	(960,000)
Cash Flow	**(5,300,000)**	**2,383,205**	**2,383,205**	**2,383,205**	**2,383,205**	**2,383,205**	**2,383,205**	**2,383,205**	**2,383,205**	**2,383,205**	**2,383,205**
NPV @15% Discount Rate	**11,960,754**										
IRR	**44%**										

9 Timeline

Timeline of Project		Project Duration																							
		Month 1				Month 2				Month 3				Month 4				Month 5				Month 6			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Milestone1	Feasibility Study for WHRB																								
Milestone 2	Fabrication of WHRB																								
Milestone 3	Commissioning																								
Milestone 5	**Start of Steam Generation from WHRB**																								

10 Annex I: WHRB Efficiency Calculations

From the combustion reaction of methane $CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$, it is clear that one mole of methane requires 2 moles of oxygen for combustion. 2 moles of oxygen also contains 7.52 moles of nitrogen because air contains 79% nitrogen and 21% oxygen (79/21 x 2 = 7.52). Combustion products include 1 mole of carbon dioxide and 2 moles of water vapors. It can be written as:

Chemical Reactants

CH_4	**1 mole**	**9% (volume %)**
O_2	2 moles	19%
N_2	7.52 moles	72%

Combustion Products

CO_2	**1 mole**	**9% (volume %)**
H_2O	2 moles	19%
N_2	7.52 moles	72%

On average 264 m^3 per hour is supplied to the captive power plant at Nimra Ltd.

Gas	Molar Volume	Relative Volume	Volume
CH_4	**1 mole**	**9%**	**264 m^3**
O_2	2 moles	19%	528 m^3
N_2	7.52 moles	72%	1,985.28 m^3
Total	**2,777.28m^3**		

10% excess air is used for the combustion so the above values of O_2 and N_2 will be as;

Gas	Molar Volume	Relative Volume	Volume
O_2	2.2 moles	21%	580.8 m^3
N_2	7.52 moles	72%	2183.8 m^3
Total	**2764.6 m^3**		

Hence the reactants quantities become;

Gas	Molar Volume	Relative Volume	Volume
CH_4	1 mole	8.71%	264 m^3
O_2	2.2 moles	9.17%	580.8 m^3
N_2	8.27 moles	72.11%	2183.8 m^3
Total	**3028.6m^3**		

3028.6 m^3 air gas mixtures will produce same quantity of flue gases with following quantities:

Gas	Molar Volume	Relative Volume	Volume
O_2	0.2 mole	1.76%	50.8 m^3
CO_2	1 mole	8.71%	264 m^3
H_2O	2 moles	17.42%	528 m^3
N_2	8.27 moles	72.11%	2183.8 m^3
Total	**3028.6 m^3**		

Density of above gases:

Gas	Density (kg/m³)
N_2	1.23
CO_2	1.952
H_2O	0.8
O_2	1.428

Average density of flue gases = 0.72 x 1.23 + 0.09 x 1.952 + 0.19 x 0.8+1.428 x 0.0176 = 1.221 kg/m^3

Specific heat of flue gases:

Gas	Density (kg/m³)
N_2	1,046 j/kg-°C
CO_2	1,004
H_2O	1,882
O_2	1,044.45

Average specific heat of gases = 0.72 x 1046 + 0.09 x 1004 + 0.19 x 1882 +1044.45 x 0.0176 = 1,189j/kg-°C

Energy in the flue gases = Q = m x cp x ΔT = 3028.6 x 1.221 x 1,189 x (390-30)

=1,583,460,748 j/hr

10.1 Energy Delivered by Waste Heat Recovery Boiler:

Capacity of WHB (Designed)	1.5 t/hr
Quantity of water used per day	13 ton
Blow down per day	0.39 ton (@3% of total steam produced)
Steam produced per day	12.61 ton
Steam produced per hour	0.52 ton
Steam energy	m λ
Enthalpy (λ) at 100 psig	2761177 j/kg (@110psi)
Steam energy per day	0.52 x 1000 x 2761177
	= 1,435,812,378 j/hr

- Energy in the Hot Water in to the boiler = Hot water obtained from economizer due to the flue gases of boiler
- Energy of Flue gases from boiler to the atmosphere are wasted

10.2 Energy Balance:

Energy In	Energy Out
Flue gas to Boiler+ Hot water	Steam + Hot water (economizer) + Exit flue gases
1,583,460,748 +hot water	1,435,812,378+hot water+ Exit flue gas

10.3 Thermal Efficiency of the WHRB:

Efficiency of boiler (Thermal)	**(Energy in steam out/ energy in flue gas in) x 100**
	(1,435,812,378/1,583,460,748) x 100
	91 %