Systematic Approach for Energy Saving in Textile Industry: A Case Study on Energy Audit

Kuldeep H. Nayi[1] Prof. K. D. Panchal[2]
[1]P.G. Student [2]Assistant Professor
[1,2]Department of Mechanical Engineering
[1,2]Government Engineering College - Valsad, Gujarat (India)

Abstract— Energy is the key point of all the processes in the world and this energy is available in many forms and utilized in any way as per the requirement. But the availability of some type of energy is not infinite however as well as high cost of fuels resulted in more activities to conserve energy to maximum extent. Continuous energy audit and process tracking is most important for reducing energy consumption to achieve energy security, energy independency and sustainable develop of individual as well as of the nation. Textile industries have higher involvement of energy uses in various processes and plant and also so much energy losses due to insufficient/ ineffective technologies. This present study mainly focused on one Textile industry to execute energy audit to find out possible reason of energy wastage. Main target is to recover or save the energy used in Boiler section by means of controlling Air-Fuel ratio (amount of excess air). From this study, we can obviously say that there is great impact of amount of air required for combustion in the energy utilization in boiler.

Key words: Energy Audit and Conservation, Textile industry, Excess Air, Boiler Section

I. Introduction

At present scenario, we all are Energy-Slave so it is most important to save and conserve the energy for our future to achieve energy security and independency and this only possible by the energy audit. Energy audit is the process or tool of examining the utilization of energy in various forms at considered area.

In India, there are great impact of industrialization and globalization therefore so many industries and manufacturing plants are installed. In any industry, the three top operating expenses are often found to be energy (both electrical and thermal), materials and labour. Amongst these entire if we think of cost or potential cost savings then energy would invariably emerge as a top ranker. Hence, energy management function constitutes a strategic area for cost reduction. Lack of awareness about energy saving, energy management, energy conservation, energy crisis, energy security, advanced technologies and financial supports for adopting such technologies are the main reason behind such situation.

Energy audit is tool that identifies criticalities is any process /industry /building and provides retrofit solution for improvement of energy efficiency and utilization.

The textile industry is one of the major energy consuming industries and retains a record of the lowest efficiency in energy utilization. About 23% energy is consumed in weaving, 34% in spinning, 38% in chemical processing and another 5% for miscellaneous purposes.

The need of energy management has assumed paramount importance due to the rapid growth of process industries causing substantial energy consumptions in textile operations. Conservation of energy can be affected through process and machine modification, new technologies and proper chemical recipes. The possibilities of utilizing new energy resources are yet to be explored.

One of the most cost effective means of improving operating efficiency is by controlling the amount of combustion air supplied to the boiler. Too low quantity of air does not achieved the complete combustion of fuel hence some much energy loss and increase the emission particle through exhaust that cause higher cost of exhaust treatment and pollute the environment. Whereas higher amount of air decrease energy efficiency of boiler due to losses up the boiler’s stack resulting from the boiler’s having to heat the extra air. All boilers required more combustion air than the theoretical minimum to ensure complete combustion. UNIDO has specified the limit for the percentage of excess air for different types of fuel used that gives maximum efficiency.

Present work is one step towards achieving energy saving and efficiency in such type of textile industry in form of Energy Audit. This paper deals with the various option of saving energy especially in Boiler by finding the causes of energy wastage. This paper gives the idea about how excess air, leakage in steam pipeline and bared pipeline (improper insulation) affect the energy consumption. Suggestion with saving amount has to be calculated for proposed/suggested modification in the plant.

II. Types of Energy Audit

There are mainly two types of energy audit…

1) Preliminary Audit (Walkthrough Audit)
2) Detailed Audit

The preliminary energy audit uses existing or easily obtained data. It is a quick exercise to:

- Determine energy consumption in the organization
- Estimate the scope for saving
- Identify the most likely (and easiest areas) for attention
- Identify immediate (especially no-cost/low-cost) improvements/savings
- Set a reference point
- Identify areas for more detailed study/measurement

Whereas A detailed energy audit provides a comprehensive energy project implementation plan for a facility, since it evaluates all major energy-using systems. This type of audit offers the most accurate estimate of energy savings and cost. It considers the interactive effects of all projects, accounts for the energy use of all major equipment, and includes detailed energy cost saving calculations and project cost. In a detailed audit, one of the key elements is the energy balance.

Detailed Energy auditing is performed in 3 phases:

- Phase I – Pre-Audit

- Phase II – Audit
- Phase III – Post-Audit

III. GENERAL PROCESSES INVOLVED IN TEXTILE INDUSTRY

A. Doubling

In the Doubling process, thin single yarn is converted to double yarn for strengthening the yarn by using doubling machine

B. Yarn Dyeing

Initially, the yarn is soaked in soap water for 24 hours to remove the dirt and other foreign materials and then after yarn is taken for bleaching. Bleaching is carried out by soaking the yarn in tanks mixed with bleaching agents and after completion of the process; the yarn is washed with normal water. The hank dyeing machine tanks are filled with required quantity of normal water and required chemicals and dyeing agents are added. The temperature of the water is raised by oil circulation or direct steam injection. Fire wood is used as fuel. The required colors are added to the yarn and the dyeing process takes about 90 to 120 minutes per batch. After dyeing, the yarn is washed with normal water, and the yarn is taken for soaping for colour fixation in hot water for about 20 minutes in hank dyeing machines. The water is drained to the waste drainage lines.

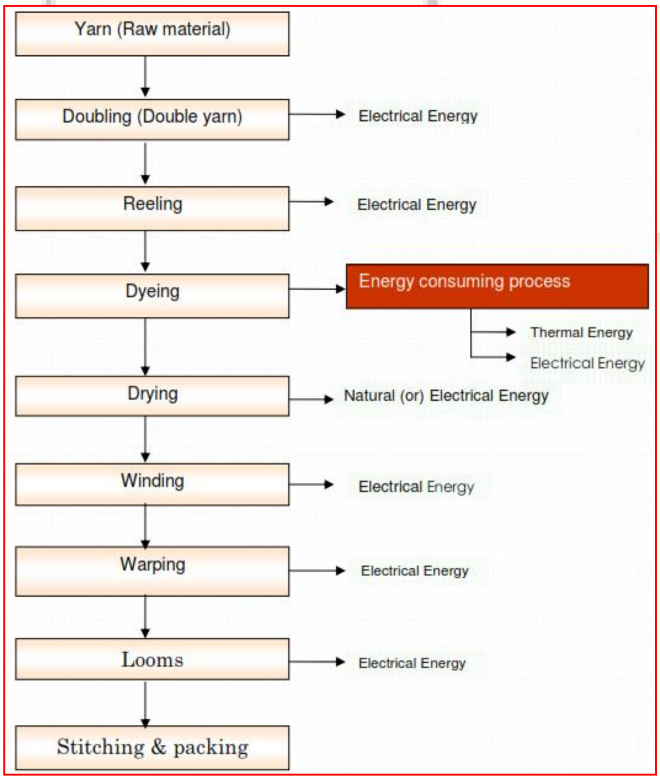

Fig. 1: Process Flow chart of Textile Plant

C. Drying

The wet yarn is taken to hydro extractors for removing the water in the yarn and taken for drying in the natural sunlight.

D. Winding

The yarn after drying is taken for winding in which the yarn is wounded to bobbins and cones. The winded yarn is taken for further process.

E. Warping

In warping, the winded yarn is wound to beams according to designed pattern (customized designs). Then the beams are taken for Weaving.

F. Weaving

The beams, which are wound with yarn are taken and placed in power looms where the designed pattern is already set. In power looms, the yarn is converted to final product by weaving machine. The product obtained from weaving is taken for stitching and packing.

For this research work I have considered one textile industry that produces Knitted fabrics, dyed cloths and yarns. For the energy auditing, Knitting section and Dyeing section had been inspected. The main objectives behind this work is to modify and upgrade the existing treatment plant, to adopt long term economically viable cleaner production approach and to investigate energy conservative measures. From the Walkthrough audit as a first and primary step of energy audit, I observed that there are so many reasons for wasting of energy in any form (i.e. thermal or electrical or material). I observed the following points…

- Leaks and overflow in production areas
- Bad housekeeping at dye kitchen
- Exhaust of boiler is at higher temperature
- Higher emission from the boiler
- Leaks is steam pipeline
- Improper arrangements of lighting and other electrical equipments
- Use of outdated equipments and technologies
- Improper insulation over steam pipeline and other pipelines
- Bad smell from WWTP/Production
- Improper utilization of WWTP
- No proper measuring instruments in boilers

IV. BOILER ANALYSIS

- Available data from measurement, indicators and control panels.

Oil fuel Consumption: m_f = 750 kg/h
Oil fuel constituents: C = 85.9 %, H = 11.8 %, S = 2 %, H_2O = 0.3 %, Ash = 0.008 %
High Calorific Value of fuel = 39,700 kJ/kg of fuel
Flue Gas Temperature = 310 ℃
Flue Gas constituents: O_2 = 8.2 %, CO_2 = 7.16 moles, SO_2 = 0.063 moles
Oil Heater = 8 kW
Oil Pump = 1 kW
Fan = 30 kW
Pumps = 16 kW
Water Feed = m_w = 10 m^3/h
Blow Down = m_b = 0.6 m^3/h
Steam Condition: 10 bar, 180 ℃
Convection & Radiation Losses = 7,50,000 kJ/h
Ambient temperature = 30 ℃
From Steam Table:…
Enthalpy of Feed Water = h_f = 217.7 kJ/kg
Enthalpy of Steam = h_s = 2,278.2 kJ/kg
Enthalpy of Water at steam = h_b = 763 kJ/kg

A. Excess Air Calculation

Theoretical Air Requirement (Theoretical A/F Ratio):
From fuel constituents.

Constituents (MW)	% weight for 100 kg of fuel	Moles (%weight / MW)	Moles of O_2 required
C (12)	85.9	7.16	7.16
H (2)	11.8	5.90	2.95
S (32)	2.0	0.063	0.063
Theoretical requirement of total moles of O_2			10.173

Table 1:

Theoretical A/F Ratio
= (O_2 Moles)(MW of O_2)+(3.76)(O_2 Moles)(MW of N_2)
= (10.173) (32) + (3.76) (10.173) (28)
= 1396.549 kg Air / 100 kg of fuel
Theoretical A/F Ratio = 13.97 kg of Air / kg of fuel

– Actual Air Requirement (Actual A/F Ratio):
From flue gas constituents.
Let, x = moles of O_2 in flue gases
N_2 (Theoretical) = 3.76 × Theo. Mole of O_2
= 3.76 × 10.173
= 38.25 moles
N_2 (Actual) = 3.76 × Actual Mole of O_2 = 3.76 x

– Total moles in flue gas
= 7.16 + 0.063 + 38.25 + x + 3.76 x = 45.47 + 4.76 x
Moles of O_2 in flue gas = $\frac{x}{45.47+4.76\,x} = \frac{8.2}{100}$
⇒ x = 6.12 moles of O_2

– Actual O_2 = 10.173 + 6.12 = 16.29 moles

– Actual A/F Ratio
= (O_2 Moles)(MW of O_2)+(3.76)(O_2 Moles)(MW of N_2)
= (16.29) (32) + (3.76) (16.29) (28)
= 2236.30 kg Air / 100 kg of fuel

– Actual A/F Ratio = 22.36 kg of Air / kg of fuel

– **Excess Air Supply**
$= \frac{\text{Actual A/F Ratio} - \text{Theoretical A/F Ratio}}{\text{Theoretical A/F Ratio}} \times 100$
= 60.06 % (Very high)

B. Energy Balance in Boiler

– Energy Input
Fuel Energy = H.C.V. of fuel = 39,700 kJ/kg of fuel
Shaft Work (Electricity Input):
Oil Heater = (8 kW × 3600) / 750 = 38.4 kJ/kg
Oil Pump = (1 kW × 3600) / 750 = 4.8 kJ/kg
Fan and Pumps=(46 kW×3600)/750=220.8kJ/kg
Total Energy input = 39700 + 38.40 + 4.80 + 220.80
= 39,964 kJ / kg of fuel

– Energy Output
Useful Output (Steam) = $m_w (h_s – h_f) / m_f$
= 10×1000 (2278.2 – 217.7) / 750
= 27,473.33 kJ/kg
Energy lost in flue gases = m C_p (T_2 – T_1)
= 22.36 × 1.0 (310 – 30)
= 6,260.80 kJ / kg
Energy Lost in Blow Down = $m_b (h_b – h_f) / m_f$
= 0.6 × 1000 (763 – 217.7) / 750
= 436.24 kJ/kg
Radiation & Convection Loss = 750000/ m_f
= 750000 / 750 = 1,000 kJ /kg
Energy Lost in water vapor = m (S+L+V)
=1.062 (292.6+2200+457.8)
= 3,133.32 kJ/kg of water
Where,
m = water formed = 0.118 × 9 = 1.062 kg / kg of fuel
S = Sensible Heat of water due to raise in temperature
= C_p (T_2 – T_1) = 4.18(100 – 30) = 292.6 kJ / kg of water
L = Latent heat of water at atm. Condition
= 2,200 kJ / kg of water
V = Sensible heat of water vapor
= 2.18 (310 – 100) = 457.80 kJ / kg of water
Total Energy output
= 27473.33 + 6260.8 + 436.24 + 1000 + 3133.32
=38,303.70 kJ/kg of fuel
(Unaccounted losses due to assumption in calculation = 1660.30 kJ/kg = 4.15 %)

– Boiler Efficiency = η = 27,473.33 / 39,964 = 0.6875 = 68.75 %

V. RESULTS AND DISCUSSIONS

Amount of excess air is must be as per requirement because lower amount of air does not achieved complete combustion of fuel whereas too much excess air cool down the fire and increase stack losses. Both way the boiler energy efficiency decreases and increase in energy losses. Excess air, as % of part load air, increases. This is because the leakage areas and consequently the tramp air ingress practically remain the same while the combustion air is reduced.

As per standards given by UNIDO, for oil fuel excess air must be approx. 20 % for maximum utilization of energy with very less energy loss but in our case it is 60.06 % which is too much higher so this is the main reason behind the losses of the energy and lower energy efficiency. This indicates that there is requirement of improvements in the control of air supply system (i.e. valves, fans, blowers etc...).

Fuel	Firing	Excess Air by Weight at Full Load (%)
PF	Water-cooled furnace	15–20
Coal	Stoker	30–45
FO	Register burner	3–15
NG, RG,COG	Register burner	3–10
BFG	Scroll burner	15–20
Bagasse	All grates	25–35
BL	Recovery furnace	5–7

Table 1: Excess Air Required For Various Fuels And Firing Equipments

– Energy savings from controlling excess air at Boiler**:**
Optimum excess air for Oil fuel is 20 %.
0.20 = (weight of opt. excess air) / (weight of theo. air)
Weight of opt. excess air = 0.20 × 13.97 = 2.794 kg
Weight of O_2 in opt. excess air = 2.794 ×0.232
= 0.65 kg
Weight of N_2 in opt. excess air = 2.14 kg
Energy losses in flue gases at opt. excess air
= m C_p (T_2 – T_1)
= (13.97 + 2.794) (1.02) (310 – 30)
= 4,787.80 kJ /kg of fuel

But Energy losses in flue gases at 60.06 % excess air is 6,260.80 kJ /kg of fuel
Energy saving at opt. excess air
= 6,260.80 – 4,787.80 = 1,473.00 kJ / kg of fuel
Energy Saving per Hour at opt. excess air
= 1,473.00 × 750 = 11,04,750.00 kJ / h

So, we can save up to 11,04,750.00 kJ/h by investing small amount in control of air supply system.

Energy savings from sealing the leakages in steam pipeline:

Leakages in steam pipeline create great impact on the efficiency and energy utilization because high temperature steam having much amount of energy escapes through the holes causes the losses in energy.

In our case.Steam pressure = 10 bar (145 psi)
Consider Hole (Leak) size = approx. 8 mm
= 0.25 inch

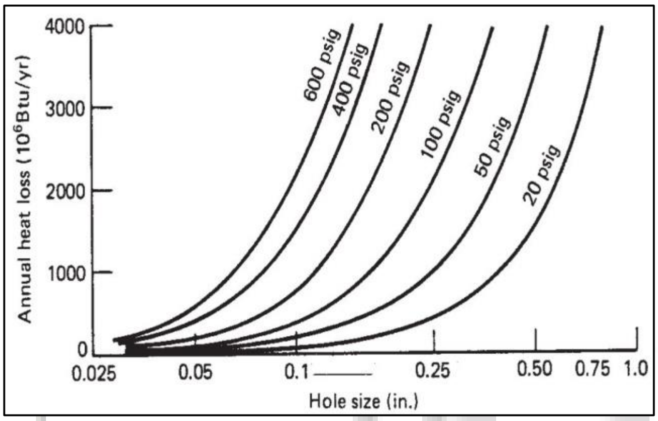

Fig. 2: Heat Loss from Steam Leaks

From the standard graph as in Fig.2.
Energy lost per year for our consideration
= $3{,}000\times10^6$ Btu/yr = $31{,}65{,}168 \times 10^3$ kJ/yr
And this loss is only from one leak…!
So, we can save up to $31{,}65{,}168 \times 10^3$ kJ/yr per leak by investing small amount for sealing/removing leakages in steam pipeline.

– Energy savings from proper insulating the un-insulated pipeline:

In our Case. Steam pressure = 10 bar (145 psi)
Consider Diameter of pipe = 25 cm (10 inch)
Exposed pipe length = approx. 5 m
From the standard graph as in Fig.3.
Energy lost per year for our consideration
= $2500 \times 10^6 \times (5/30.48)$ Btu
= $4{,}32{,}684 \times 10^3$ kJ/yr
So, we can save up to $4{,}32{,}684 \times 10^3$ kJ/yr per 5 m long bare pipe by investing small amount for covering it with good insulation**.**

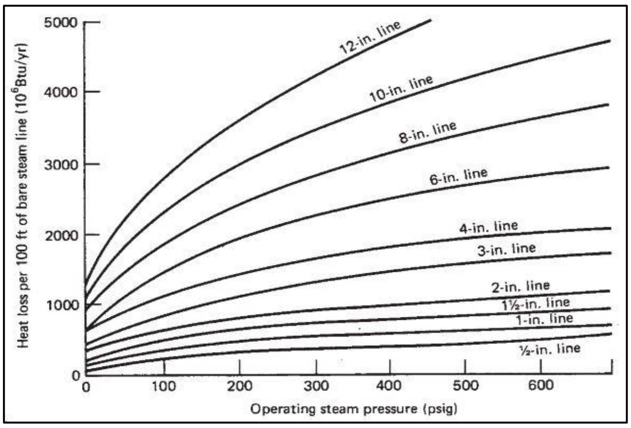

Fig. 3: Heat loss from bare steam pipelines
(For 100 ft = 30.48 m long pipe)

VI. CONCLUSION

In present scenario the energy conservation plays an important role which is only achieved by energy audit because consumption of energy is increasing day by day and the generation is not matching with it. The energy conservation helps in reducing the energy consumption and provides the savings. Textile industry has higher use of energy. By adopting proper measures as suggested in the report after performing audit, i.e. controlling excess air supply to boiler by proper maintenance in supply system and adapting advanced effective technologies, providing proper insulation and sealing the leakages in pipelines etc., spreading energy awareness among the people the required result can be achieved.

From this work it is cleared that we can save 11,04,750 kJ/hr (= $96{,}77{,}610 \times 10^3$ kJ/yr) by controlling excess air supply to optimum rate(20%), $31{,}65{,}168 \times 10^3$ kJ/year per leak by sealing the leakage in steam pipeline and $4{,}32{,}684 \times 10^3$ kJ/year per 5 m long bare pipe by providing proper insulation over it. And the investment or expenses for following above suggestion in industry is very minor so payback period is very short. So finally it will be beneficiary for industry as well as for the nations towards to achieve the energy security.

It is also reported that this audit was aimed at conservation of energy only in boiler section only. If energy audit for the entire industry is conducted, the quantitative energy conservation will be more.

REFERENCES

[1] Bureau of Energy Efficiency, Ministry of Power, Government of India, - Hand Book on Energy Efficiency
[2] Matteo Dongellini et al. "Energy Audit of an Industrial Site: Case study" 68th Conference of the Italian Thermal Machines Engineering Association, ATI2013, Energy Procedia 45(2014) 424-433
[3] Energy Audit and Management-IECC Press-Energy Conservation Vol.:1
[4] Energy Efficiency in Thermal System – IECC Press
[5] Boiler: A Practical Reference by Kumar Rayaprolu – CRC Press
[6] Energy Management Handbook 6th Edition by Wayner C. Turner and Steve Doty – CRC Press.

