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Performance optimization of thermal systems in textile industries

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Abstract: *Energy consumption has been growing very rapidly due to population growth, rapid urbanization and industrial development. For future planning, it is important to know the current specific energy consumption and the energy intensity in order to estimate future energy consumption. In the industrial sector especially in textile units' large amount of energy wasted due to improper working and lack of energy saving measures. In this study, the various measures that causes the main energy losses are investigated .In the textile dyeing sector, the main processes are associated with steam in various proportions. For the steam production, steam boilers of different types are used for different applications. The efficiency of the boiler varies from one industry to other based on various parameters such as quality of the water, fuel used, blow down quantity, etc. Steam traps are also having influence on the boiler efficiency. In the case of steam leakage the performance of the system decreases as the consumption of fuel increases to produce more steam. Thus by adopting various recovery methods we can reduce the energy losses and fuel consumption.*
Keywords*-Boiler blow down, Condensate recovery, Steam systems, Steam trap management, Steam utilization*

I. Introduction

Optimization of industrial steam systems represents one of the largest non processes, industrial energy opportunities, with improvements of 30% readily achievable in typical plants through the introduction of a best practice approach. m. Developing an accurate steam balance of actual operating conditions is an excellent tool for understanding the steam system. To optimize a steam system, the plant must be integrated as much as possible so that one operating area's excess steam can eliminate the deficit of steam in another area. To eliminate the excess steam condition, all sources of steam that contribute to the excess steam condition must be identified. If it is not possible to eliminate excess low-pressure steam, then effectively utilizing the steam is the next best alternative. Repairing steam leaks and insulating equipment is also important at steam boilers. Textiles (dyeing and printing) are energy intensive industries. In the face of rising costs and increased competition, efficient utility management is a major focus area in these industries [1].

In this paper, the major heat recovery areas were found to be in boiler blow down, condensate and proper steam trap management that drained after the dyeing process. A study conducted in textile sector Tirupur district of Tamil Nadu to generalize the direct impact of boiler blow down, condensate and waste water heat recovery on fuel consumption. As a part of study, energy and mass balance is performed on boiler and calculated the amount of energy can save through recovering the heat from boiler blow down, condensate recovery and waste water that is disposed to sewage. In all the industries, their main investment is in the steam production. As the industrial sector continues efforts to improve its energy efficiency by reducing heat losses provides an attractive opportunity for performance optimization of the boiler.

II. Areas Of Optimization In Textile Industries

The main areas of energy optimization in textiles are boiler blow down, steam trap management, condensate recovery, etc.

2.1 Boiler blow down

When water is boiled and steam is generated, any dissolved solids contained in the water remain in the boiler. If more solids are put in with the feed water, they will concentrate and may eventually reach a level where their solubility in the water is exceeded and they deposit from the solution. Above a certain level of concentration, these solids encourage foaming and cause carryover of water into the steam. The deposits also lead to scale formation inside the boiler, results in localized overheating and finally causing boiler tube failure.

It is, therefore, necessary to control the level of concentration of the solids and this is achieved by the process of 'blowing down', where a certain volume of water is blown off and is automatically replaced by feed water - thus maintaining the optimum level of total dissolved solids (TDS) in the boiler water. Blow down is necessary to protect the surfaces of the heat exchanger in the boiler. However, blow down can be a significant source of heat loss, if improperly carried out. Since it is tedious and time consuming to measure total dissolved solids (TDS) in boiler water system, conductivity measurement is used for monitoring the overall TDS present in the boiler. A rise in conductivity indicates a rise in the "contamination" of the boiler water [2].

Minimizing blow down rate can substantially reduce energy losses, as the temperature of the blown-down liquid is the same as that of the steam generated in the boiler. Minimizing blow down will also reduce makeup water and chemical treatment costs. Insufficient blow down may lead to carryover of boiler water into the steam, or the formation of deposits. Excessive blow down will waste energy, water and chemicals.

2.2 Steam traps

Steam traps are a type of automatic valve that filters out condensate (i.e. condensed steam) and non-condensable gases such as air without letting steam to escape. In industry, steam is used regularly for heating or as a driving force for mechanical power. Steam traps are used in such applications to ensure that steam is not wasted. Steam traps play a vital role in steam distribution network and steam using network. Traps removes condensate formed within steam lines which is most essential to avoid the water hammer in the line and in case of process equipment remove the condensate to have better and quicker heating by latent heat in the steam. Trap inspections are typically performed one time per year. The problem with this approach is that steam traps fail every day. These undetected failures lead to system irregularities, which, when left undetected long enough, can result in severe problems and losses [3].

Standardization of steam trap installation at the plant will reduce the failure rate of steam traps in the plant. A high percentage of steam trap failures are due to an incorrect steam trap installation. Proper trap sizing is the most important factor in obtaining efficient steam trap operation. Even though the correct operating design of a steam trap was selected, and the installation was correct, improper steam trap sizing will cause either condensate to back up in the system or excessive steam loss into the return system. The large variety of steam traps and their operating characteristics, users may encounter some difficulty when trying to select the correct trap to most effectively drain condensate from their steam applications.

Live steam is invisible, and when a trap is leaking the short distance of space between the pipe outlet and visible vapor will tend to be clear and of relatively higher velocity and force. If the vapor seen is lower velocity and appears visible immediately at the pipe outlet, then it is most likely flash steam. A quick check of the trap operation will confirm its condition. Condensate flows through piping at a pressure higher than atmosphere. When condensate is discharged to atmosphere, a portion of it immediately evaporates because of the pressure difference. This phenomenon is known as flash evaporation. The vapor clouds at the outlet of traps appear when this flash evaporated steam (flash steam) condenses in the air to form tiny water droplets. Because of the pressure difference between the trap inlet and outlet, traps discharging hot condensate will always generate some flash steam. This is a time when the outside temperature is low and more vapor than usual is generated - a cause for concern for the persons doing trap maintenance. It is recommended that a failed trap be replaced as soon as it is found.

2.3 Steam leakage

Steam leaks result in the loss of both latent and sensible energy. While plant personnel would be well advised to pay attention to all utility losses, greater attention should be paid to the costs and problems associated with losses related to steam. Steam leaks result in higher energy losses than comparable compressed air leaks. Leaks in the steam and condensate system can contribute to significant energy losses—as great as 19 percent of the overall energy consumption—in a plant's operations. In fact, due to the high cost of these energy losses, the correction of steam and condensate leaks offers very lucrative paybacks. The greatest benefit of a proactive steam and condensate leakage correction program is that most leaks can be corrected without expending capital.

2.4 Condensate recovery

Heat energy contained in steam consists of sensible heat and latent heat, the latter only being utilized in most types of steam using equipment. Heat energy contained in the condensate amounts to as much as 20 – 30% of total heat of the steam [4]. To maintain the maximum efficiency of steam equipment, condensate formed in the equipment should be discharged through steam traps as quickly as possible. In other words, the higher the temperature of discharged condensate, the higher the efficiency of the equipment. Condensate is the liquid formed when steam passes from the gaseous to the liquid state. Turning water into steam is a two-stage process. Water must first be heated to its boiling point. This initially provided energy is called 'sensible heat'. Then, it must be heated until it vaporizes. This additional energy is called 'latent heat'. If steam loses its latent heat (i.e., by transferring its latent heat to a product), it reverts back to the liquid state, becoming condensate. Since this condensate still contains a large amount of sensible heat, it is best to reuse it to help conserve energy and resources. The discharged condensate has a fair amount of heat. If this hot water is fed to the boiler, the amount of heat required to heat it back to the saturation temperature of the boiler reduces. This means that every 6 ^{0}C rise in feed water temperature leads to a reduction of 1% in fuel consumption.

Condensate recovery is a process involving the recovery and reuse of condensate discharged from a steam system to save energy and resources. In a heating process, once steam has transferred its latent heat to the product being heated, it turns into condensate. Recycling this condensate by returning it to the boiler system is a common form of condensate recovery. Some of the plant's condensate was not recovered due to malfunctioning pumps and worn piping in the medium pressure condensate recovery system. This led to greater than necessary consumption of water and energy. By repairing the condensate line and pumping stations, 15% more condensate could be recovered.

Significant amounts of energy and resources can be saved by setting up a system to quickly recover and reuse condensate.

III. Optimization Methods

Steam plant optimization is the overall improvement of the plant's operation. The most common strategies used to accomplish this task include, and generally focus on the improvement of primary equipment operating efficiency, i.e. fuel and energy savings. In heavy commercial and industrial boiler applications these efficiencies are normally found in the application of waste heat recovery equipment, systems and process automation, and improved operating practices**.**

3.1 Feed water management

The importance of the boiler feed tank, where boiler feed water and make-up water are stored and into which condensate is returned, is often underestimated. It is important that the water in the feed tank is kept at a high enough temperature to minimize the content of dissolved oxygen and other gases. The increase in the feed water temperature increases the boiler efficiency by saving the fuel quantity to heating water to the required temperature. The feed tank provides a reserve of water to cover the interruption of make-up water supply. Traditional practice is to have a feed tank with sufficient capacity to allow one hour of steaming at maximum boiler evaporation. For larger plants this may be impractical and an alternative might be to have a smaller feed tank with additional cold treated water storage. It should also have sufficient capacity above its normal working level to accommodate any surges in the rate of condensate return. As steam is generated, the water within the boiler evaporates and is replaced by pumping feed water into the boiler [5].

3.2 Steam trap management

Steam traps play an important role in maintaining efficient transportation of steam through a mill; the traps remove moisture from the steam lines and prevent further condensation, thereby preventing heat loss and reducing fuel consumption. Failed steam traps allow live steam to escape into the condensate system or even to ditches. In steam systems that have not been adequately maintained, between 15 percent and 30 percent of the traps may have failed. It should be common practice to replace a steam trap as soon as it is out of order. In addition, steam traps should be installed at appropriate intervals (typically one about every 25 meters) in the main steam headers. This best practice requires routine inspection of steam traps (monthly testing is recommended) and repairing or replacing broken steam traps as soon as the problem is detected. Because no significant expenses are associated with implementing this practice, it pays for itself immediately (less than one month).

3.3 Condensate recovery with flash vessel

As the steam passes around the system to the various items of steam-using plant, it changes state back to condensate, which is, essentially, very good quality hot water. Unless some contamination, this condensate is ideal boiler feed water. It makes economic sense, therefore, to return as much as possible for re-use. In reality, it is almost impossible to return all the condensate; some steam may have been injected directly into the process for applications such as humidification and steam injection, and there will usually be water losses from the boiler itself, for instance, via blow down. Make-up water will therefore have to be introduced to the system to maintain the correct working levels. The return of condensate represents huge potential for energy savings in the boiler house. Condensate has a high heat content and approximately 1% less fuel is required for every 6°C temperature rise in the feed tank.

Heat content in the flash steam from Boiler blow down and condensate can be recovered back to pre heat the boiler feed water and Flash steam produced due to excess boiler blow down also can reduced fuel consumption rate. Condensate is discharged through traps from a higher to a lower pressure. As a result of this drop in pressure, some of the condensate will then re-evaporate into 'flash steam. The flash steam generated can contain up to half of the total energy of the condensate, hence flash steam recovery is an essential part of an energy efficient system[5].

$$\%\ \text{flash steam} = (SH-SL)/H*100 \quad (1)$$

Where SH = Sensible heat in the condensate at the higher pressure before discharge, SL = Sensible heat in the condensate at the lower pressure to which discharge takes place and H = Latent heat in the steam at the lower pressure to which the condensate has been discharged [4]. Flash Steam Heat Recovery Unit is an engineered package designed to facilitate heat recovery from flash steam, condensate, or both. The flash steam recovery system is ideally suited for heating continuous flow of fluid, such as make-up water to a boiler feed water system. The atmospherically vented unit helps recovery and utilize valuable heat generally lost during boiler blow down. A Shell and Tube Recovery Module with U-tube configuration is used for recovering energy from the flash steam, while the condensate utilizes an efficient Plate and Frame Recovery Module. Non-continuous flow applications may require additional recirculation and relief valves. An optional make-up water control valve may be installed upstream of the unit in order for the make-up to be allowed to thermally expand to atmosphere to prevent system damage[6].

One of highest return on investments is to return condensate to the boiler. As fuel costs continue to rise, it's imperative to focus on recovering condensate in every industrial steam operation. Returning hot condensate to the boiler makes sense for several reasons. As more condensate is returned, less make-up water is required, saving fuel, makeup water, and chemicals and treatment costs. Less condensate discharged into a sewer system reduces disposal costs. The amount of condensate and flash steam produced in each industry is given in table 3.1.

Table 3.1 Amount of condensate formed

Industry	Steam production(kg/day)	Amount of condensate(kg/day)	Amount of flash steam recovered (kg/day)
D.S.P PROCESS	2028	1530	155.4
KONGOOR	6355	5788	645
SENBAGAM	3593	3353	340.5
DOWIN	1909	1728	192.7
K.A.K	3187	2812	285.6
JAYASAKTHI	1456	1409	129.2
K.B.R COLORS	3576	2910	295.5
SRI BALAJI	1909	1630	165.5
S.K PROCESS	4408	3799	209.3
G.M.S	5273	5027	510.5

From the audit conducted in 10 textile processing unit it is observed that nearly 2% of total fuel consumption is wasted through condensate drainage. i.e., nearly a 500 kg fuel is wasted per day, which can be saved through proper condensate recovery method.

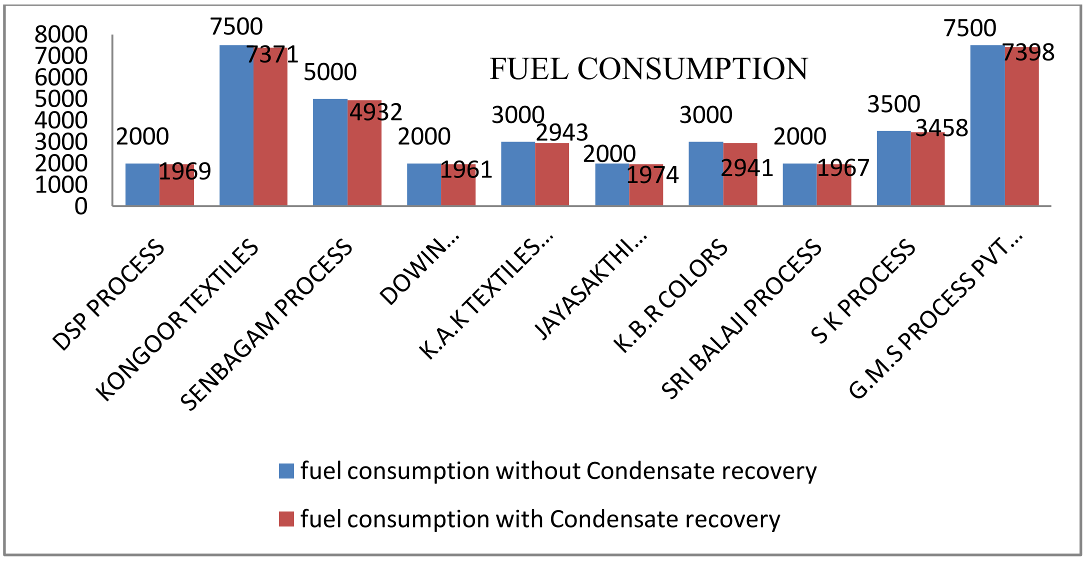


Fig 3.1 Variations in fuel consumption with condensate recovery

3.4 Automatic blow down

With an automatic blow down-control system, high- or low-pressure probes are used to measure conductivity. The conductivity probes provide feedback to a blow down controller that compares the measured conductivity with a set-point value, and then transmits an output signal that drives a modulating blow down release valve. Conductivity is a measure of the electrical current carried by positive and negative ions when a voltage is applied across electrodes in a water sample. Conductivity increases when the dissolved ion concentrations increase. The measured current is directly proportional to the specific conductivity of the fluid. Total dissolved solids, silica, chloride concentrations, or alkalinity contribute to conductivity measurements. These chemical species are reliable indicators of salts and other contaminants in the boiler water[7].

An automatic blow down-control system optimizes surface-blow down rates by regulating the volume of water discharged from the boiler in relation to the concentration of dissolved solids present. Automatic surface-blow down control systems maintain water chemistry within acceptable limits, while minimizing blow down and reducing energy losses. Cost savings come from the significant reduction in the consumption, disposal, treatment, and heating of water. Boilers without a blow down heat-recovery system and with high blow down rates offer the greatest energy-savings potential. The optimum blow down rate is determined by a number of factors, including boiler type, operating pressure, water treatment, and makeup-water quality. Savings also depend upon the quantity of condensate returned to the boiler. With a low percentage of condensate return, more makeup water is required and additional blow down must occur.

Table 3.2 Fuel wastage in Industries

Industry	Blow down rate(kg/day)	Amount of Fuel wasted(kg/day)
D.S.P PROCESS	3240	86.5
KONGOOR	3816	101.9
SENBAGAM	3024	91.9
DOWIN	3636	110.5
K.A.K	4032	122.6
JAYASAKTHI	3360	102
K.B.R COLORS	2424	73.7
SRI BALAJI	3636	110.5
S.K PROCESS	2592	78.8
G.M.S	2424	73.6

From the audit conducted in 10 textile processing unit it is observed that nearly 4% of total fuel consumption is wasted through blow down. i.e., nearly a 1537 kg of fuel (wood) is wasted as blow down, which is equivalent to a price value of 5300rs/day. In actual blow down losses may includes the makeup water cost and its treatment cost.

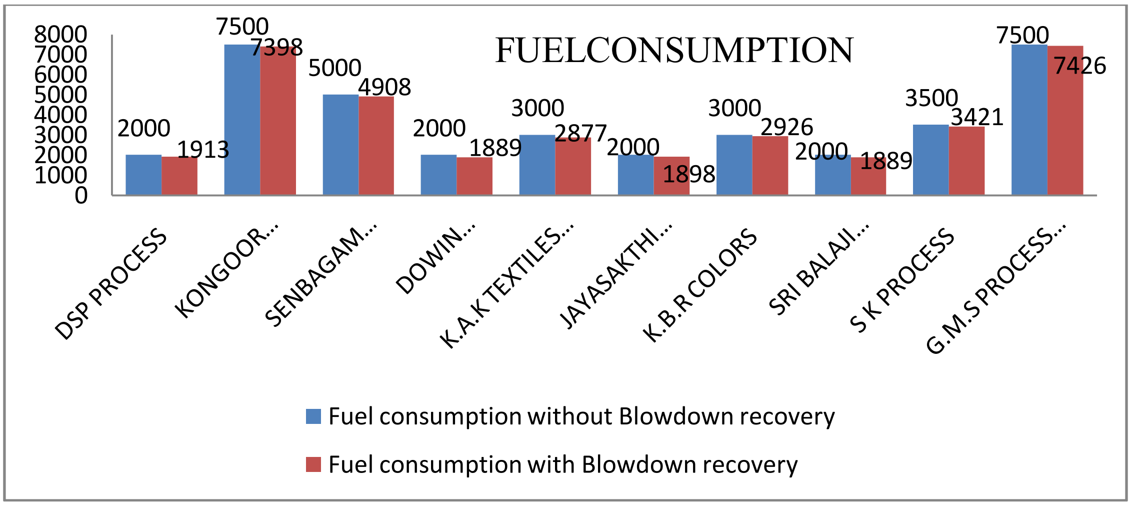
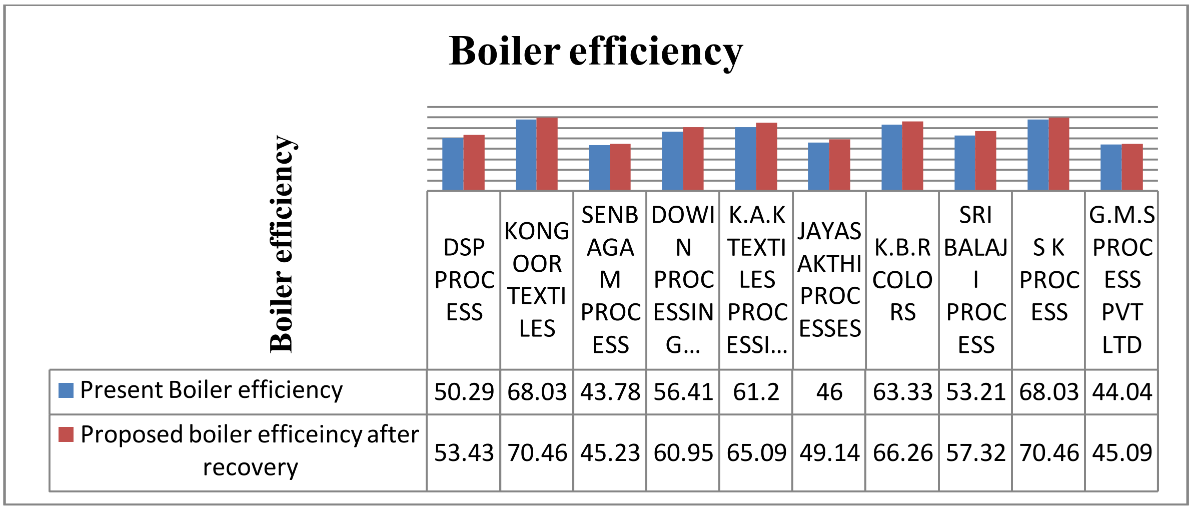


Fig 3.2 Variations in fuel consumption with blow down recovery



	DSP PROCESS	KONGOOR TEXTILES	SENBAGAM PROCESS	DOWIN PROCESSING...	K.A.K TEXTILES PROCESSI...	JAYASAKTHI PROCESSES	K.B.R COLORS	SRI BALAJI PROCESS	S K PROCESS	G.M.S PROCESS PVT LTD
Present Boiler efficiency	50.29	68.03	43.78	56.41	61.2	46	63.33	53.21	68.03	44.04
Proposed boiler efficeincy after recovery	53.43	70.46	45.23	60.95	65.09	49.14	66.26	57.32	70.46	45.09

Fig 3.3 Changes in the boiler efficiencies in industries

It is found that boiler efficiency has significantly improved after flash stem recovered from the boiler blow down. Installation of heat recovery equipment is valuable only when energy from the flash tank or the blow down water can be recovered and utilized. In flash recovery system, the blow down water is directly supplied to a flash vessel which is at atmospheric pressure. Due to the change in enthalpies of water at boiler pressure and atmospheric pressure nearly 13% of blow down water is converted into flash steam. This steam is directly supplied to the feed water tank hence the temperature of feed water is raised due to high enthalpy value of steam.

With every 6% rise in the temperature of feed water it is observed that a 1% reduction in the wood consumption. Reduction in wood consumption means that the increased efficiency of boiler. From the analytical comparison between the system with heat recovery and without heat recovery, it is observed that the efficiency of boiler if nearly 2% rise.

Table 3.3.Total fuel savings

Industry	Savings in Fuel		Monitory Savings(Rs/annum)
	(kg/day)	Tons/annum	
DSP PROCESS	117.54	29	1,01,500
KONGOOR TEXTILES	230.73	57	1,99,500
SENBAGAM PROCESS	159.92	40	1,40,000
DOWIN PROCESSING MILLS	149	37	1,29,500
K.A.K TEXTILES	179.59	45	1,57,500
JAYASAKTHI PROCESSES	127.93	32	1,12,000
K.B.R COLORS	132.68	33	1, 15,500
SRI BALAJI PROCESS	143.56	36	1,26,000
S K PROCESS	120.59	30	1,05,000
G.M.S PROCESS PVT LTD	175.63	69	2,41,500

IV. Conclusion

The steam is mostly used in the process heating applications in process industries because of its various properties and ease of control. The boiler efficiency depends on certain parameters such quality of water , fuel used, blow down quantity , feed water and make up water temperature , condensate recovery methods ,etc .In most of the industries the blow down type is manual , which results in excess blow down quantity than the required and also increases the fuel consumption rate. By adopting automatic blow down control system , we can minimize the wastage of energy through the blow down quantity. The condensate recovery by using flash vessels can minimize the wastage of steam through condensate flash steam. By regular inspection and proper maintenance of steam trap will avoid the unnecessary leakage of steam through traps.

By implementing the above energy recovery methods we can conserve the energy in the process industries. The improvements in the boiler blow down, condensate recovery and proper steam trap management and feed water management will optimize the energy performance of thermal systems of textile industries.

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