DESIGN AND IMPLEMENTATION OF AN AUTOMATIC CONTROL SYSTEM TO AVOID FOULING IN PIPES WITH BLOW DOWN HEAT RECOVERY IN STEAM BOILERS

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Abstract. The aim of the present work is to solve the problem of fouling in boiler pipes and improve energy efficiency of steam boilers in the south refineries company, Al-Basrah province, Iraq. An automatic control system with a novel electronic circuit has been proposed to achieve this aim. This system consists of an on-line conductivity sensor and a conductivity monitor connected to an additional resistance to measure the concentrations of dissolved solids in boiler water. A square wave feedback has been employed to determine the levels of solid concentrations and controls the surface blow down process through electronic circuit. This circuit consists of a D.C power supply, an amplifier, a rectifier, comparators and a driver sub-circuits for solenoid valve. The driver sub-circuit consists of two transistors and three relays. The solenoid valve is used with throttle valve to control the flow rate of boiler blow down water. Two flow meters are used to measure blow down and feed water flow rates. The design and implementation of a heat recovery unit is also included. It consists of a heat exchanger (shell and coiled tube) type used to recover heat energy from blow down water. To measure the inlet and outlet temperatures of feed water and blow down water, four (k-type) thermocouples were used. A pump was used to pump feed water from the storage tank in to the boiler. To automatically control water level inside the boiler two electrodes (water level sensor) were used integrated with the float less level switch circuit. The experimental results proved the effectiveness of the innovative control system in improving boiler efficiency and in fouling control through enhancing the blow down process and reducing indirect losses. The blow down quantity reduced from 2244.897 kg/h to 1111.111 kg/h. Which provided 27210.864 kg/day of blow down water. Hence, saved 158450201.2 ID/ year or 83.16% of the energy lost with blow-down water can be recovered using heat-recovery unit with an energy saving of 103411.8 MJ/day. Which will save a mass of fuel equals to 482.46 ton/ year. The automatic control system proved to be a good solution for saving energy and reducing harmful emissions to the environment and it contributes to the maintenance of sewage pipes from damage caused by the heat of discharged water.

1. INTRODUCTION

The most prominent targets of modern technology are to improve the efficiency of energy technology in industrial processes. They seek opportunities to reduce production costs without negatively affecting product. Petroleum refineries are more focused on improving utility consumption and reducing stack emissions. Private industries that generate their own steam need to optimize their energy generation and use by taking all the measures to reduce energy loss [1]. Since steam boilers are the main fuel consumers in the petroleum refineries where the petroleum industry uses about 40% of its energy to generate steam [2]. So optimization of a boiler system is one of the best solutions to save energy and reduce pollutions [3].

Blow down is the main energy loss at a place where steam is generated. Hence the amount of water to be blown down is to be optimized to reduce the heat energy waste [4]. When steam is generated it leaves practically all the dissolved solids. If more solids are with feed water, they will be concentrated and may eventually reach a level where their solubility is exceeded hence, 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, resulting in localized overheating and finally causing damage to boiler tubes, steam traps, or process equipment [5, 6].

In order to reduce the level of suspended solids and total dissolved solids in the boiler water within the acceptable levels, a blow down process must be achieved. Blow down is water intentionally wasted from a boiler while the boiler is operating to avoid concentration of impurities [7]. There are two sources of blow down water: bottom blow down which is the removal of the sludge accumulated at the bottom of a fire tube boiler, or in the mud drum of a water tube boiler. While surface blow down is often done as a continuous removal of dissolved impurities from the surface of water in a steam boiler [8].

Insufficient blow down may lead to the formation of deposits. While, excessive blow down will waste energy and chemicals added. Therefore, it is necessary to control the level of minerals concentration in boilers. There are two methods to control the boiler blow down, these are: Manual blow down control method: which requires checking of boiler water many times a day or according to a set schedule to adjust suspended solids, TDS, pH, Silica and Phosphates concentration including sludge formed in the boiler water and adjust blow down accordingly [9, 10] with manual boiler blow down control, operators are delayed in knowing when to conduct blow down or for how long. They cannot immediately respond to the changes in feed water conditions or variations in steam demand. The other method is automatic blow down control: In which boiler water conductivity is continuously monitored and the blow down rate is accordingly adjusted. A probe measures the conductivity and provides feedback to the controller of the blow down valve. An automatic blow down control system can keep the blow down rate uniformly close to the maximum allowable dissolved solids level, while minimizing blow down and reducing energy losses [11].

Several studies focused on boiler blow down techniques. Lakshmi and Pillai (2015)[12] compared between manual and automatic boiler blow down methods to determine the rate of blow down in each case. Their results showed that there was about 1.28% difference between the two methods. This has led to an increase in boiler efficiency by using automatic blow down method.

Godwin and Johnson (2003)[13] invented a mechanical method for automatically controlling boiler blow down system by using bimodal feed water pumps. In this study the control process was done by removing boiler water at a predetermined rate equal to a selected percentage of the feed water. Gupta, et al. (2011)[14] suggested an automatic blow down system consisting of continuous monitoring of conductivity. Zainal and Nor(2012) [15] conducted an experimental study on two boilers for the optimization of boiler blow down frequency and its effect on the chemical values of the water steam cycle. Their results showed that boiler blow down must be carried out if one of the chemical parameters in the steam cycle and water was trending upwards and attained the limit value. Panda, et al. (2013) [16] proposed a design for the control system using neural network technology for optimization of blow down of a power plant boiler. The design proved to be efficient for calculation and optimization of the blow down since the blow down water contains a large quantity of energy. As well as, any boiler with continuous blow down exceeding 5% of the steam rate is a good candidate for the introduction of blow down waste heat recovery. Also, heat can be recovered to preheat boiler makeup water [17].Bahadori and B.vuthaluru (2010) [18] developed an accurate and simple method for estimation of heat recovery from blow down systems during steam generation. Madhav D., et al. (2013) [19] presented a design for heat recovery system consisting of a flash vessel and a heat exchanger to minimize heat losses. They used mathematical modeling to calculate energy recovered by this system. Sherin and prince (2013) [20] carried out an investigation on mathematical modeling of boiler and heat exchanger to generalize the direct impact of boiler blow down condensate, waste water heat recovery and fuel consumption. The results found that boiler efficiency has significantly improved up to 2% with every 6% rise in temperature of feed water due to blow down and a 1% reduction in fuel consumption. Also, Arunkumar S., et al.(2014) [21] designed a heat recovery system consisting of a plate type heat exchanger to recover heat from blow down and supply it to the boiler.
feed water. The results showed that 6.61 kg/day total energy was saved in the process. Vandani, et al. 2015 [22], performed energy and exergy analysis for heat recovery of boiler blow down on a steam power plant to estimate the performance effect of heat recovery system. Their results showed, that the net generated power was increased by 0.72% with blow down recovery mechanism, and efficiency was raised by (31.68 – 31.91) %. Their results also showed that energy and exergy efficiencies were increased by 0.23 and 0.22, respectively. Exergy efficiency reached (30.66) %, which showed that, there was (1.86) percent increase with respect to a situation where a flash tank has been used. The south refineries company/ Al-Basrah province/ south of Iraq suffers from serious fouling problems in boiler pipes because of high salinity water in such locations.

The aim of the present work is to solve the problem of fouling in boiler pipes and improve energy efficiency in the south refineries company. This has been achieved through enhancing the boiler blow down process by designing and implementing an automatic control system with a novel electronic circuit to determine the concentration of dissolved solids in the boiler water at different levels. As well as, a heat exchanger of shell and coiled tube type is designed and manufactured to recover heat from surface blow down water. The proposed improving method utilizes an on-line conductivity sensor and a conductivity monitor that is connected to an additional resistance to measure the concentrations of dissolved solids in boiler water, then generation of a feedback signal to determine the level of solid concentrations and hence control the surface blow down process.

2. MATERIALS AND METHODS

2.1 Materials:
The materials include two types of water: blow down water and feed water. These waters were used to determine the maximum and minimum limits of concentrations of salt allowed in boiler water. The samples of these materials were taken from the boilers blow down and feed water from south refineries company- Al-Basrah/ Iraq. The properties of these samples are given in Table (1).

| Property | Blow down | Feed water |
|----------|-----------|------------|
| pH       | 11.0      | 8.7        |
| E.C (µs/cm) | 302      | 5.5        |
| B-ALK    | 60        | -          |
| M-ALK    | 80        | -          |
| T-H (ppm) | 0.4      | 0.16       |
| TDS (ppm) | 211      | 7          |
| Ca-H (ppm) | 0.29     | 0.1        |
| Mg-M (ppm) | 0.11     | 0.06       |
| Cl⁻ (ppm) | 1.6      | 0.4        |
| SiO₂ (ppm) | 0.810    | 0.06       |
| P₂O₅ (ppm) | 1.6      | 0.3        |

2.2 Experimental system:
Figure 1 is a schematic diagram of the experimental rig. The main parts used in the experimental system are: boiler, feed water tank, feed water pump, electrical control panel, heat recovery unit, and automatic control system which consists of: conductivity monitor, throttle valve and automatic control circuit. The measuring devices are conductivity monitor, flow meter, temperature controller, thermocouples, an oscilloscope and a digital multimeter.
The main parts of the automatic control system are:

I- Conductivity monitor: Intelligent microprocessor conductivity measurement instrument as shown in Figure 3 was used to measure the conductivity and TDS on-line. It has been used to monitor conductivity automatically and generate a square wave through additional resistance. Conductivity sensor of stainless material with (10) m cable was used to sense the concentrations of salts in the boiler water and provide feedback to the connectivity monitor; it was installed inside a cell flow.

II- Solenoid valve (drive actuator): An electromechanical controlled valve type (2w-250-25); was used to automatically control the flow rate of boiler blow down water.

III- Electronic circuit: The control circuit is shown in Figure 3. It consists of: DC power supply circuit, amplifier circuit, rectifier circuit, comparator circuit and a driver circuit.
Working principles of the automatic control circuit: The control circuit is shown in Figure 4. The first step is to amplify the low signal square wave voltage from the conductivity sensor generated from conductivity monitor. The second step is to convert the amplified signal to direct voltage signal (DC voltage). The third step is to compare the DC voltage with a two set point values by comparator device. When the concentration of dissolved solids signal value reaches the lower set point value (minimum level), the comparator device for minimum level generates a signal (high) to activate relay (K1). At this condition the switch of K1 closes the solenoid valve which remains inactivated and blow down is in off state. When the concentration of dissolved solids reaches the maximum level, the comparator device of maximum level generates a signal (high) to activate relay (K2). When relays (K1 and K2) are in activated state, this will cause relay (K3) to be in activated state, and the switch of (K3) will be in closed condition or solenoid activated, and then blow down water will discharge outside the boiler. During the blow down process, feeding water is supplied to the boiler to compensate for the blow down water. The concentrations of dissolved solids begin to drop from the maximum level, relays (K1) and (K2) remain activated and the solenoid valve in ON state. When the concentrations are reduced to reach a value below the minimum level, relays (K1) and (K2) are not in activated state. This will cause relay K3 to be in an inactivated state, switch of K3 will be in open condition and solenoid valve in OFF state. The output voltage signals from comparators circuit (two binary digital) operate the blow down valve as in truth values shown in Table 2.

![Automatic control circuit design](image)

**Figure 4: Automatic control circuit design.**

| Initial state of solenoid valve | Maximum level | Minimum level | Solenoid valve |
|-------------------------------|---------------|---------------|----------------|
| OFF                           | 0             | 0             | 0              |
|                               | 0             | 1             | 0              |
|                               | 1             | 1             | 1              |
| ON                            | 1             | 1             | 1              |
|                               | 0             | 1             | 1              |
|                               | 0             | 0             | 0              |
The main parts of the heat recovery unit are: shell and coiled tube type heat exchanger as shown in Figure 5. It was used to heat the make-up water that enters at ambient temperature, and cools the blow down water before it is drained to sewers. Table 3 shows the data adopted for the design of the heat recovery unit.

![Figure 5: shell and coiled tube heat exchanger.](image)

| parameter                        | specification       |
|----------------------------------|---------------------|
| Shell material                   | 316L stainless steel|
| Inner and outer diameter of shell| 13.6 cm, 14 cm      |
| Length of shell                  | 43 cm               |
| Tube material                    | 316L stainless steel|
| Number of coiled tubes           | Two                 |
| Inner and outer diameter of coiled tube | 7 mm, 10 mm       |
| Length of coiled tube            | 30 cm               |
| Number of turns                  | 15                  |
| Outer and inner diameter of the coil | 11 cm, 8 cm       |
| Distance between two coils       | 1.5 cm              |
| Pitch for each coil              | 20 mm               |

In the present work the blow down water (hot fluid) flows in the shell side and make-up water (cold fluid) is supplied through coiled tube side. The shell of the heat exchanger was isolated by aluminum foil thermal insulation rubber foam roll, with a thickness of 10 mm to reduce heat dissipation. Two flow meters are installed upstream of the heat exchanger to measure the flow rate of the hot and cold stream. Two PVC ball valves were used to control the flow rate of cold and hot water inside the flow meters. To measure the inlet and outlet temperatures of cold and hot water, four k-type thermocouples were inserted in the small holes drilled in the inlet and outlet tubes of heat exchanger. They are sealed to prevent any leakage. The thermocouples were joined to a digital temperature indicator installed in the electrical control board.

To operate and assess the pilot plant designed for automatic control of the surface blow down process in the steam boiler, various concentrations of samples as listed in Table 4 were used. These concentrations were the maximum levels of dissolved concentrations allowed in the boiler water. A number of experiments were carried out to recover the latent heat in the waste water discharged during the surface blow down process. The blow down water was supplied to the heat exchanger at
atmospheric pressure. The experiments were conducted by passing feed water (cold fluid) through coils tube and the blow down (hot fluid) in the shell side; this was done for counter flow operation. Measuring the heat gained by feed water QF.W and heat lost by blow down water QB.D has been done by keeping the flow rates of feed water constant, while, blow down flow was changed from 0.06 m3/h to 0.14 m3/h with 0.02 m3/h interval. Next, the flow rates of blow down water was kept constant and the flow rates of feed water was varied from 0.1 m3/h to 0.5 m3/h with 0.1m3/h interval. All the data contained in this work are based on average values of five conducted experiments.

| Sample No. | Mixing ratio (mL) | E.C (µs) | TDS (ppm) | Voltage of reference point at the max. level (volt) |
|------------|------------------|----------|-----------|--------------------------------------------------|
| 1          | 100 B.D +150 F.W | 86.5     | 60        | 2.7                                              |
| 2          | 150 B.D +150 F.W | 130      | 91        | 4.1                                              |
| 3          | 175 B.D +75 F.W  | 146      | 102       | 4.6                                              |
| 4          | 200 B.D +50 F.W  | 163      | 114       | 5.1                                              |
| 5          | 225 B.D +25 F.W  | 175      | 122       | 5.5                                              |

3. RESULTS AND DISCUSSIONS
3.1 Automatic control circuit results: A test was carried out on each stage of the electronic control circuit. The amplifier stage, the rectifier stage, comparator stage and the driver stage were tested using an oscilloscope. Figures (6 a, and b) show the signal of an on line conductivity sensor for the additional resistance for minimum and maximum allowable levels of TDS in the boiler water. The average values of minimum and maximum voltages are ± 30 mV, and ± 0.6 V, respectively. Figures (7 a, and b) show the output of the amplifier circuit which represent the amplified signal of the minimum and maximum levels of TDS, respectively with a gain of 10. The square voltage of minimum level was amplified to ± 0.3V and the voltage of maximum level was amplified to ± 6 V. Figures (8 a, and b) show the signals output of the rectifier circuit which represent the DC voltage signal of the minimum and maximum levels of TDS, respectively. The voltage of minimum level is 0.3 V and the voltage of maximum level is 6 V. Figures (9 a, b and c) show the signal output from comparators circuit compared with the voltage of a set point at minimum level of 0.3 V and a maximum level of 6 V. These signals are used to control the switches of relays K1, K2 and K3. If the measured voltage of the boiler water is lower than the voltage of minimum and maximum setting point, then the output signal of comparators are as depicted in Figure 9 (a), where relays K1, K2 and K3 are normally opened and solenoid valve is in (OFF state). If the voltage measured of the boiler water was higher than the voltage of minimum set point and lower than the voltage of maximum set point. The output signal of comparators are depicted in Figure 9 (b), where switch K1 is closed, relays K2 and K3 are normally opened and solenoid valve is in (OFF state). If the voltage measured of the boiler water is higher than the voltage of minimum and maximum setting points, then the output signal of comparators is as depicted in Figure 9(c), where switches K1, K2 and K3 are activated and solenoid valve is at (ON state) during blow down process. Figures (10 a, and b) show the signal output from comparators circuit compared with the voltage of set point at minimum level of 0.3 V and maximum level of 6 V during feed water supply to the boiler. When the concentration is between maximum level and minimum level, the output of the comparators is as shown in Figure 10 (a). The relays K1, K2 and K3 are in activate state; solenoid valve is at (ON state). When the concentration of the boiler water becomes below the minimum level, the output of the comparators become as shown in Figure 10 (b). The relays K1, K2 and K3 are normally opened, solenoid valve is at (OFF state).
Figure 6: Measured voltages for (a) minimum level equal to $\pm 30$ mV, (b) for maximum level equal to 0.6 V.

Figure 7: Output voltages of the amplifier circuit (a) for minimum level equal to $\pm 0.3$ V, (b) for maximum level equal to $\pm 6$ V.

Figure 8: Output voltage of the rectifier circuit (a) for minimum level equal to 0.3 V, (b) for maximum level equal to 6 V.
Figure 9: output of the comparators circuit: (a) for the measured voltage lower than minimum and maximum voltage of setting point, (b) for the measured voltage higher than minimum and lower than maximum voltage of setting point, (c) for the measured voltage higher than minimum and maximum voltage of setting point (during blow down process).

Figure 10: output of the comparator circuit: (a) during feed water supply to the boiler, (b) when finishing the blow down and feed water process.
3.2 Comparison between current treatment method and the proposed method using the innovative circuit:
Figures 11 and 12 show a comparison between the present methods of treatment for boiler water used in the South Refineries Company- AL Basra (manual blow down method) and the proposed method in the present study (automatic blow down method) to adjust the concentration of total dissolved solids (TDS) in boiler water.
Figure 11 shows the reading of the TDS concentration of boiler blow down water recorded along three days (20/3/2017 to 22/3/2017) for the manual blow down method of 30TPH water tube boiler in the South Refineries Company- AL Basra. It is observed that there is a variation in the values of blow down water TDS. This difference in concentrations of blow down water is because the treatment done manually. Also, the figure shows that the actual TDS blow down rate at which the manual blow down process occurred, is significantly below the maximum allowable TDS. Low level of blow down water TDS than the maximum allowable level of TDS leads to higher losses of the boiler water.
Figure 12 shows the level of concentration of the blow down water TDS by using the automatic control circuit to maintain the TDS in the boiler water at an allowable level. It is observed that the boiler water TDS can be adjusted to be close to the maximum allowable level. This will reduce the losses of boiler water resulting from the blow down process.

3.3 Effect of automatic control circuit on blow down rate:
The use of an electronic circuit is to control the concentrations of TDS in the boiler water to be close to the maximum allowable dissolved solids level. It reduced the rate of blow down water during surface blow down process by regulating water blow down volume in relation to amount of total
dissolved solids. According to the operating conditions in the South Refineries Company - Iraq, listed in Table 5, the boiler water analysis was carried out for five water tube boilers operating in the production unit of thermal energy to estimate the value of savings in boiler water blow down when installing the automatic blow down control circuit.

| No. | Variables                                           | quantity          |
|-----|-----------------------------------------------------|-------------------|
| 1   | Amount of steam generated by boiler                 | 110000 kg/h       |
| 2   | Maximum allowable TDS in boiler water as design     | 700 ppm           |
| 3   | Feed water TDS                                      | 7 ppm             |
| 4   | Average TDS maintained in boiler at manual blow down| 350 ppm           |

3.4 Calculation of blow down rate and quantity during the manual and automatic blow down processes:

Using the data available in table (5) for a boiler, the blow down rate at manual process can be calculated as:

\[
B.D \% = \frac{\text{feed water TDS (ppm)}}{\text{max permissible TDS in boiler water (ppm) - feed water TDS (ppm)}} \times 100\% \quad (1)
\]

Blow down rate at manual process = \( \frac{7}{350-7} \times 100\% = 2.04\% \)

\[
B.D \text{ quantity} = \frac{\text{feed water TDS (ppm) \times amount of steam generated by boiler (kg/h)}}{\text{max permissible TDS in boiler water (ppm) - feed water TDS (ppm)}} \quad (2)
\]

\[
B.D \text{ quantity} = \frac{7 \times 110000}{350-7} = 2244.897 \text{ kg/h}
\]

And the blow down rate at automatic control process can be calculated as:

Blow down rate at automatic process = \( \frac{7}{700-7} \times 100\% = 1.0\% \)

Blow down quantity = \( \frac{7 \times 110000}{700-7} = 1111.111 \text{ kg/h} \)

Excess amount of B.D rate = 2.04 – 1.0 = 1.04 %

Excess amount of B.D quantity = 2244.897 – 1111.111 = 1133.786 kg/h

From the comparison between the results of blow down rate and quantity of blow down with manual blow down system and automatic blow down system, it is observed that the blow down rate is reduced by 1.04 percent by raising the average boiler water total dissolved solids. Also the blow down quantity is reduced by 1111.111 kg/h by utilization of the automatic control circuit.

3.5 Effect of Blow down flow rate on the heat energy rate:

The effect of volumetric flow rate on the heat energy lost by the blow down water in the shell side and the heat gained by the feed water in coiled tube side are illustrated in Figures 13 to 16.

Figure 13 shows the effect of different coiled tube flow rates of feed water on heat energy lost \( Q_{B.D} \) while keeping the shell side flow rate constant. It is observed that heat energy lost from blow down water increases with increasing volumetric flow rate of feed water because as the volume of feed water increases there is more heat being transferred from the blow down water. Figure 14 shows the effect of variation in the blow down water volumetric flow rate from 0.06 m³/h to 0.14 m³/h with an interval of 0.06 on heat energy gained by the feed water \( Q_{F.W.} \). It is observed that the heat energy
gained by feed water increases gradually with increasing volumetric flow rate of blow down water, because when the flow rate of blow down increases, there is a large amount of heat transferred to the feed water. Figures (15 and 16) show the relationship between the heat energy lost $Q_{B,D}$ and heat energy gained $Q_{F,W}$ with the volume flow rate of blow down water and feed water. It is observed that the heat energy lost $Q_{B,D}$ and heat energy gained $Q_{F,W}$ increased when the flow rate of blow down water and flow rate of feed water were increased, respectively. This is because the heat energy rate is a function of mass flow rate, when the mass flow rate increases; it increases the heat energy rate.

**Figure 13:** The effect of feed water flow rates on heat energy lost from blow down water

**Figure 14:** The effect of blow down water flow rates on heat energy gained by feed water

**Figure 15:** The effect of blow down water flow rates on heat energy lost

**Figure 16:** The effect of feed water flow rates on heat energy gained
3.6 Optimum conditions for heat energy transfer:
As a result of experiments conducted for heat exchange by changing the flow rate of blow down water and feed water, the optimum conditions for heat transfer are obtained by calculating the heat energy gained and lost by working fluids as shown in Table 6. The optimum conditions were volumetric flow rate of blow down water = 0.14 m$^3$/h and volumetric flow rate of feed water = 0.1 m$^3$/h. Where, at these values of flow rates maximum heat exchange has been obtained.

Table 6: Optimum operating conditions for heat exchanged.

| Fluid       | $T_{in}$ C | $T_{out}$ C | $T_{mean}$ | $\rho$ kg/m$^3$ | $\dot{V}$ m$^3$/h | $C_p$ kJ/kg.k | $\Delta$ $T$ C | $m$ kg/s |
|-------------|------------|-------------|------------|-----------------|------------------|----------------|-------------|---------|
| B.D water   | 90         | 57          | 73.5       | 975.7           | 0.14             | 4.190.4        | 33          | 0.038   |
| Feed water  | 18         | 47          | 32.5       | 994.8           | 0.1              | 4.179.3        | 29          | 0.027   |

4. CONCLUSIONS
From the obtained results it can be concluded that the proposed design of automatic control system to control the surface blow down process proves to be an efficient system to regulate the volume of water discharging form the boiler in correspondence with the concentration of dissolved solids in boiler water. It provides the possibility of working the boiler close to the maximum allowable levels of dissolved solids concentration and this leads to minimize energy losses. The technology of the on-line conductivity monitoring device provided precision in measurement and reduced the complexities associated with the testing process. The innovative design of the electronic control circuit achieved high accuracy and flexibility in controlling the concentrations of dissolved solids in boiler water at desired levels. When installing the novel automatic control system, 1133.786 kg/h of blow down water was saved. This reduces the indirect losses and improves the efficiency of the boiler system. Also, installation of the heat recovery unit contributed in recovering 83.15% of energy wasted with discharge blow down water from flash tank at 90 C. The automatic control system proved to be a good solution to save energy. There is also no need for blow down cooling before discharging to the sewer system.

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