SCOPE OF ENERGY CONSERVATION IN A PHARMACEUTICAL INDUSTRY

A dissertation

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for the award of degree
of

Master in Technology
In
ENERGY TECHNOLOGY AND MANAGEMENT

Submitted by

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DECLARATION

I hereby declare that the project work entitled "**Scope of Energy Conservation in Pharmaceutical Industry**" in fulfillment of the requirements for the award of degree of **Master in Technology** in **Energy Technology and Management**, submitted in Department of School of Energy and Environment of Thapar University, Patiala, is an authentic record of my own work carried out at Thapar University, Patiala as requirements of one year project internship for the award of degree of M.Tech, under the guidance of Dr. Anoop Kumar during June 15, 2015 to June 15, 2016.

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Certified that the above statement made by the student is correct to the best of our knowledge and belief.

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ABSTRACT

Energy analysis and management is a study of a plant and facility to determine how and where energy is used, along with identification methods for energy savings. There is now a universal recognition of the fact that new technologies and more efficient use of the ones that already exist provide the most promising prospects for the energy savings. The opportunities lie in the use of existing renewable energy technologies, greater efforts at increasing the energy efficiency and the implementation of new technologies and options. Energy analysis of **IndSwift Laboratories Ltd.** is presented in this dissertation work and energy conservation measures are proposed, taking into account the analysis of boiler, turbine, steam trap and air handling unit. Also designing of the steam layout and water balance sheet has been done in the work. Energy Analysis in dissertation is focused on possible reduction in energy wastage in various processes. Various weak areas are identified on account of energy wastage. In this dissertation, multiple measures are suggested to industry's administration to reduce the energy wastage.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND AND MOTIVATION

The demand for energy in the world is increasing rapidly and for the coming years the energy price is unavoidably expected to increase [1]. For companies and industries the energy cost will be an extremely important aspect to consider as part of the total cost of ownership and production. Perhaps the use of renewable sources of energy will be the perfect response to this issue in the long term. The effective practice for industries and factories, in the short term, is the reduction of energy consumption through the reducing wastage through the losses [1]. In order to achieve this, the companies should improve their ability to manage energy consumption and move towards the development of energy management systems in agreement with the recent publication of the standard [2]. Energy management is a well-structured and is both technical as well as managerial in nature. By the use of techniques and principles of the both fields, the energy management systems should be developed to monitor, record, analyze, change and control the energy consumption within the organization. Simultaneously it should be ensured that production systems are supplied with the energy as efficiently as possible for reducing energy losses [3]. In pharmaceutical plants the major portion of the energy is consumed by the utilities (compressors, boilers, refrigerators, etc.), therefore these were grouped by technological affinity to describe the first level of the energy meters tree in the boilers (used for the production of steam), compressors, refrigerators and air treatment systems. For these items, the company initially measures the electricity and gas consumption only. Hence, it was mandatory to recognize the factors that determine the energy consumption of the principle users. The companies should develop integrated methods for energy efficiency; based on a systematic approach for energy consumption/cost reduction from energy production to energy utilization [4]. The major challenges are to develop an effective and efficient monitoring and controlling systems for energy consumption. As a matter of fact, knowledge of energy usage inside the industry i.e. how much it is being used and when/where it being used is the foundation of a systematic approach towards the improvement of energy efficiency. The regular monitoring of usage of energy leads to the understanding how production systems and utilities employ energy, showing irregularities in functioning therefore allowing the organization and identification of the actions or methods needed for improvement which are often little or nothing too expensive.

Generally, the energy-intensive industries use huge amount of steam, so efficient working of all parts of the system is extremely important. The condensate pipelines between the steam generation plant and processes using steam are generally neglected. The workers at a steam generation plant should produce steam as efficiently as possible. People employed at the production lines should ensure the processes quality and quantity. Neither worker at steam generation plant nor workers at condensate pipelines is seldom interested in energy related details.

Currently, Indian pharmaceutical industry tops the chart amongst India's science-based industry with extensive capabilities in complex filed of drugs development, manufacturer and related technology. In terms of technology, quality and the vast range of medicines that are manufactured Indian pharmaceutical industry ranks very high amongst all the third world countries.

India presently represents small share of U.S. $6 billion of total $550 billion global pharmaceutical industry. In comparison to 7 percent annual growth for the world market overall, India's share is increasing at 10 percent a year. Also it in fourth place worldwide and accounts for 13 percent by value, and growth in drug export is 30 percent annually even though Indian sector represents just 8 percent of the global industry total by volume. The energy distribution in pharmaceutical industry [5], is given in following figure 1.1.

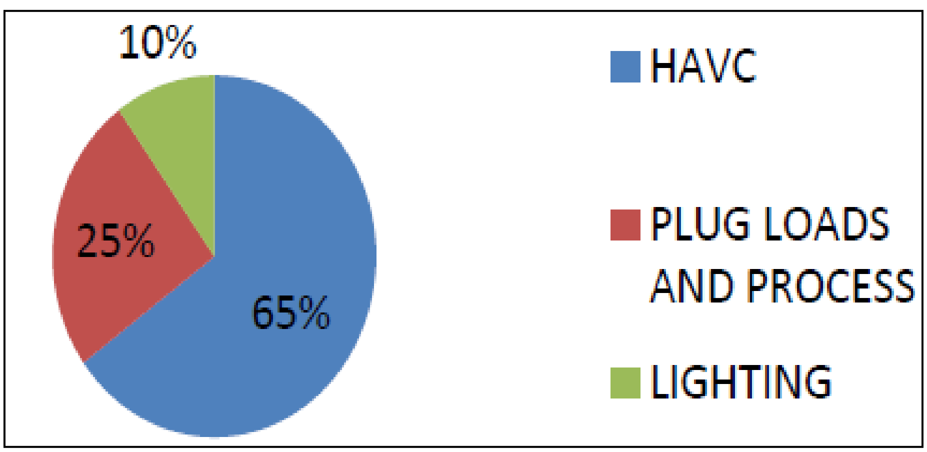

Figure 1.1 Distribution of energy in Pharmaceutical Industry

The strategic goal for any plant manager or manufacturing professional working in the drug industry today should be improving energy efficiency. The increase in the energy efficiency reduces overall manufacturing cost and environmental emissions further establishing a strong foundation for a corporate greenhouse-gas-management program. Heating, Ventilation and Air Conditioning (HVAC), in pharmaceutical manufacturing plants, is typically the largest consumer of energy.

The project work in the IndSwift Laboratoriess Ltd. aims at minimizing the losses at various possible sectors in the plant. Various processes carried out in the plant are studied and the main emphasis was laid upon the main areas/sectors which were the main sources of energy losses. Various suggestions were made to mitigate the identified energy losses. Working of boilers & turbines is analyzed & various energy losses are identified & worked upon. Various calculations were made to estimate the percentage losses. Same study was carried out for electrical transmission losses. Also the water balance, steam layout & steam traps were studied in detail.

1.2 OBJECTIVES

The objectives of the project work can be summarized as:

- Study various processes and equipments used in the IndSwift Laboratories Ltd.
- To determine all losses occurring during the generation, transmission and consumption of steam and power.
- To calculate turbine efficiency and boiler efficiency by both direct and indirect method.
- Abate or minimize those losses to make it more energy efficient by identifying and controlling leakages, modifying or replacing the steam traps, insulation check.
- To check amount of makeup water added into the circulating process in Power Plant by preparing water balance sheet after making and analyzing process flow chart for water demineralization.
- To design layout plan of steam lines of plant, and to check working status of several steam straps, to trace the leakages using visual method.

CHAPTER 2

LITERATURE SURVEY

Heat related energy savings has a major effect in boiler efficiency. It is in this manner imperative to expand the exchange of heat to the water and reduce the loss of heat in the boiler. Different methods have been involved in loss of heat from the boiler, including hot pipe gas loss, radiation losses. However in steam boilers, blow-down loss occurs [7]. To enhance the operation of a boiler plant, it is important to recognize where energy wastage is prone to happen. A lot of energy is lost through vent gasses as all the warmth created by the smoldering fuel can't be exchanged to water or steam in the evaporator. As the temperature of the vent gas leaving a boiler commonly goes from 150 to 250º C, around 10–30% of the heat energy is lost during the process. Since the greater part of the heat loss from the boiler show up as heat in the pipe gas, the recuperation of this heat can bring about generous energy reserve funds [8-9].This demonstrates that there is enormous savings possibilities of a boiler energy by reducing the energy losses. Having been around for centuries, the innovation required in a boiler can be seen as having achieved a level, with even negligible increment in productivity carefully difficult to accomplish [10]. The First Law of Thermodynamics is ordinarily used to dissect the energy use, yet it can't account the quality part of energy. That is the place energy investigation gets to be important. Exergy is the resulting of Second Law of Thermodynamics. It is a property that empowers us to decide the helpful work capability of a given measure of energy at some predetermined state. Exergy examination has been broadly utilized as a part of configuration, recreation and execution assessment of warm and thermo-concoction frameworks. The vitality utilization of a nation has been surveyed utilizing exergy examination to pick up knowledge of its productivity and potential for further change. Exergy examinations of the vitality use were initially presented in USA by Reistad (1975) [11] and have been done for different countries.

Dincer et al. (2004a)[12] presented that, exergy, by all accounts, to be a key idea, since it is a linkage between the physical and building world and the encompassing environment, and communicates the genuine productivity of designing frameworks, which makes it a valuable idea to discover upgrades. As a supplement to the present materials and vitality equalizations, exergy computations can give expanded and more profound knowledge into the procedure, and in addition new unexpected thoughts for enhancements. Therefore, it can be highlighted that the potential convenience of exergy examination in sectoral vitality usage is generous and that the part of exergy in energy approach making exercises is essential [13]. A comprehension of both energy and exergy efficiencies is crucial for outlining, dissecting, advancing and enhancing energy frameworks through suitable energy arrangements and procedures. On the off chance that such arrangements and procedures are set up, various measures can be connected to enhance the productivity of mechanical boilers [14]. An exergy investigation is typically expected to decide the most extreme execution of the framework and/or recognize the destinations of exergy pulverization. Distinguishing the primary locales of exergy annihilation, reasons for devastation, genuine greatness of pulverizations, demonstrates the course for potential enhancements for the framework and parts [14-15]. Dincer (2004a–b) reported the connection amongst vitality and exergy, exergy and the earth, vitality and reasonable advancement, and vitality approach making in subtle elements. So from the above talks and literary works clearly investigation of exergy is vital for vitality arranging, asset advancement and worldwide ecological, local, and national contamination lessening [12-13]. Exergy examination that might be viewed as bookkeeping of the utilization of vitality and material assets gives data with respect to how compelling and how adjusted a procedure is in the matter of moderating regular assets [16]. This kind of data makes it conceivable to recognize territories in which specialized and different upgrades could be attempted and shows the needs that could be doled out to preservation techniques. Exergy cognizant usage of vitality sources would progress innovative improvement towards asset sparing and productive innovation can be accomplished by enhancing configuration of procedures with high exergetic effectiveness. Use of the exergy examination in outline and advancement of supportable procedures likewise gives data to long haul arranging of asset administration [17]. Jamil (1994) concentrated on thermodynamics execution of Ghazlan force plant in Saudi Arabia where blend of methane, ethane and propane were utilized as powers and found that exergy proficiency in the kettle heater was around 18.88%. He additionally found the aggregate loss are high in the evaporator particularly in the heat exchanger (43.4%) contrasted with different gadgets and contemplated qurayyah influence plant where exergy proficiency in the heater was around 16.88% and in the heat exchanger 25.19% [18]. Gonzalez (1998) [19] contemplated the change of heater execution by utilizing economizer demonstrate and utilized hot gasses recuperation framework to enhance the execution of the evaporator. He reported that up to 57% of expense can be spared with the warmth recuperation framework. In this study energy, exergy proficiency, vitality misfortunes, and exergy detruction for an evaporator is distinguished and approaches to lessen kettle vitality utilization utilizing variable rate drive and nanofluids to improve heat exchange connected and vitality and monetary advantage have been investigated. It might be noticed that a heater vitality use can be decreased by numerous different courses for instance by controlling abundance air, upgrading heat exchange rate, enhancing burning proficiency, utilization of more ecological well disposed fuel, recuperating waste warmth, recouping condensate, streamlining blowdown process, avoiding spillage and giving legitimate protection. Financial advantages connected with vitality funds has been broke down and introduced too. It is essential to note that exergy decimations are because of irreversibilities in the turbine, pump and condenser. The essential method for keeping the exergy annihilation in an ignition procedure inside a sensible limit is to decrease the irreversibility in warmth conduction through appropriate control of physical procedures and synthetic responses bringing about a high estimation of fire temperature however bring down estimations of temperature angles inside the framework. The ideal working condition in this connection can be resolved from the parametric studies on burning irreversibilities with working parameters in various sorts of blazes. The most effective execution is accomplished when the exergy loss in the process is the base. These should be possible by enhancing heat exchangers, blades, warm protection, ignition process [20]. In this study exergy examination on a kettle is done by technique utilized by Rosen (1999) and Aljundi (2009b) [21-22]. As a boiler is utilized as a part of numerous mechanical applications and use huge measure of vitality, its proficiency change and decreased losses/exergy annihilation will assume a noteworthy part in vitality funds and alleviation of natural contamination. It might be expressed that this study will be valuable to arrangement creators, engineers, mechanical vitality clients and researcher in modern boiler energy use.

Saidur et al (2009) reported that 2–8% vitality can be spared by upgrading heat exchange rate of vent gasses utilizing nanofluids [23].

Saidur et al (2010) found that the burning chamber is the real supporter for exergy decimation took after by heat exchanger of a heater framework. Moreover, a few vitality sparing measures, for example, utilization of variable rate drive in evaporator's fan energy savins and heat recuperation from vent gas are connected in decreasing a boiler vitality use. It has been found that the payback period is around 1 yr for heat recuperation from an evaporator vent gas. The payback time frame for utilizing VSD with 19 kW engine observed to be monetarily reasonable for vitality investment funds in an evaporator fan [24].

VERTICAL GAS FLOW BOILERS HAVING HORIZONTAL TUBES

Foundation OF THE INVENTION: The present innovation identifies with boilers, and, specifically, to vertical gas stream boilers having flat tubes. While the case of the innovation depicted thus relate for the most part to warmth recuperation steam generators and allude to water as the working liquid, the present creation might be utilized as a part of different boilers, in atomic reactors, and in other warmth exchangers where there is two-stage stream.

Heat recuperation steam generators are boilers which take waste heat (more often than not from a gas turbine) and use it to make steam. Two fundamental sorts of warmth recuperation steam generators (boilers) are known- - vertical gas stream boilers (vertical boilers) and level gas stream boilers (even boilers).

Even boilers are generally utilized as a part of the United States and have the preferred standpoint that they work by normal dissemination. The tubes in which heat trade happens are vertical, and the distinction in thickness between the water going into the warmth trade tubes and the water/steam blend in the tubes and between the tubes and the drum acting over a stature makes the main thrust which causes the regular course. Flat boilers utilize a food water pump, yet they don't require costly flowing pumps and related valves and funneling, and they don't require expansive consumptions of energy to work coursing pumps. Be that as it may, flat boilers are more intricate in operation; they are hard to clean; they have a moderately huge impression (and accordingly take up a ton of floor space); and the heat move in a level heater is not as effective as in a vertical boiler.

Vertical boilers are normally utilized as a part of Europe and have the preferred standpoint that they have a little impression; the evaporator itself serves as a stack, so it is not important to assemble an extensive stack, as is fundamental with even boilers; they are anything but difficult to clean; and they have more proficient heat exchange. Additionally, in light of the fact that vertical boilers use flowing pumps to pump the water through the evaporators, they have great control over the water speeds inside the evaporator tubes. The immense hindrance of vertical boilers is that they require costly flowing pumps and related valves and funneling, and they require uses of vitality to work those pumps.

Constrained course vertical boilers incorporate both a food water pump and circling pumps. The coursing pumps in commonplace constrained dissemination vertical boilers pump roughly 5-8 times the stream rate of the food water pump, contingent on the flow proportion of the heater. Likewise, the coursing pumps work at much higher temperatures than does the food water pump and once in a while have a high channel weight, requiring costly pumps and expansive consumptions of energy. It would be exceptionally alluring to have the capacity to wipe out these circling pumps, which make such a substantial cost.

A characteristic dissemination vertical boiler with level evaporator tubes would be the best of both universes, taking out the cost of the flowing pumps and the vitality they utilize, while having every one of the advantages of a vertical heater. In any case, in this way, it has not been conceivable to make such a boiler, to the point that would be dependable, on the grounds that the driving leader of the common flow vertical kettle with even tubes is insufficient to dependably make adequate speed in the evaporator tubes.

The main wellspring of a characteristic flow driving head in a vertical boiler is the contrast between the water thickness in the down-comers and the thickness of the steam-water blend in the risers connected over the stature of the risers. The thickness contrast between the steam-water blend in the evaporator tubes and the water thickness in the down-comers can't be utilized to bring about course, on the grounds that the tallness of the tubes is zero (for even tubes). Hence, there is a generally low driving head. The issue is exacerbated, on the grounds that there is an extensive weight drop in the level containers of the evaporator, which implies that the driving head might be scarcely adequate, and now and again deficient, to bring about the fundamental regular flow. Likewise, the startup of such boilers is an issue, on the grounds that there is no wellspring of normal flow until there is a steam/water blend in the risers. This implies a helper wellspring of steam must be utilized to warm up the risers to kick the regular dissemination off, or some other outer means must be utilized, which makes its own issues.

OUTLINE OF THE INVENTION: The present development gives an enhanced vertical boiler which does not require the costly coursing pumps of earlier craftsmanship vertical boilers yet guarantees sufficient stream rates through the evaporators amid all unfaltering state and transient burden conditions, including amid startup, without the requirement for assistant steam sources or other outside means.

The present innovation gives a vertical boiler in which each evaporator is isolated into two areas - a first segment, which is driven by the food water pump, and a second segment, which depends basically on characteristic course.

A vast part of the dissipation happens in the main evaporator segment, and, since the stream which goes through the primary evaporator segment does not go during that time evaporator segment, this evacuates a considerable stream of steam from the second evaporator area, accordingly lessening the weight drop in the second evaporator segment, which makes it simpler for the regular head to drive the course in the second evaporator segment.

Likewise, in a favored exemplification of the development, the food water pump additionally viably upgrades the course in the second evaporator segment by giving injectors at the time when the yield of the main evaporator segment converges with the yield of the second evaporator area, so that the stream of the primary evaporator segment drives the stream in the second evaporator segment.

The principal steam-infused gas turbines in the mid 1950s channeled steam specifically to within the combustor liners. Steam was infused into the compressor release (CD) air through ports in the packaging amid the 60s. All the more as of late steam has been infused with the fuel (or around the fuel-spout tips) to control NOx. Hydro power (Renewable vitality where force is made by the development of vast amounts of water) era in India began in 1897 when 200KW hydro-station was initially authorized at Darjeeling (Bill Williams, 2002) [25]. Ivan G presents steam rates for different gas turbines with and without a garnish steam turbine capacity. The steam rates for high cycle weight proportion and high TIT gas turbines are obviously lower than steam rates for gathering steam turbines. The steam rate is around 4 lb/KW hr (1.8 KG/KW hr) while considering a CPR of 20, a TIT of 2450°F (1343°C) and when a 2400 psig 1000/1000°F (166.5 bar 538/538°C) RH topping steam turbine is used. The diagrams introduced can be utilized to acquire assessed steam rates for any given cycle weight proportion and TIT. Both straightforward and warm gas-turbine cycles are incorporated. The least steam rate is acquired for the warm gas turbine using a fixing steam turbine - for instance utilizing separated steam from a steam turbine. Natural concerns and government directions for toxin levels in emanations of modern plants have made the quest for more productive force era fundamental. The paper business specifically has expanded concoction recuperation limit and power era needs because of changing procedures intended to meet new and expected benchmarks [26]. Southards (1999) utilized a joined cycle power era and substance recuperation framework has a gasifier framework for delivering a fuel gas from a by-result of a modern procedure, for example, dark alcohol from a paper factory and a diesel or double fuel. Motor/generator associated with the gasifier framework to get the fuel gas for combusting to deliver electrical force. Fumes gasses from the diesel motor/generator might be utilized for steam era as a part of a boiler [27].

The disintegration brought on by wet steam stream diminishes the effectiveness of the last stage rotor sharp edges of consolidating steam turbines, and makes their administration life shorter. To date there has been lacking information on the disintegration procedure which the steam turbine rotor cutting edges are liable to amid the operation, information which could be a premise for improvement and confirmation of numerical models to gauge the administration life of dissolved rotor sharp edges. Stanisa B. et al (1995) checked on the consequences of numerous years observing and inquiring about of the laws of the disintegration procedure and its system for rotor edges of gathering steam turbines and assessed their administration life on the premise of the acquired laws of the rotor cutting edges disintegration process and an improved model [28].

These days, the need to keep up a high plant execution in prospect to fluctuating vitality request from electric network has turned into an extremely basic issue in the energy division. Barelli L et al (2015) demonstrated an imaginative consolidated cycle arrangement that permits to expand the plant operational adaptability enhancing, in the meantime, its worldwide proficiency to some degree load operation. The arrangement is described by a supercharged gas turbine, with an inventive control methodology, coordinated in a customary NGCC (common gas joined cycle). This proposed arrangement, called SNGCC (supercharged customary characteristic gas joined cycle), with an extra compressor organize upstream of the GT (gas turbine) cycle, has permitted to accomplish, amid part-stack operation, essentially higher proficiency appreciation to traditional regular gas consolidated cycle. Thusly, additionally the conceivable operation extent is broadened [29].

Improvement of clean coal innovations for force era is essential in meeting the European Union 2050 focus to lessen nursery gas emanations. CO2 catch innovation utilizing substance solvents at present has the most elevated potential to decarbonise coal-based force era. Substitution of amine dissolvable with NH3 has been proposed as a suitable alternative to decrease the productivity punishment. In this study, Hanak D. et al (2015) demonstrated supercritical coal-let go power plant retrofitted with a chilled smelling salts process catch plant and CO2 pressure unit in a typical reproduction environment. To completely evaluate the combination sway on force plant execution, the weight misfortune because of steam extraction has been considered by utilizing the Stodola oval law. Examination of an essential joining situation uncovered that the productivity punishment fell somewhere around 10.4% and 10.9% focuses relying upon the stripper weight. The nature of extricated steam got to be inadequate to meet the reboiler heat prerequisite over a stripper weight of 21.8 bar, and the most minimal proficiency punishment was gotten when reboiler condensate was come back to the deaerator in the force plant. In assessing measures to enhance mix, the effectiveness punishment was lessened to 8.7–8.8% focuses through the combination of a solitary stage or two-phase assistant steam turbine, individually, and a back-weight turbine. In any case, the examination has shown that the net effect on force plant execution is like that of an amine-based post-burning CO2 catch plant [30].

AIR HANDLING UNIT

Establishment of the INVENTION: Past ventilating mechanical get together to warm and/or cool air for a space to be served by the unit, for example, multi-zone air taking care of units which can fuse air warming and air cooling plans to give particularly molded air to different ranges inside a building, had for the most part given intends to mixing characteristic air with a picked measure of air returning from the space served by the unit. Diverse air channel game-plans have been given in such aeration and cooling systems and cooling frameworks to explicitly coordinate the measure of air familiar with the ventilating instrument, however such game plans are for the most part not gave intends to proficient blending of the arrival air and outside air before redistribution to the spaces served by the unit.

In addition, previous air channel measures of activity have required a couple of expensive engine worked dampers to coordinate the surge of fresh and return air to the circulating air through and cooling unit and exhaust a part of the arrival air from the unit. The air delta dampers in such device have been arranged in next to each other relationship to coordinate the arrival air stream and natural air stream in parallel stream ways. In some such mechanical assembly extra blending dampers or fights are given downstream of the delta dampers to blend the air streams before conveyance to the ventilating components and in those aeration and cooling systems where blending dampers or puzzles are not gave the floods of air are not blended so a few zones served by the unit get principally return air while different zones get basically outside air and not very many zones get the wanted mix of both.

Synopsis of the INVENTION: The present creation perceives that it is attractive to give an air bay chamber to altogether blend controlled parts of air came back from the served space with controlled segments of natural air drawn into the unit before the air goes through the cooling components.

The present development gives a clear air bay course of action for an aerating and cooling mechanical assembly which can incorporate just two engine worked dampers and favorably gives intends to effective blending of return air and outside air streams preceding the acquaintance of joined streams with the ventilating components of the unit. Accordingly, every range served by the aerating and cooling mechanical assembly is given a more uniform blend of outside air and return air.

The present innovation further perceives that by beneficially arranging the dampers controlling the outside air supply and return air supply inside the air channel States Patent 0 m 3,464,487 Patented Sept. 2, 1969[31] chamber in somewhat confronting connection, the two air streams are effectively blended and vast dampers can be utilized to decrease the weight drop experienced by the air stream going through the dampers so the limit of the air moving gear connected with the aerating and cooling unit is expanded.

Different components of the present innovation will get to be clear to those gifted noticeable all around after perusing the exposure put forward hereinafter.

Consistent steam line support in industry spins around keeping heat exchange surfaces clean, averting line steam spillages and planning boilers, weight vessels and warmth exchangers for lawful examinations. Steam traps have a tendency to get little consideration halfway in light of the fact that they are small things - frequently introduced in entirely darken regions of the plant. Be that as it may, likewise, Sandeep [32] has watched that "absence of steam trap learning is the weakest connection" in steam line upkeep. Also, when legitimately chose and introduced – frequently with master inclusion – they give solid administration amid their configuration life. This tends to shield consideration from them. What's more, if introduced to release to the air – similar to the circumstance for this situation study – streak steam release is a piece of their typical operation. Along these lines, a standard eyewitness may not effectively recognize trap advancement to aggregate disappointment.

Numerous steam traps are intended for a 3 to 5 year life [33]. This is not generally refreshing in industry. For instance, at two driving East African Industries, the larger part steam traps had not been traded for more than a quarter century. Indeed, even in the South African production line under thought they have been on line subsequent to the pre 1994 days. However agreeing Gardner [34] and different specialists like in a portion of the US Federal Government departments [33,35],by the third to fifth year, 30 to50% of them may have fizzled. In an assessment of a Belfast oil refinery steam plant, McKay and Holland [36] discovered 25% of the traps releasing live steam. They assessed that up to £121 500 could be saved money on yearly premise by counteractive action of the steam waste. The suggestion is that at some stage, traps must be supplanted.

The interdependency amongst water and energy, once in a while called the water-vitality nexus, is developing in significance as interest for both water and vitality increments. In the US, warm power plants make up 70% of the current armada [37]. These plants require expansive amounts of water, fundamentally to cool [38-39], and represent 40% of the aggregate crisp water withdrawals consistently [40]. This has an effect both on the oceanic life forms and on the water assets of the district where the force plant is found [41-42]. A report from the US Department of Energy [43] recognized an aggregate of 347 coal-let go power plants (from an examination set of 580 plants) as helpless against water request and/or water supply concerns. Thusly, it is critical to comprehend the water impression of the distinctive power era advances. Lamentably, the essential wellspring of information is from direct overviews of force plant administrators, which are frequently problematic and deficient [44-46]. With a specific end goal to better comprehend the water impression of warm power plants, this paper introduces a straightforward, non specific model to anticipate their water use.

CHAPTER 3

BOILERS AND TURBINES

3.1 BOILERS

The essential components of steam engine are steam generator and boiler when it is considered as a main powerhouse. However it needs to be treated separately, as to some extent a variety of generator types can be combined with a variety of engine units. The boiler consists of furnace and a firebox which are used to generate energy by burning fuel. The produced heat then transferred to water tank and converting water into steam. Then the generated steam converted to saturated steam having pressure greater than the boiling water pressure. The production of steam depends on the furnace temperature i.e. the higher the furnace temperature, the faster the steam production. Further the saturated steam either used to produce power by using a turbine and alternator or again superheated to a higher temperature. This superheated steam used to reduce suspended water content making a given volume of steam produce more work and creates a greater temperature gradient that can help in reducing the potential to form condensation. The remaining heat in the combustion gases can then either be evacuated or made to pass through an economizer, the role of which is to warm the feed water before it reaches the boiler.

3.1.1 Working Principle of Boilers

The controlled combustion of fuel is being required to heat water in gas and oil fired boilers. The key boiler components involved in this process are the burner, heat exchanger, control valves and combustion chamber. The burner mixes fuel and oxygen with the support of an ignition device to provide a platform for the combustion. The generated heat from the combustion chamber after mixing of fuel and O_2 then transferred to water through heat exchanger. The controls used in boilers help to regulate ignition, burner firing rate, water temperature, steam pressure, fuel supply, air supply, exhaust draft, and boiler pressure. The boiled water from the boilers then pumped to pipes and delivered throughout the building by the pipes, which includes service hot water heating equipment, hot water coils in air handling units, , and terminal units. The produced steam from boilers flows through pipes from areas of high pressure to areas of low pressure using an external source such as a pump. The steam using equipment utilizes steam for heating purposes and can provide heat through a heat exchanger that supplies hot water to the equipment. The discussion of different types of boilers provides more detail on the designs of specific boiler systems as given below.

3.1.2 Classification of boilers

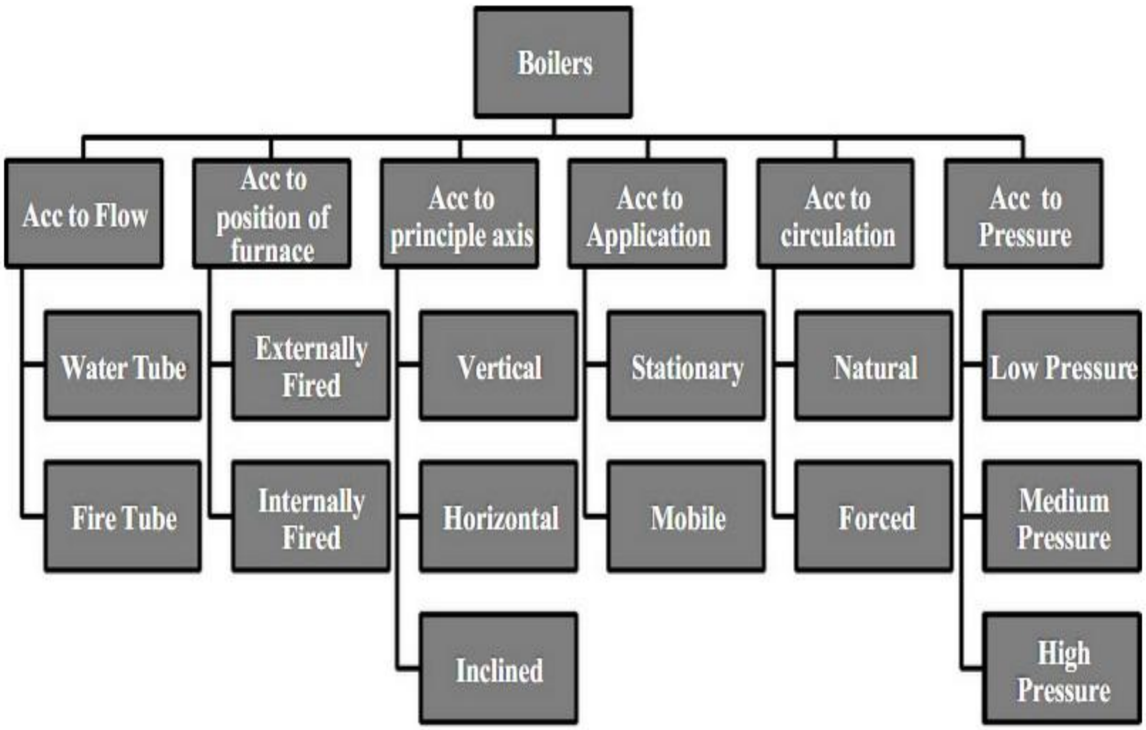

Figure 3.1 Classification of Boilers.

In IndSwift Laboratories Ltd., vertical drum-type boiler with enhanced circulation and horizontal evaporator tubes is provided with steam generation capacity of 37.5 TPH as shown in Figure 3.2. By using advanced circulation methods in vertical drum-type boilers and horizontal evaporator tubes the steam generation capacity can be enhanced up to 37.5 TPH. The evaporator can be divided into two different parts which are connected in parallel to drum. For providing forced circulation of water pump first evaporator section has been used and the natural circulation of pump has been done by using second evaporator section This design provides a vertical boiler which is consistent for all operating conditions such as transient conditions, start-up and steady state conditions without the requirement of circulating pumps and an auxiliary energy source such as steam, water, gas, etc.

Figure 3.2.Vertical drum-type boiler

3.1.3 Heat losses in Boilers

i. Dry flue gas
ii. Evaporation of water formed due to H2 in fuel
iii. Moisture present in combustion air
iv. Un-burnt fuel in fly ash
v. Evaporation of moisture in fuel
vi. Un-burnt fuel in bottom ash
vii. Radiation and other unaccounted losses

3.2 STEAM TURBINE

The working principle of a steam turbine is based on the conversion of high pressure & temperature steam into kinetic energy thus providing torque to a moving rotor. To convert energy from one form to another converging and diverging sections are required. Such above requirement is built up in the space between two consecutive blades of fixed and moving blades rows.

3.2.1 Types of Steam Turbine

A. IMPULSE TURBINE:

- In the impulse turbines the pressure drop takes place in fixed blades only, not in the moving blades.

- It is also called the De Laval turbine after its inventor .In these type impulse blades are attached to a single rotor.
- The steam is fed through one or several nozzles which do not extended completely around the circumference of the rotor, so only part of the blades are impinged at any one time.
- The pressure drop in this type occurs mainly in the nozzle and the velocity drops on the blades.

B. REACTION TURBINE:

In a stage of Reaction Turbine the Pressure/enthalpy drop takes place in both the fixed and moving blades.

- Reaction turbines are invited by C.A Parsons. It has three stages, each composed of a row of fixed blades and row of moving blades.
- The stationary blades are designed in such a fashion that the passages between them form the flow areas of nozzles, so they become nozzles with full steam admission around the rotor periphery.
- The moving blades of a reaction turbine are differ from the impulse turbine blades in that they are not symmetrical and act partly as nozzles.
- The pressure drops through all rows of blades. The pressure change gets greater as the steam pressure gets higher.
- The absolute steam velocity changes within each stage and repeats from stage and repeats from stage to stage.

3.2.2 Steam Turbine Pressure Classifications

Turbines are also classified by the pressure of the steam, which is supplied to the casings:

i. A high pressure (HP) turbine
ii. An intermediate pressure (IP) turbine
iii. A low pressure (LP) turbine

3.2.3 Steam Turbine Losses:

i. Friction losses
ii. Leakage losses
iii. Windage loss (More in Rotors having Discs)

iv. Exit Velocity loss
v. Incidence and Exit loss
vi. Secondary loss
vii. Loss due to wetness
viii. Loss at the Bearings (approx. 0.3% of total output)

3.3 RESULTS AND DISCUSSIONS:

In the power plant of IndSwift Laboratories the fuel used are Pet coke and Indo-coal in the boiler. The Pet coke constitutes 80% of the total fuel and indo-coal constitutes 20% of the fuel. Below various results are shown after thoroughly analyzing the power plant which shows the various specifications, efficiency and losses from the turbine and boiler.

3.3.1 Turbine Losses & Efficiency

T_G Load = 3.7 MW

Net T_G Load = 199800 KJ/min (Considering Transmission Loss factor of 0.9)

Table3.1. Parameter measurement of inlet and outlet steam of boiler.

	Pressure (Kg/cm^2)	**Temperature (^{o}C)**	**Flow Rate (TPH)**
Main Steam	60.8	473	28.1
Bleed Steam	8.6	288	2.9
Extraction Steam	4.8	252	15
Condensed Steam	0.85	56	10.2

Loss %= 5.84%

Turbine Efficiency, η = 94.15%

3.3.2 Boiler Efficiency

The boiler efficiency was calculated by both direct method and indirect method. The significance of indirect method is so that various losses can be analyzed thoroughly caused in boilers.

Table 3.2 Standard values of Water flow and Fuel consumption for efficiency calculations

Steam Flow (TPD)		688
Feed Water Flow (TPD)		691
De-aerator O/L Temperature (^oC)		109
Economizer I/L Temperature (^oC)		111
Economizer O/L Temperature (^oC)		208
Steam Temperature (^oC)		472
GCV of Pet Coke (KJ/Kg)		35145.6
GCV of Indo coal (KJ/Kg)		17154.4
Fuel Consumption (TPD)	Pet Coke	67.1
	Indo Coal	16.845
Steam Pressure (kg/cm^2)		64

Efficiency of boiler (By Direct Method) = 78.25 %

3.3.3 Boiler Losses

INDIRECT METHOD (80% PET COKE + 20% INDO COAL)

1. Indo Coal (as fuel)
    - Heat Loss in Dry Flue Gas: 4.14 %
    - Heat loss due to formation of water from H_2 in fuel: 6.26%
    - Heat loss due to moisture in fuel: 6.59%
2. Pet Coke (as Fuel)
    - Heat Loss in Dry Flue Gas: 4.30 %
    - Heat loss due to formation of water from H_2 in fuel: 1.65%
    - Heat loss due to moisture in fuel: 0.15%
3. Losses due to convection, radiation: 1%

Due to insufficient data various other losses such as losses due to ash, humidity in atmosphere, partial conversion of C to CO could not be evaluated. However, it was found to be 12.48% =[100- (78.25+9.27)].

Total Losses: 9.27%

Table3.3. Fuel analysis of boiler

	Moisture %	Ash %	C %	S %	O_2 %	N_2 %	H_2 %	GCV (Kcal/Kg)
Indo Coal	38.35	14.30	32.96	0.8	8.1	1.39	4.09	3600
Pet Coke	2.16	0.41	87.71	6	2.48	0.48	0.76	8200

3.3.4 Theoretical Air Requirement:

The need for the calculation of the theoretical air requirement for the boiler was to properly analyze the air requirements of the boiler so that the boiler might perform at its best and also to study various losses caused inside or outside the boiler. Various losses which are caused inside the boiler can be convection and radiation losses. The losses which play the major role are due to flue gases. So it was necessary to calculate the air requirement so that the boiler can perform at optimum level and losses can be reduced.

Now the scenario here was that fuel used was a mixture of indo coal and pet coke. The pet coke constituted around 80% of the total fuel and indo coal constituted 20% of the fuel. Both were mixed thoroughly and then fed into the boiler. Thus now separate calculations were done in order to find losses caused due to pet coke as a fuel and indo coal as a fuel.

(i) For Indo Coal:

Table 3.4 Stoichiometric air requirement for indo coal

O_2 in Flue gas	5%
Ambient Temperature	30ºC
Average Flue Gas Temperature	125 ºC
Total Oxygen required	113.31 kg of O_2
Air Required	492.65 kg of air
Theoretical Air Required	4.92 kg of air/ kg of fuel
Nitrogen in flue gases	379.34 kg of N_2
Percent Air Excess Supplied	31.25 percent
Actual mass of air supplied	6.45 kg / kg of fuel
Actual mass of flue gases	6.55 kg / kg of fuel

Table 3.5 Loses due to Indo coal

S.No.	Type of Losses	Calculated Value (%)
1.	Heat loss in dry flue gas	4.14
2.	Heat loss due to formation of water from H_2 in fuel	6.26
3.	Heat loss due to moisture in fuel	6.59
4..	Total	16.99

- Indo Coal constitutes 20% of the total fuel hence the above total value will be multiplied by a factor of (0.2).
- Net Value = 3.39%

(ii) Pet Coke:

Table 3.6 Loses due to pet coke

S.No.	Type of Losses	Calculated Value (%)
1.	Heat loss in dry flue gas	4.30
2.	Heat loss due to formation of water from H_2 in fuel	1.65
3.	Heat loss due to moisture in fuel	0.15
4.	Total	6.10

Table3.7 Stoichiometric air requirement for pet coke.

O_2 in flue gases	5%
Ambient temperature	30^{o} C
Average flue gas temperature	125^{o}C
Total oxygen required	258.97 kg of O_2
Air required	1125.95 kg of air
Theoretical air required	11.25 kg / kg of fuel
Nitrogen in flue gases	866.98 kg of N_2
% Excess air supplied	31.25 %
Actual mass of air supplied	14.73 kg of air / kg of fuel
Actual mass of flue gases	15.47 kg / kg of fuel

- Pet Coke constitutes 80% of the total fuel hence the above total value will be multiplied by a factor of (0.8).
- Net Value = 4.88%
- Heat loss due to convection and radiation is considered as 1%
- Various other losses such as: losses due to ash, humidity in atmosphere, partial conversion of C to CO are not considered due to insufficient data.

- **Final Losses = (3.39 + 4.88 + 1)% = 9.27%**

Final losses are the exact value of the losses including all the losses observed in the boiler. This includes sum of the losses caused when 20% of Indo coal is used as fuel and 80% of pet coke is used as fuel.

- **The computed boiler efficiency (η) = 90.73%**

This computed boiler efficiency is the exact value of efficiency calculated after thoroughly analyzing all the steps starting from fuel consumption of the boiler to the exit of flue gases.

CHAPTER 4

ELECTRICAL LOSSES IN POWER PLANT

4.1 TRANSFORMER LOSSES

Transformer losses are dominated by core losses and winding resistance joule losses. Mostly it is useful to demonstrate all these losses in terms of full load losses, half-load losses, no load losses and so on. Eddy current and hysteresis losses dominate highly without load and remains constant at almost all load levels, While the joule losses increases with the increase in load. The no-load losses can affect the idle transformer significantly as due to no-load loss an idle transformer has a drain on electric supply. For lowering transformer losses to have energy efficient transformers, it requires a higher quality silicon steel, a larger core, or amorphous steel. Various transformer losses are listed below:

- Hysteresis losses: The magnetisation and demagnetisation of the core due to flow of current is forward and reverse directions during each cycle results in hysteresis losses. Every time when the magnet field reverses, very small amount of energy is lost within the core due to hysteresis.

$$P_h \approx W_h f \approx \eta f \beta_{max}^{1.6}$$

f: frequency

η: hysteresis coefficient

β_{max}: maximum flux density

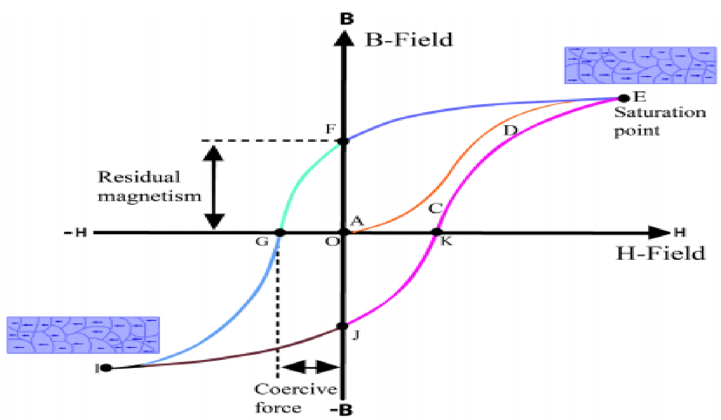

Figure 4.1: Hysteresis loop

- Eddy Current losses: A solid core of ferromagnetic material can efficiently acts as a short-circuited turn. Due to circulation of induced eddy currents in the core in a plane which is normal to the flux resistissve heating of the material of core is initiated. Eddy current loss is complex function of Inverse Square of thickness of material and square of supply frequency. F or reduction of eddy current losses electrical insulation of stack of plates in core is necessary and should use laminated cores.
- Magnetostriction Losses: Due to alternating magnetic field the core undergoes contraction and physical expansion with each cycle. Effect of magnetostricition causes losses in the core due to frictional heating. Frictional energy is the cause of an audible sound mains hum or may be called as transformer hum. It is mostly objectionable in transformers at high frequencies.
- Stray Losses: Leakage flux can affect the core by not linking all the magnetic field in the primary winding to the secondary winding resulting in induce eddy currents. These induces currents in transformer core gets converted to heat and is lost in the surroundings.
- Copper Losses: When current moves through the windings made of copper wire, they get heated due to joule effect. Proximity effect and Skin effect add up to the losses due to the winding resistance at higher frequencies.

4.2 TRANSMISSION LOSSES

Transmission losses are of two types Line losses and conductor losses. Fraction of energy is lost due to resistance when transmitting electricity at very high voltage. Resistance varies for different conductors, length of the transmission line, current flowing. Higher the voltage lesser the current for given power resulting in the resistive losses in conductor. Factors those are responsible for loss of conductors in transmission line includes spiralling, temperature and the skin effect. Changes in temperature can affect the power losses in life significantly. The increase of conductor resistance due to stranded conductors is known as spiralling. Increase in effective resistance of conductor at higher frequency is due to an effect known as skin effect.

4.3 RESULTS AND DISCUSSIONS

Table 4.1: Power Consumption

Days	ΔT_g X (MWh)	ΔTR-1 (HT) (MWh)	ΔTR-1 (LT)(a) A (MWh)	ΔTR-1 (LT)(b) B (MWh)	ΔTR-2 (LT) C (MWh)	Losses = X-(A+B+C) (KWh)	Losses %
Day 1	9.1596	5.4936	2.856	2.6538	3.3464	303.4	3.31
Day 2	9.5816	5.8816	3.0136	2.6888	3.5752	304	3.17
Day 3	8.524	4.86	2.5048	2.16	3.4912	368	4.31
Day 4	9.54	6.0752	2.812	3.0714	3.3736	283	2.96
Day 5	9.2648	5.714	2.7288	2.825	3.3944	316.6	3.41
Day 6	10.2936	6.6716	3.0944	3.3494	3.5472	302.6	2.93
Day 7	9.356	5.978	2.9786	2.886	3.241	250.4	2.67
Day 8	9.482	6.012	2.813	3.089	3.368	212	2.23
Day 9	9.876	5.879	2.726	3.051	3.776	323	3.27
Day 10	9.578	6.0231	2.76	3.1549	3.3459	318.2	3.32
Day 11	9.243	5.238	2.610	2.515	3.785	333	3.6
Day 12	9.664	5.487	2.876	2.479	4.091	218	2.26
Day 13	9.818	5.727	2.912	2.612	3.971	323	3.28
Day 14	9.716	5.912	3.121	2.598	3.618	379	3.9
Day 15	9.912	6.012	3.384	2.514	3.684	330	3.33
Day 16	9.879	5.827	3.416	2.315	3.833	315	3.18
Day 17	9.762	5.267	2.898	2.186	4.381	297	3.04
Day 18	9.4689	5.814	2.896	2.718	3.6249	232.2	2.4
Day 19	9.5014	5.720	2.694	2.916	3.6073	284.1	2.99
Day 20	9.6621	5.5197	2.886	2.5917	3.9134	271	2.8
Day 21	9.9216	5.926	3.014	2.812	3.7856	312	3.42
							Total=65.78%

Tabular description of Generation and distribution of power in turbine sector is framed in this table. Turbine power Generation denoted by ΔT_g is distributed to two transformers denoted by ΔTR-1 and ΔTR-2 respectively. Transformer ΔTR-1 is subdivided into two lines namely: ΔTR-1 LT (a), ΔTR-1 LT (b) where LT is a low voltage line. LT has supply of 440 volts for 3 phase connection and 230 volts for single phase connection. Actual losses were nearly 1.5% and losses shown above were higher than that of actual losses because of metrical and human error. For calculation of losses the share of power in two transformers ΔTR-1, ΔTR-2 is subtracted from total turbine power generation.

Mean loss percentage: Total loss percentage by total number of days comes out to be 3.13 %.

CHAPTER 5

AIR HANDLING UNIT

5.1 INTRODUCTION TO AIR HANDLING UNIT (AHU)

Air-handling unit is box-like apparatus with a cooling coil and a fan inside. Air filters are present in some units. The fan and motor assembly comprises of, bearings, shaft, belting and pulley are usually put inside the Air handling unit.

AHU has its basic function to suck air from the rooms and then letting it pass through the water cooling coils and then cooled air is discharge back to the rooms. Air is also filtered when passing through the bag filters. Air in the rooms can be replaced by introducing fresh air at suction duct. Air Handling Units come in several shapes and sizes. Various factors that are considered while choosing the AHU are air flow requirements and the cooling capacity. Humidity of the air is controlled by installing heating coils or other steam coils. For cleaning the air, special HEPA filters are installed at ducting outlets or at filter box. Connection of air with the chilled water coils condenses the moisture in the air. To drain the collected water a pipe is installed at the bottom of AHU.

An air handler is a device applied to circulate and condition air as part of air-conditioning, heating and ventilating system. Air handling unit is a large metal box comprises of heating or cooling elements, blowers, chambers or filter racks, dampers and sound attenuators. Ductwork ventilation system is connected to Air handling unit for distribution of conditioned air throughout the building and then returning back to AHU. AHUs supply and return air directly to and from the space assisted without ductwork.

Small air handlers that are applied for local use are known as terminal units, and consist of blower and an air filter coil. These terminal units are called fan coil units or blower coils. A larger air handling unit that conditions approximately full 100% outside air there is negligible re-circulated air is called as a makeup air unit (MAU). An air handler that is designed for outdoor use mainly on roofs is known as a rooftop unit (RTU) or packaged unit (PU).

The motor and fan assembly is mounted on vibration dampers that are used to absorb vibrations generated. Removable panels are installed to allow the personnel to enter the AHU for maintenance. Maintenance includes washing or changing of air filters, changing of belts, general inspection, cleaning work and greasing of bearings.

5.2 CONSTRUCTION OF AHU

Construction of air handler is normally around a framing system consisting of metal infill panels which is required to suit the component configuration. The frame is made up of metal sections or channels and with the single skin panels of metal infill. Galvanization of the metalwork is usually done for long term protection. For protection of outdoor unit additional sealing around joints and weatherproof lid is provided.

For manufacturing larger air handlers a double skinned square section steel framing system with insulated infill panels is required. These constructions help to reduce heat gain or loss from the air handler, and such constructions are even helpful in providing acoustic attenuation. Larger air handlers are several meters long and they are manufactured in a sectional manner. To provide strength and rigidity to the unit steel section base rails are installed below the unit.

For balanced ventilation system supply and extract air is required in equal proportions. The supply and extract air handlers can be joined together using side by side or stacked configuration. Components described below are in an order from the return duct though the unit to supply duct:

Filters: Air filtration is required to provide clean dust-free air throughout the building occupants. This can be done via, HEPA, simple low-MERV pleated media, electrostatic, or combination of various techniques. Ultraviolet air treatments and gas phase may also be employed. Air handling units perform Filtration at first priority so as to keep all the downstream components completely clean. Filter arrangement in banks depends on the grade of filtration required. The panel filter protects the more expensive bag filters and is cheap with zero maintenance. By monitoring the pressure drop through the filter one can access the life of filter.

Heating and/or cooling elements: Air handlers are needed to provide cooling, heating, or even both to change the humidity level and supply air temperature. Heat exchanger coil is employed to provide conditioning within the air handling unit. Direct heat exchangers contain those for fuel-burning heaters or a refrigeration evaporator which is placed directly in the air stream. Even Electric resistance heaters and heat pumps can be used. Evaporative cooling is possible only when climate is dry. Indirect coils use chilled water for cooling and hot water or steam for heating purposes, (major energy for cooling and heating is provided by central plant somewhere else in the building).

- **Humidifier:** Humidifier as the name suggests makes dry air humid. In the colder climate regions the continuous heating makes the air void of moisture which results in uncomfortable air quality and increased static electricity. Humidification is done in order to maintain required air quality. Various types of humidification may be used are given below.
  1. **Evaporative**: Blowing of the dry air over a water reservoir evaporates some of the water. This increases the moisture content of the air. Spraying the water onto baffles in the air stream can also be done.
  2. **Vaporizer**: The water is converted into steam or vapors. Blowing of steam or vapor from a boiler directly into the air stream makes air humid.
  3. **Spray mist**: Water is converted into fine droplets by a nozzle or other mechanical means. The droplets are then carried away by the air making carrier air moist.
  4. **Ultrasonic:** Ultrasonic heating device is used to excite a tray of water for forming fog over which dry air is blown.
  5. **Wetted medium**: A fine fibrous medium which is kept moist with water from a header pipe containing small outlets is used. When the air passed through the medium it entraps the water in fine droplets. In order to prevent clogging the primary air filtration quality should be maintained.

- **Mixing chamber:** Indoor air quality is maintained, by allowing the introduction of outside fresh air into, and the exhausting of air from the building. The mixing chamber is used for this purpose. Mixture of the cooler outside air with warmer return air is used to approach the desired supply air temperature in temperate climates. A mixing chamber uses the dampers, controlling the ratio between the return, outside, and exhaust air.

- **Blower/fan:** A blower is driven by an AC induction electric motor to move the air is employed in air handler unit. The blower can be single speed or offers a variety of set speeds. The wide range of air flow rates can be obtained by a motor driven by a Variable Frequency Drive. Inlet vanes or outlet dampers on the fan are used to control flow rate. Brushless DC electric motor that has variable speed capabilities is used residential air handlers.
- **Heat recovery device:** For energy savings and increasing capacity a heat recovery device or heat exchanger may be fitted to the air handler between supply and extract airstreams.
  1. **Plate Heat exchanger:** It is sandwich of metal plates with interlaced air paths with 4 to 6mm spacing between plates. The heat is transferred between airstreams from one side of the plate to the other giving efficiency of up to 70%.
  2. **Thermal Wheel or Rotary heat exchanger**: It is a gently gyrating matrix of finely corrugated metal, operating in both opposing airstreams. In the heating mode, heat absorption occurs when air goes through the matrix in the exhaust airstream during first half rotations and released during the second half rotation into the supply airstream in a continuous process. In cooling mode, heat is released as air passes through the matrix in the exhaust airstream, during one half rotations, and absorbed during the second half rotation into the supply airstream. Hydroscopic coating on wheel provides latent heat transfer and also humidification of airstreams. It has heat recovery efficiency of up to 85%.
  3. **Run around coil:** It consists of 2 air to liquid heat exchanger coils, in opposing airstreams, wrapped together with a circulating pump and uses brine or water as a medium for heat transfer. This equipment permits recovery of heat between remote exhaust and supply air currents and provides efficiency of 50% in heat recovery.
  4. **Heat Pipe**: It operates it both opposite air paths & uses restricted coolant as a medium for heat transfer. Several sealed pipes affixed in coil configuration constitute the heat pipe. Heat transfer is increased by connecting fins to the sealed pipes. In the evaporation of the coolant, heat is absorbed whereas condensation of coolant releases heat. The process is repeated by the flow of condensed coolant to the other side of pipe by gravity. Condensed refrigerant flows by gravity to the first side of the pipe to repeat the process. Heat recovery efficiency is up to 65%.

CHAPTER 6

WATER BALANCE AND DISTRIBUTION

6.1. WATER BALANCE

Water balance in simplest way possible can be described as the ratio between the water assimilated into the body to that lost from the body. Same definition of water balance can be applied to water balance in industry, considering it as single body.

Formerly the estimates of water usage or water loss have been made for theoretical power plant configurations. These estimates have been used as the foundation for comparisons of the water impacts of technology options. These former estimates were made using available incomplete flow sheet data, and misleading comparisons were generated. This is the important reason that any comparisons should be made using data from complete flow sheets. In the water balance all uses, makeup streams, discharges, internal generation and losses should be accounted for in order to form reliable conclusions.

The purpose of the study presented here is

i. To form basis for detailed accounting of water usage in the power plant and establish a reliable procedure for future studies.
ii. To give a baseline set of cases and water loss data for evaluating likely improvements and assessing R&D programs.
iii. To provide a basis for comparing water usage in different kind of power systems.

6.2. PARAMETERS DEFINED IN WATER BALANCE SHEET

The important terms defined for forming water balance sheet are given below.

- **Raw Water Usage**: It is the water measured from a raw source of water and used in the plant processes for any and all purposes. The water used can be accounted from cooling tower makeup, condenser makeup, slurry preparation makeup, ash handling makeup, synthetic gas humidification, quench system makeup, and FGD system makeup. In our study, all plants have evaporative cooling towers, and process blow down streams/channels are assumed to be recycled to the cooling tower after treatment. The complete effect of the process on the water source is represented by the usage.

- **Water Loss**: It is the water exiting/leaving the system and amount to the overall "loss" of water to the environment. These losses can occur as physical losses consist of process blow down streams, or they can occur through chemical reactions such as gasification shift or hydrolysis .or water entrained in solids or gas streams vented to the atmosphere. The difference between raw water usage and water loss represents the release of fuel bound moisture and outcome of combustion goes to the atmosphere. This prospective gross production of water resources (water out > water in) is not directly available and is "lost" to the water budget.
- **Dual Media Filter**: In order to remove turbidity and suspended solids as low as 10- 20 microns the dual media filter is implemented. Dual media filter is both very efficient at particle removal and has high filtration rate.
- **Multi Grade Filters:** it is made up of vertical or horizontal pressure sand filters which have different layers of coarse and fine sand (pebbles and gravels) in a fixed proportion. It is a deep filter bed with satisfactory pore dimensions for filtering both large as well as small dissolved and suspended impurities. This multi grade filtration system works on higher specific flow rates in comparison to usual sand water filter. It is also a low cost pre-treatment system for membrane systems such as reverse osmosis etc. and ion exchangers (deionizer and softener). It protects ion-exchange membranes from physical fouling due to suspended impurities in the water.

6.3. WATER CONSERVATION MEASURES

Water Audit and Analysis: In order to carry out water balance with a reasonable accuracy by systematic water auditing and quantifying water flows at each pumping station is required. By measuring inflows and outflows, the losses or wastage can be quantified. This will be helpful in adopting appropriate measures. Based on water audit studies, given below are the possible options for savings both in terms of water and Energy.

1. **Reducing leaks and over flows:** Generally water leaks from Valves, Taps, Fire-fighting hoses, Flanges, underground fire-fighting lines, cooling tower basin etc. Overflows occur

from cooling towers of AC plants, Air washers, and Overhead tanks due to non-functioning of float systems. It was observed that preventing this loss due to the leaks and overflows can reduce the water consumption by 3-5 per cent.

2. **Increasing cycles of concentration (COC):** The maximum water loss in the thermal power plants is from the cooling towers by of evaporation. It requires 180 M^3/hr cooling water flow to the condenser for generation of 1MW power. Empirical relation often used to calculate evaporation ratio is Evaporation ratio (M^3/hr) = (circulation rate in M^3/hr x Temperature Difference in ^oC/675). For the compensation of this evaporation loss, the blow down losses and drift should to provide make up water. The concentration of dissolved solids increases over a period of time as the water is circulated many times in the closed loop).

   The cycles of concentration (COC) = $\frac{\text{dissolved solids in the circulating water}}{\text{the make-up water}}$

   Based on this formula, the expected evaporation ratio for every 1 MW of power generation is 2.6 M^3/hr. For a 210 MW power plant, the expected evaporation loss would be 550 M^3/hr. Normally the cooling towers are designed for a COC of around 3. "To keep of COC of 3, there is need to provide a blow down of around 275 M^3/hr, for a 210 MW power plant. Since many thermal power plants face water shortage during summer, by increasing COC, the blow down quantity can be reduced. By external water treatment and adding water treatment chemicals, COC of even 10 can be reached. By increasing COC from 3 to 10, we can reduce the blow down quantity drastically from 275 M^3/hr to 30 M^3/hr, which is a savings of 88 per cent [48]"

3. **Others:** Some other suggested measures for reducing water consumption are:

- Use of air cooling instead of water cooling systems
- Reduction of water loss from waste water treating
- Water recovery from combustion flue gas
- Rain water utilization
- Water recovery for lignite drying
- Use of dry bottom ash removal system

6.4. RESULTS AND DISCUSSION:

6.4.1. Water Consumption in INDSWIFT

The simple model presented here allows one to quickly estimate water use for the whole range of thermal power plants, which is crucial due to the fact that most of the existing data on water use in power plants is incomplete or unreliable. One of the advantages of the model is that it helps to easily identify and understand what drives water use in a power plant. Water balance is also very useful in developing strategies to reduce water withdrawal and use.

The main water consuming areas of the industry are power plant and cooling tower of the various plants. The cooling towers are placed in most of the plant as it is very important to maintain the temperature inside each and every plant. As told earlier it's a pharmaceutical industry so it's important to keep the temperature under required limits.

The following Tables 6.1 shown below depicts per day water drawn from bore well and overall water consumption of the plant.

Table 6.1 Details of Raw Water Consumption per Day from Bore well

S No.	Services	Consumption Quantity (M^3)	Consumption Details			Evaporation Loss	Effluent generation
			Bore well	Reuse			
			Quantity (M^3)	Source	Quantity (M^3)	Quantity (M^3)	Quantity (M^3)
1	Power Plant Boiler/ Standby Boiler water	680	174	Steam Condens ate	400	51	123
				Treated Water after RO	106		
2	Cooling Tower	567	382	Treated Water after RO	215	266	116
3	D.M. / Softener / Rinse / Regeneration	5	5				5
4	Domestic water	33	33			6	27
5	Process Water	65	65			4	61
6	Equipment / Floor wash	100	100			3	97
7	Wet Scrubber / Pilot Plant	10	10			8	2

8	Construction, Gardening	20		Treated Water after RO	20		
9	Fire fighting	5		Treated Water after RO	5		
10	Spray / Misc.	15		Treated Water after RO	15		
Total :-		**1530**	**769**		**761**	**338**	**431**

10% Design Safety Margin:-	**77**
Grand Total:-	**846**

Details of Raw Water Consumption Quantity

Raw Water Consumption — 1530 M^3 / Day

A. Fresh withdrawal from Bore well:- — 769 M^3 / Day

B. Recycle

a) Steam — 400 M^3 / Day

b) Utility Treated water — 106 M^3 / Day

c) Bio treated water after RO — 215 M^3 / Day

d) MEE Condensate water after RO — 40 M^3/ Day

Total: **761 M^3 / Day**

Grand Total (A+B): **1530 M^3 / Day**

C. Evaporation Loss: — 354 M^3 / Day

D. Effluent Generation:

Table 6.2 Effluent generation in plant

Source	Quantify (M^3 /Day)	Stream				
		HTDS (M^3 / Day)	LTDS (M^3 / Day)	Utility (M^3 / Day)	Domestic(M^3/Day)	
a)Process	63	43	20	-	-	
b)Utility	105	-	121	-	-	
c)Power Plant	123	-	-	123	-	
d)Factory General	97	-	97	-	27	
e) Domestic	27	-	-	-	-	
Total :-	**415**	**43**	**123**	**123**	**27**	**431**

The above Tables 6.2 show the total amount of water extracted from the bore well per day which is **846 M^3**. Now this consumption has to be shown as what are the places where this quantity is divided. After observing the readings from the flow meter the above results were depicted, which shows that **174 M^3** amount of water is sent to the power plant and **382 M^3** to the cooling tower to full fill the makeup water requirements. The other requirements are at the plants for various processes called as process water which is **100 M^3**. The major water loss is due to evaporation taking place in the power plant steam lines and cooling towers of all the plants which is **51 M^3** in case of power plant and **266 M^3** in case of cooling towers. The water generated as effluent is sent to ETP plant and MEE plant to make it re-usable again. **1530 M^3** is the amount of the water that is required every day by the industry. Total water lost due to evaporation is **354 M^3**.

6.4.2 Water Balance Sheet of Power Plant

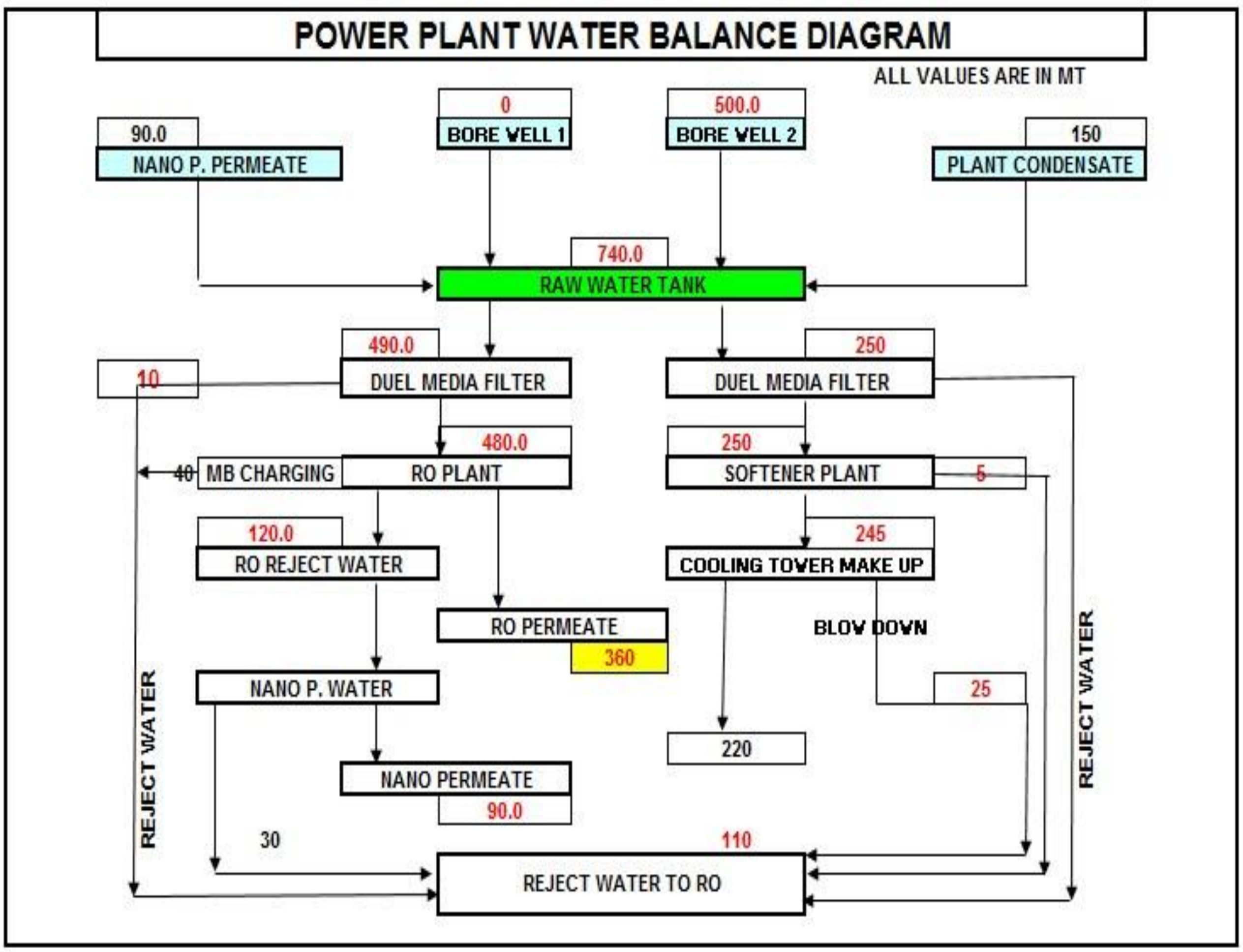

Figure 6.2 Water balance diagram of Power Plant

The above Figure 6.1 is the water balance sheet of the power plant of IndSwift Laboratories Ltd. The description of the above water balance sheet can is given as

- Bore well 2 extracts 500 m^3/day of underground water. The bore well 1 is not in use in the plant.
- The plant recovers 150 m^3 per day of condensate from it's evaporates which is collected by raw water tank. The water from bore well, plant condensate and Nano plant permeate is collected in raw water tank and constitutes 740 m^3 of water per day.
- From the raw water tank 480 m^3 per day of water is treated by reverse osmosis & 250 m^3 water is treated by softener plant. 120 m^3 per day of water rejected water from RO plant is sent for nano filtration which generates 90 m^3 per day of nano permeate & rest 30 m^3 of water is rejected.
- Clean water forming RO permeate is sent to the boiler of the plant for energy generation.
- Cooling tower make up recirculates 220 m^3 per day of soft water in plant for cooling purposes.
- The rejected water from dual media filter, RO plant, softener plant, nano-filtration & cooling tower totals to 110 m^3 per day of water which is then treated by reverse osmosis plant.
- Evaporated water losses = 740 m^3 (raw water tank) – 360 m^3 (used in boiler) -220 m^3 (cooling tower) – 110 m^3 (total rejected water) = 50 m^3 per day

CHAPTER 7

STEAM LINES AND STEAM TRAPS

7.1. STEAM LINES

In the design and development of any industry, power generation plants, petrochemical or refinery, substantial amount of money is spent on piping, considering fabrication costs, material costs, engineering costs etc. Thus to control the total installation cost, design & routing of pipes should be properly planned & executed. The piping which contributes to minimum expanses over prolonged time is characterized as best piping. To achieve this configuration we need to consider various parameters like easy maintenance, stability, stress level concerns, installation cost, fatigue failure etc.

To economically and safely transmit brine, steam and two-phase flow to destination of source the geothermal piping design should be within acceptable levels of pressure loss. The geothermal power-plant piping is split into two parts, first is the steam field piping, and second is the piping inside the power plant. The steam field piping's consists of pipelines linking separate stations to production well and the one running between separate stations to power plant across the country. The pipelines across the country runs on cross roads, bridges, hill slopes etc. are under the threat of possible damage due to land-slides, rain, wind etc. The geothermal piping design should have enough flexibility & stiffness for allowing thermal expansion and withstanding operational & seismic load actions respectively.

The steam line layout gives us information about the path followed by steam lines running throughout the plant. Steam line layout is useful in detecting the location of possible steam trap malfunction, source of leakage, & problems related to insulation. Also these layouts come handy while taking out tapings from the steam lines. The following figure 7.1 shows the steam line layout of the IndSwift Laboratoriess Ltd. The steam line layout has been drawn by tracking each of the pipeline through visual observation.

7.1.1 Steam Lines Layout

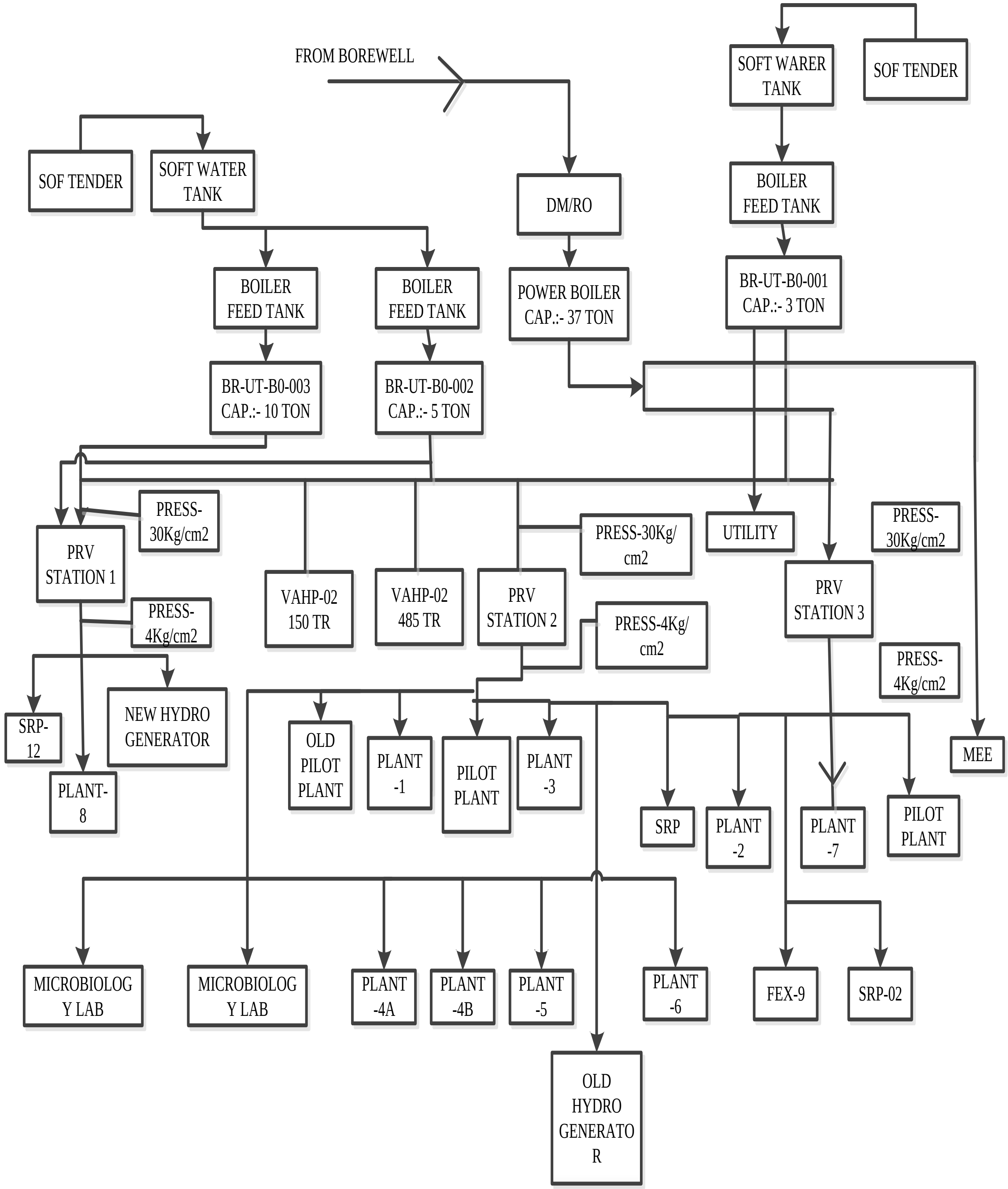

Figure 7.1 Steam line layout of IndSwift Laboratories Ltd.

7.2. STEAM TRAPS

Steam traps are automated valves connected in steam condensate circuit to drain non condensable gases, condensate and air. They prevent the leakage of steam & thus reduce energy wastage. By removing the condensate, it maintains the heat transfer rate & flow capacity of steam. Also it prevents "water hammer" condition that may arise due to excessive accumulation of steam, thus preventing disastrous failures. Also it removes the residual air after start-up of system & thus prevents possible decrease in temperature & steam pressure. Non condensable gases, like O_2 & CO_2, causes corrosion & thus needs to be removed using steam traps. The steam trap also prevents the annular flow of steam pipeline thus allowing increase in flow area & reduces the pressure losses of steam line. Since the flow-rate & pressure of condensates vary across steam distribution line, various different types of steam traps are developed to deal with such issues. Depending upon the physical process responsible for open & close of valves, steam traps are categorized as:

1) Mechanical, 2) Thermostatic 3) Thermodynamic.

1) Mechanical steam trap: The working of mechanical steam-trap valve is based on the difference in density between condensate and steam. In any vessel, which contains two fluids, the condensate being higher in density settles at the bottom of the vessel. The level of condensate in vessel will increase with increase in generation of condensate. In a mechanical steam trap, "free float" and connecting levers is used to transmit this action to valve.
2) Thermostatic steam trap: The working of thermostatic steam-trap valve is based on the difference in temperature between sub cooled condensate and steam. The expansion & contraction of bellows (filled with liquid) or bimetallic element causes actuation of valve.
3) Thermodynamic steam trap: The working of thermostatic steam-trap valve is based on the difference in steam and condensate pressure. Design of trap effects the pressure and flow velocity of steam. Different types of thermodynamic traps are: Piston, lever & disc.

Most of the steam traps installed on the steam lines of IndSwift Laboratories Ltd. are thermodynamic steam traps. Thus thermodynamic steam traps ae studied in detail. In a thermodynamic steam trap, with the entry of sub-cooled condensate, the disc is lifted off its seat due to increase in pressure. Thus allowing the flow of condensate out of the trap and into the chamber. As per the Bernoulli’s equation & first law of thermodynamics, the flow of condensate through narrow inlet port of the trap, decreases the pressure & increases the velocity of condensate. Because of the restricted drop in pressure, the temperature of the condensate entering the trap increases. This causes the condensate to flash to steam, which further decreases the pressure & increases the velocity, thereby resulting in the closing of the disc against the seating surface. The force created by the nominal pressure of the flash steam, acting on entire surface of the disc, is higher than the inlet condensate and steam pressure on the opposite side of the disc, acting on a much smaller portion of the disc. This causes, the disc chamber to cool, thereby condensing the flash steam. Thus the pressure of the condensate at the inlet will now be sufficient to lift the disc and the cycle is repeated.

7.2.1 Performance Assessment of Steam Traps

The performance of the steam trap is assessed by: (i) Checking whether or not, the steam trap is working properly, and (ii) In case of steam traps failure, checking whether the trap failed in closed or open position.

If the trap has failed in open position, it causes loss of steam and energy. In this the condensate is not returned, which further causes loss in water. This decreases the heat capacity of steam, and causes substantial economic loss. Traps that has failed in closed position, doesn’t cause a loss in energy or water, but may damage the steam heating equipment and/or reduces the heating capacity [47].

SIGHT METHOD

The sight method involves visually observing the downstream fluid of the trap. It is possible only if the installed valves, allow the downstream fluid in condensate recovery system to discharge briefly or condensate recovery system does not exist. In both these cases, the person evaluating the steam traps should be able to differentiate between “live stream” and “flash stream”. The flash streams implies that the steam trap is working properly whereas the live stream implies that a substantial amount of steam is leaking through the trap & thus the steam trap has failed in open position.

In case of trap is working properly, some amount of the condensate flash to vapor, due to expansion to atmospheric-pressure, thus creating flash stream. Flash steam has a comparatively puffy, surging plume. Whereas, live steam, has a sharp plume of high velocity which sometimes might not be instantly observable when it leaves the steam-trap. Figure 7.2 shows the visual difference between flash & live steam [49]. Evaluator analyzing the steam traps visually can also use sight glasses. However sight glasses have certain downsides. Firstly the sight glass view degrades with time due to external or internal fouling. Secondly both the condensate and steam inside the pipe appears as clear fluids. However to deal with this issue, certain enhanced features have been incorporated in sight glasses allowing the identification of condensate and steam.

Figure 7.2 (a) Live steam **(b) Flash steam**

Appendix A contains the list of steam traps installed in the Indswift industry, and the parameters of the steam traps like their locations, make, applications, working status etc.

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APPENDIX A

STEAM TRAPS SHEET

Tag No	Location	Make	Pressure (kg/cm^2g)	Application	Choice	Working Status	Remark
1	SRP-02 HE-014	Oscar	3	Heating	NOK	OK	By-pass open
2	SRP-02 HE-20	Oscar	3	Heating	NOK	OK	By-pass open
3	SRP-02 HE-16	Oscar	3	Heating	NOK	OK	By-pass open
4	SRP-02 distillation column header drain	Oscar	3	Header drain	OK	OK	
5	SRP-2 main steam line header drain	Oscar	3	Header drain	OK	OK	
6	SRP-2 boiler reactor-001	Oscar	3	Heating	OK	NIO	
7	SRP-02 rector-001	Pennant	3	Heating	OK	OK	By-pass open
8	SRP-02 rector-002	UKL	3	Heating	NOK	OK	By-pass open
9	SRP-02 reactor-006 (002)	Pennant	3	Heating	OK	OK	
10	Un-identified location	Pennant	3	Heating	NOK	NIO	
11	SRP-02-006	Pennant	3	Heating	NOK	NIO	
12	SRP-old main steam line	Oscar	4	Header drain	OK	OK	
13	SRP-old reactor-007	Spirax	3	Heating	NOK	NIO	By-pass open
14	SRP-old reactor-005	Spirax	3	Heating	NOK	OK	By-pass open
15	SRP-old reactor-	Spirax	3	Heating	NOK	OK	By-pass open

	008						
16	SRP-old reactor-004	Spirax	3	Heating	NOK	NIO	By-pass open
17	SRP-old reactor-001	Spirax	3	Heating	NOK	OK	
18	SRP-old reactor-002	Spirax	3	Heating	NOK	NIO	
19	SRP-old reactor-003	Spirax	3	Heating	NOK	OK	
20	Plant-7 extension reactor	UKL	3	Heating	NOK	NIO	
21	Plant-7 extension reactor	UKL	3	Heating	NOK	NIO	
22	Header drain near T-7126	Pennant	5	Header drain	OK	NIO	wrongly installed
23	Hot water tank near-T-7126	UKL	2	Heating	NOK	NIO	By-pass open
24	HE-T-2104	UKL	3	Heating	NOK	NIO	
25	Header drain back side plant-2	Oscar	3	Header drain	OK	NIO	
26	D-101	Pennant	3	Heating	OK	OK	By-pass open
27	D-105	Pennant	3	Heating	OK	OK	By-pass open
28	T-169 hot water tank	Oscar	3	Heating	NOK	OK	By-pass open
29	VAM-UTCH-003	Spirax	3.5	Heating	OK	OK	SLR-open
30	VAM-UTCH-003	Spirax	3.5	Heating	OK	OK	SLR-open
31	VAM-UTCH-003 PRS header	UKL	4	Header drain	NOK	Water logged	
32	AVAM-UT-BR-002	Spirax	3	Heating	OK	OK	
33	AVAM-	Spirax	3	Heating	OK	OK	

	UT-BR-001						
34	AVAM-UT-BR-004	Spirax	3	Heating	OK	OK	
35	AVAM-UT-BR-004	Spirax	3	Heating	OK	OK	
36	VAM-UTCH-005	Spirax	3	Heating	OK	OK	
37	Main steam line near DG set	UKL	10	Header drain	OK	OK	
38	PRS header near D-801	UKL	7	Header drain	OK	OK	
39	D-808	Mercey	3.5	Heating	OK	NIO	
40	Header drain YFHB-37	UKL	6	Header drain	OK	Passing	Replace the trap
41	SRP-02-R01	UKL	3	Heating	OK	OK	By-pass open
42	SRP-02-R03	Pennant	3	Heating	NOK	OK	By-pass open
43	SRP-02 header dead end	Pennant	3	Header drain	OK	Water logged	Need maintenances
44	SRP-02 reboiler-3	Pennant	3	Heating	OK	NIO	
45	SRP-02 header dead end	Pennant	3	Header drain	OK	OK	
46	SRP header drain	Pennant	3	Header drain	OK	OK	
47	SRP header drain	Pennant	3	Header drain	OK	OK	
48	SRP-R-004	Pennant	3	Heating	OK	OK	
49	SRP-Reboiler-01	Pennant	3	Heating	OK	NIO	wrongly installed
50	HE SRP01-021	Pennant	3	Heating	OK	NIO	

51	R-SR01-007	Pennant	3	Heating	OK	NIO	
52	R-SR01-005	Pennant	3	Heating	OK	NIO	
53	T-SRP-025	Pennant	3	Heating	NOK	OK	
54	T-SRP-053	Pennant	3	Heating	NOK	NIO	
55	D-302	Oscar	3	Heating	NOK	NIO	
56	D-1705	UKL	3	Heating	OK	NIO	
57	Plant-17 near dryer-1705	UKL	3	Heating	OK	OK	
58	Plant-17 near dryer-1705	UKL	3	Heating	NOK	NIO	
59	Plant-17 near dryer-1705	UKL	3	Heating	OK	OK	
60	Plant-17 near dryer-1705	UKL	3	Heating	OK	NIO	
61	R-1712	UKL	3	Heating	OK	NIO	
62	R-1711	UKL	3	Heating	OK	NIO	
63	D-1710	UKL	3	Heating	NOK	OK	By-pass open
64	R-1710	UKL	3	Heating	OK	OK	
65	D-308	Spirax	3	Heating	OK	OK	
66	D-307	Spirax	3	Heating	OK	OK	By-pass open
67	R-1708	UKL	3	Heating	OK	NIO	By-pass open
68	R-1707	UKL	3	Heating	OK	NIO	By-pass open
69	R-310	UKL	3	Heating	NOK	Water logged	Need maintenances
70	R-332	UKL	3	Heating	NOK	OK	By-pass open
71	R-313	UKL	3	Heating	NOK	NIO	By-pass open
72	R-312	UKL	3	Heating	NOK	NIO	By-pass open
73	R-315	UKL	3	Heating	OK	OK	
74	R-314	Oscar	3	Heating	NOK	OK	wrongly installed
75	R-316	Oscar	3	Heating	NOK	OK	
76	R-317	Oscar	3	Heating	NOK	NIO	By-pass open
77	R-318	Oscar	3	Heating	NOK	OK	By-pass open
78	R-311	UKL	3	Heating	OK	OK	By-pass open
79	4c-FBD	UKL	3	Heating	OK	Passing	Replace the trap
80	D-404	UKL	3	Heating	OK	OK	By-pass open

81	D-403	UKL	4	Heating	OK	OK	
82	D-403	UKL	4	Heating	OK	OK	By-pass open
83	Hot water tank near-T-439	Thermax	3	Heating	OK	NIO	
84	R-1806	Spirax	3	Heating	OK	NIO	By-pass open
85	R-1803	Spirax	3	Heating	OK	NIO	
86	R-1802	Spirax	3	Heating	OK	NIO	
87	R-1801	Spirax	3	Heating	OK	NIO	
88	Plant-18 main steam header drain	-	3	Header drain	OK	OK	By-pass open
89	R-1805	UKL	3	Heating	OK	NIO	
90	R-1804	UKL	3	Heating	OK	NIO	By-pass open
91	Plant-18 main steam header drain	UKL	3	Header drain	NOK	OK	
92	D-476	Pennant	3	Heating	NOK	OK	
93	D-474	UKL	3	Heating	NOK	NIO	
94	D-475	UKL	3	Heating	NOK	NIO	By-pass open
95	Near D-475	Oscar	3	Heating	NOK	OK	By-pass open
96	D-303	Oscar	3	Heating	NOK	NIO	
97	D-304	Oscar	3	Heating	NOK	OK	
98	D-305	Oscar	3	Heating	NOK	NIO	By-pass open
99	R-412	Oscar	3	Heating	NOK	NIO	By-pass open
100	Plant-4 header one	Pennant	4	Header drain	NOK	Water logged	Need maintenances
101	R-405	Pennant	4	Heating	NOK	OK	By-pass open
102	R-411	Pennant	4	Heating	OK	NIO	
103	R-413	Pennant	4	Heating	NOK	NIO	
104	R-414	Pennant	4	Heating	NOK	NIO	
105	R-415	Pennant	4	Heating	NOK	NIO	
106	R-408	Pennant	4	Heating	NOK	OK	
107	R-411	Pennant	4	Heating	NOK	OK	
108	R-404	Pennant	4	Heating	NOK	NIO	
109	R-410	Pennant	4	Heating	NOK	NIO	
110	T-4-20	Pennant	4	Heating	NOK	OK	
111	Header drain near RT-4A-01	UKL	4	Header drain	NOK	OK	
112	Plant-4B Near Lab dryer	UKL	4	Heating	NOK	OK	

113	Plant-4B Near Lab dryer	UKL	4	Heating	NOK	OK	
114	Plant-4B Near Lab dryer DH-4B-002FBD	UKL	4	Heating	NOK	OK	
115	DH-4B-001	UKL	4	Heating	NOK	OK	
116	D-PP-003	UKL	4	Heating	NOK	NIO	
117	R-912	UKL	4	Heating	NOK	NIO	
118	R-917	UKL	4	Heating	NOK	NIO	
119	R-906	Pennant	4	Heating	OK	NIO	
120	R-905	Pennant	4	Heating	OK	NIO	
121	R-918	Pennant	4	Heating	OK	NIO	
122	R-917	Pennant	4	Heating	OK	NIO	
123	Near T-1111	Pennant	4	Heating	OK	NIO	
124	Near T-1104	Pennant	4	Heating	OK	NIO	
125	Near T-1104	Pennant	4	Heating	OK	NIO	
126	Near-1127	Pennant	4	Heating	OK	NIO	
127	Near-1127	Pennant	4	Heating	OK	NIO	
128	Near-1123	Pennant	4	Heating	OK	NIO	
129	Near-1123	Pennant	4	Heating	OK	NIO	wrongly installed
130	Near-1124	Pennant	4	Heating	OK	NIO	By-pass open
131	Near-1124	Pennant	4	Heating	OK	NIO	By-pass open
132	Near-1133	Pennant	4	Heating	OK	NIO	By-pass open
133	Near-1133	Pennant	4	Heating	OK	NIO	By-pass open
134	Plant-11 header drain	Pennant	4	Header drain	NOK	NIO	
135	Near T-1003	Pennant	4	Heating	OK	OK	
136	Near T-1003	Pennant	4	Heating	OK	OK	
137	Near T-1012	Pennant	4	Heating	OK	NIO	
138	Near T-	Pennant	4	Heating	OK	NIO	

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139	Plant-10 main steam line drain	Pennant	4	Header drain	NOK	OK	
140	Hot water tank near hydrant-YF-HB-27	Thermax	4	Heating	OK	NIO	wrongly installed