KALINA CYCLE BASED UTILIZATION OF WASTE HEAT RECOVERY FOR INDUSTRIAL

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***Abstract:** To recover the heat energy from such a system, different factors like flue gas dirt rate of deposition ought to be thought-about which in it should be an entire project. This needs a close study on however the exhaust heat may be recovered with very little or no deposition on the economizer tubes and alternative associated instrumentation to confirm long life spans for the chosen elements. The Kalina cycle may be a variation of the Rankine cycle, employing a mixture of ammonia and water because the operating fluid. A key difference between single fluid cycles and cycles that use binary fluids is that the temperature profile throughout boiling and condensation. This permits higher thermal matching with the waste heat supply and with the cooling medium within the condenser. Consequently, these systems come through considerably larger energy efficiency.*

Index Terms - Heat pipe heat exchanger, Waste heat utilization, On-line cleaning device,

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I. INTRODUCTION

The rapid rise in electronic field, industrialization and application of electronic components in recent years has led to a rapid increase in concentration of thermal systems. Generation and rejection of heat is essential to all electronic components from microprocessor to high end power converters for their reliable operation. As electronic designs are enclosed in smaller packages dissipating the heat becomes a critical design factor. To overcome such heat rejection issues heat sinks are used. Due to compactness and energy consumption, the electronic devices require more cooling than the capacity of the standard metallic heat sinks. To rectify these needs using the heat pipe becomes a major tool for thermal management. The idea of heat pipe was first designed by Gaugler (1944). He applied a heat transfer design to a refrigeration system by using a wick. This application was redesigned by Grover et al (1964) and coined the name heat pipe. In the past few years, the electronic industry embraced heat pipe as reliable, cost effective solution for high and cooling applications. The heat transfer mechanism of heat pipe shows that the heat transfer capacities vary from one hundred to several thousand times to that of an equivalent piece of copper. The main advantages of heat pipes are long life time, low cost, high flexibility and high reliability.

Common heat transfer working fluids vide air, water; ethylene glycol and engine oil are used in the heat pipe for heat transport. But these conventional working fluids show very low thermal conductivity compared to solids.

To overcome these difficulties the present study focused on the intensification of the poor thermal conductivity of liquids by appending the solid particles to them. James Clerk Maxwell (1863) introduced a theoretical model of the electrical conductivity of disparate solid particles. While scrutinizing the thermal conductivity of mixtures of solid particles and liquids the classical Maxwell model has been applied. Overall, these investigations have been demonstrated with milli meter or micro meter-sized particles. The disadvantage of the usage of micro particles is that they settle easily in liquids and these results in corrosion, clogging, and creation of pressure drops. To get better results in the thermal conductivity of these suspensions high particle concentrations are required. These issues limit the use of conventional solid liquid suspensions as practical heat transfer fluids. In spite of massive efforts, the problems associated with such technical barriers still prevail. Modern nanotechnology validated the production of nano particles with average particle sizes below 100 nm. These nano-sized particles have peculiar mechanical, optical, electrical and thermal properties.

II. WASTE HEAT RECOVERY OPTIONS AND TECHNOLOGIES

Methods for waste heat recovery include transferring heat between gases and/or liquids (e.g., combustion air preheating and boiler feed water preheating), transferring heat to the load entering furnaces (e.g., batch/cullet preheating in glass furnaces), generating mechanical and/or electrical power, or using waste heat with a heat pump for heating or cooling facilities.

2.1. Kalina Cycle

The Kalina cycle is a variation of the Rankine cycle, using a mixture of ammonia and water as the working fluid. A key difference between single fluid cycles and cycles that use binary fluids is the temperature profile during boiling and condensation. For single fluid cycles (e.g., steam or organic Rankine), the temperature remains constant during boiling. As heat is transferred to the working medium (e.g., water), the water temperature slowly increases to boiling temperature, at which point the temperature remains constant until all the water has evaporated. In contrast, a binary mixture of water and ammonia (each of which has a different boiling point) will increase its temperature during evaporation. This allows better thermal matching with the waste heat source and with the cooling medium in the condenser. Consequently, these systems achieve significantly greater energy efficiency.

The cycle was invented in the 1980s and the first power plant based on the Kalina cycle was constructed in Canoga Park, California in 1991. It has been installed in several other locations for power generation from geothermal energy or waste heat.

Fig.1 Kalina Cycle Installation

The waste heat recovery system, including the recovery mechanism, energy conversion and utilization, was designed based on the Kalina Cycle and incorporated individual designs of the unit's components which comprised, the heat exchanger, piping system and the working fluid (mixture of ammonia and water), economizer, regenerator, evaporator separator, storage tank and the circulating pump. The proposed recovery system uses ammonia-water mixture as the working fluid as a direct heating system as shown in the flow on Figure 2.

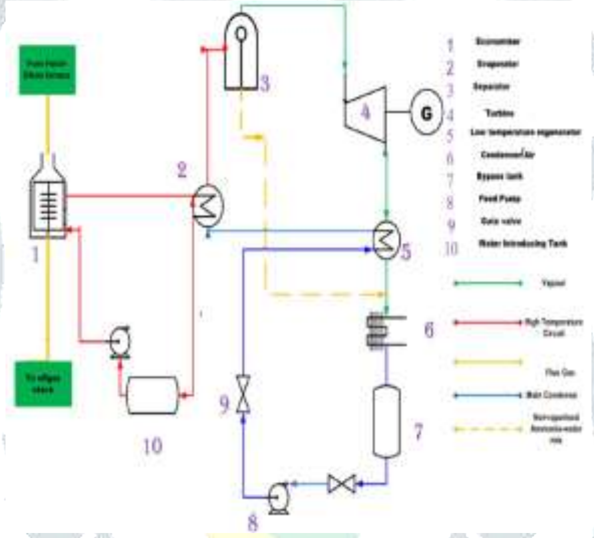

Fig.2 The proposed waste heat recovery system based on the modified Kalina Cycle

III. PROPOSED METHODOLOGY

Energy-Utilization Diagrams (EUD) is an important engineering tool to improve energy efficiency of energy conversion systems (Ishida and Zheng, 1986 and Ishida et al., 1987). The energy losses of the system are shown by a graphical presentation which gives a useful overall description of the process.

The use of mixtures as working fluids has opened new possibilities to improve the efficiency of power and refrigeration cycles with less costly equipment. Mixtures may be an important substitute for CFC refrigerants, thus, decreasing environmental problems. The Kalina cycle, which uses an ammonia-water mixture, may show 10 to 20% higher energy efficiency than the conventional Rankine cycle (Kalina, 1984 and El-Sayed and Tribus, 1985). The ammonia-water mixture boils at a variable temperature unlike pure water which boils at a constant temperature. Variable temperature boiling permits the working fluid to maintain a temperature closer to that of the hot combustion gases in the boiler, thus, improving the energy efficiency, a fact which has been well known among scientist and engineers. But there was no practical, efficient way to condense the mixture back to a fluid for recycling until the Kalina cycle was introduced.

Figure 3 shows the simplified Kalina cycle based on this study. This is a bottoming cycle feed by exhaust gases (1, 2) to the boiler. Superheated ammonia-water vapor (3) is expanded in a turbine to generate work (4). The turbine exhaust (5) is cooled (6, 7, 8), diluted with ammonia-poor liquid (9, 10) and condensed (11) in the absorber by cooling water (12, 13). The saturated liquid leaving the absorber is compressed (14) to an intermediate pressure and heated (15, 16, 17, 18). The saturated mixture is separated into an ammonia-poor liquid (19) which is cooled (20, 21) and depressurized in a throttle and ammonia-rich vapor (22) is cooled (23) and some of the original condensate (24) is added to the nearly pure ammonia vapor to obtain an ammonia concentration of about 70% in the working fluid (25). The mixture is then cooled (26), condensed (27) by cooling water (28, 29), compressed (30), and sent to the boiler via regenerative feedwater heater (31).

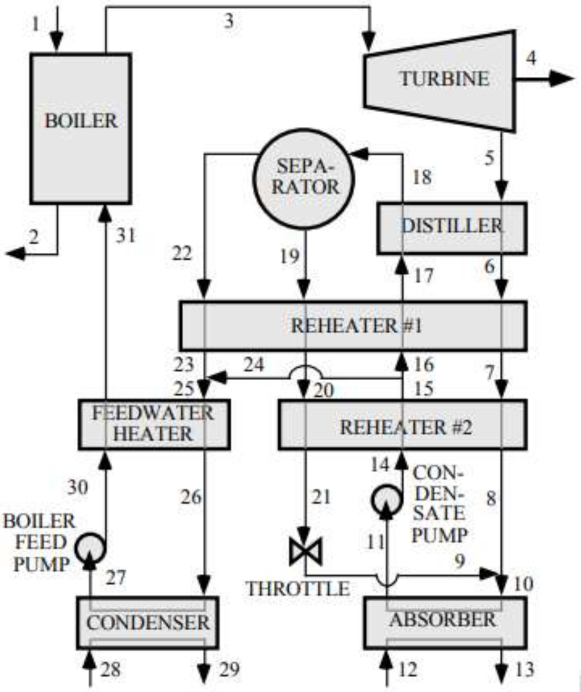

Fig.3 A simplified Kalina cycle

A simple model is assumed for the physics properties of the ammonia-water mixture utilized in the Kalina cycle. Within the gas section, on top of the saturation temperature of water Tsw, the superheated mixture is assumed to behave as a perfect resolution of superheated ammonia and water vapor (fig. 4). Once the temperature is between the pure water saturation temperature Tsw and also the mixture saturation point Td, within the gas section, the water part is assumed during a meta-stable vapor state at the thought-about pressure. Similarly, within the liquid region, between the saturation temperature of pure ammonia Tsa and also the bubble purpose of the mixture Tb we tend to assume a meta-stable liquid state for ammonia. Within the wet vapor mixture region Td > T > Tb we've a saturated vapor mixture with ammonia mass fraction X_g and a saturated liquid mixture with ammonia mass fraction X_f.

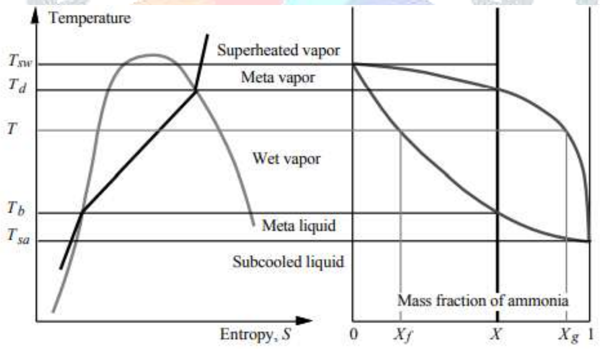

Fig.4 The various states on T-S and T-X diagrams

In the liquid region, below the bubble point of the mixture Tb, a Gibbs excess function for the departure from ideal-solution behavior is assumed.

IV. ENERGY-UTILIZATION DIAGRAM OF THE KALINA CYCLE

Figure 5 shows the Energy-Utilization Diagram for the Kalina cycle given above. This diagram shows the scheme of energy transformations by plotting the quantity of energy transformed on the abscissa (i.e., coordinate for the primary law of thermodynamics) and therefore the energy levels of the donor method (A^{ed}) and also the acceptor method (A^{ea}) on the ordinate (i.e., coordinate for the second law).

It is found that there are pinches at many points. Hence, it's not very easy to work the system and far attention ought to be paid particularly to those pinches. However, once this is often solved, the uniform distribution of energy loss shows that this technique is well-optimized. The diagram is split into completely different elements associated with the parts of the Kalina cycle in Fig. 3. This figure clearly shows whether or not the standard of the energy, i.e., energy, provided is sufficient and also the level of excess. The full energy loss in every system is shown because the space between the energy donating and energy acceptive lines. (The shadowed area.) Within the boiler energy from the exhaust gases, the energy donating line is curved down, is transferred to the ammonia-water mixture, wherever we will see the half indicating variable temperature boiling within the middle of the energy acceptive line. For the turbine gas expansion is that the energy donor and its energy level becomes larger than unity, whereas a piece sink with A = one is that the energy acceptor. The world between these 2 energy levels offers the energy loss within the turbine and also the work generated is obtained because the width of Hea. The remaining a part of the diagram shows the heat exchange within the remaining subsystems indicating a really well optimized system.

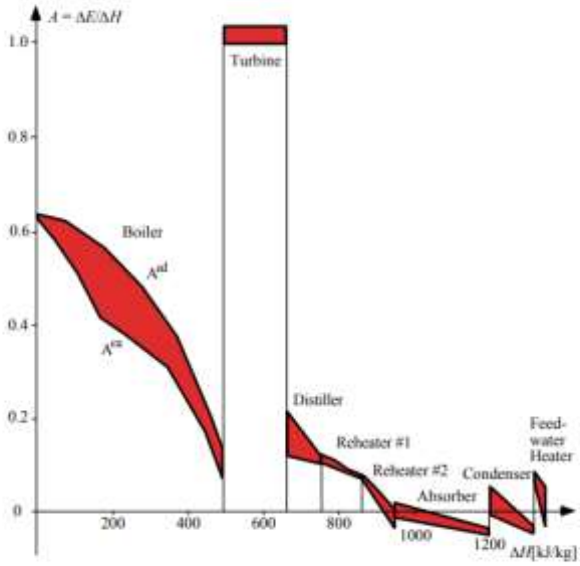

Fig.5 Energy-Utilization Diagram for the Kalina cycle

V. RESULT DISCUSSION

Three possible ideas were thought of for the waste energy recovery system supported established principles, specifically the Kalina Cycle that utilizes an ammonia-water mixture, thermal oil and ORC wherever the system heats the operating fluid indirectly and thermal storage and power generation. Exploitation the binary dominance matrix and weighted objectives, the Kalina Cycle provided the simplest answer and was selected because the most optimum idea supported functionality, reliableness, ease with that it may be manufactured and maintained, efficiency, ergonomics, quality and value. this idea was then developed additional, element by element, as well as the incorporation of positive attributes from the opposite 2 ideas to develop and propose the waste energy recovery system. However, there are varieties of limitations that were discovered that may be handled by future and additional work. To recover the heat energy from such a system, different factors like flue gas dust rate of deposition ought to be thought of which in it should be a whole project. this needs an in depth study on however the exhaust heating are often recovered with very little or no deposition on the saver tubes and different associated equipment to confirm long life spans for the chosen elements.

Although this may be a really sound investment, more work additionally has to be administered to determine functionality by putting in a model and running it below real time observation. The platinum process company has been one among the only a few companies in Zimbabwe still in operation near 100% capability utilization because of its foreign possession and support it gets from the parent company in terms of experience, systems and instrumentality. the corporate ought to therefore cash in of this and invest in innovative comes like the waste heat recovery system so as to stay afloat particularly seeable of the inconsistent power provides. There ought to even be a reliable system, like the utilization of fuzzy logic and programmable logic controllers to observe and control temperature, pressure and flow rates on entry and exit, significantly for the ammonia-water mixture that ought to operate below 132oC, and also the flue gas close temperature when leaving the economizer should be larger than100oC to avoid formation of water droplets within the flue gas which can increase the load on the induced draft fans. The control mechanism is programmed to observe leakages and clogging similarly, which can cause heat losses and delay in condensate come back, severally. Inspection and maintenance of heat exchangers and pumping units for fouling and corrosion is suggested to be done often, let alone repair or replacement of seals within the pumping units to reduce water loss by dripping. To realize variable fluid flow, variable speed drives ought to be utilised on pumping systems to permit pump speed changes over.

VI. CONCLUSION

This study evaluated technologies and current waste heat recovery practices during a type of applications: melting furnaces; boilers; coke ovens, blast furnaces, basic element furnaces, and electric arc furnaces within the steel industry; glass melting furnaces, primary and secondary refinement furnaces within the aluminium industry; cement kilns; and ethylene furnaces. The instrumentality evaluated consumes a complete of 8,400 TBtu/yr, or concerning one third of the energy delivered to industrial facilities. Systems analyzed varied considerably in terms of typical recovery practices. Industrial boilers account for concerning 70th of the energy analyzed, and these systems generally incorporate heat recovery. Meanwhile, analysis of different processes showed that heat recovery is usually used with clean foamy streams in high ¬capacity furnaces. However, heat recovery tinyer amount} common in applications that have dirty exhaust streams and/or in small scale applications. Many furnaces continue operative at efficiencies below 500th owing to high exhaust temperatures. To boot, whereas this study targeted on gaseous exhaust streams, it had been complete that alternate sources of waste heat are often vital and need more investigation. Large quantities of low¬ temperature waste heat are offered in cooling water. in addition, vital heat is lost from hot instrumentality surfaces (e.g., Al cell sidewalls) and from product streams (e.g., cast steel, blast furnace slag, etc).

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