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WASTE HEAT RECOVERY FROM COMPRESSED AIR- A REVIEW

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ABSTRACT

This research paper presents a review of various works focused on waste heat in industry for improving energy efficiency. It refers to energy that is industrial processes without utilization and it is almost waste. Many of recovery technologies are already well developed and give best results. It indicates that there may be lot of opportunities for improving industrial energy efficiency with the help of waste heat recovery. The different reviews based on the aspects of heat recovery and the methodologies and technologies being employed for its optimization in industries also study through literature. Air compressor is universal machine which is used in all sectors of industries. This work also concentrated on the use of air compressor and possibilities of waste heat recovery from compressed air. Heat loss can be classified into high temperature, medium temperature and low temperature grades. Waste Heat Recovery (WHR) systems are introduced for each range of waste heat to allow the most optimum efficiency of waste heat recovery to be obtained. the use of waste heat recovery systems in industrial Processes have been key as one of the major areas of research to reduce fuel consumption, lower harmful emissions and improve production efficiency.

At present the major uses of the refrigerated air dryers but uses of the HFC, HCFC refrigerant are for reason of the global warming and ozone depletion potential. Hence the waste heat from the compressed air is best solution to replace the vapour compression refrigeration to vapour absorption refrigeration system. It may directly saving of electrical energy.

: **Keyword:** Waste heat recovery, Air Compressor, Air dryers, heat exchanger

I. Introduction

Waste heat is generated from industrial application. The largest sources of waste heat for most industries are exhaust and flue gases and heated air from heating systems such as high-temperature gases from burners in process heating; lower temperature gases from heat treating furnaces, dryers, and heaters; and heat from heat exchangers, cooling liquids, and gases. While waste heat in the form of exhaust gases is readily recognized, waste heat can also be found within liquids and solids. Waste heat within liquids includes cooling water, heated wash water, and blow-down water. Solids can be hot products that are discharged after processing or after reactions are complete, or they can be hot by-products from processes or combustion of solid materials. With the growing trend of increases in fuel prices over the past decades as well the rising concern regarding global warming, engineering industries are challenged with the task of reducing greenhouse gas emissions and improving the efficiency of their sites. In this regard, the use of waste heat recovery systems in industrial processes has been key as one of the major areas of research to reduce fuel consumption, lower harmful emissions and improve production efficiency. Industrial waste heat is the energy that is generated in industrial processes which is not put into any practical use and is wasted or dumped into the environment. Sources of waste heat mostly include heat loss transferred through conduction, convection and radiation from industrial products, equipment and processes and heat discharged from combustion processes. Heat loss can be classified into high temperature, medium temperature and low temperature grades. Waste Heat Recovery (WHR) systems are introduced for each range of waste heat to allow the most optimum efficiency of waste heat recovery to be obtained.

1.1 Relevance:

At present every industrial process generates waste heat – the challenge is to recover this heat and make use of it economically. Waste heat will be available as a flow of liquid or gas at a temperature hotter or colder than its surroundings. Key to its successful recovery is identifying its sources and potential uses. Once the sources and uses of waste heat have been identified, a detailed assessment will determine whether recovering the waste heat will be practical and economic. Some examples are as given in following table

Waste Heat Sources	Uses for Waste Heat
• Combustion Exhausts: Glass melting furnace Cement kiln Fume incinerator Steel reverberatory furnace Boiler • Process offgases: Steel electric arc furnace Steel reverberatory furnace • Cooling water from: Furnaces Air compressors Internal combustion engines • Conductive, convective, and radiative losses from equipment: HallHèroult cells • Conductive, convective, and radiative losses from heated products: Hot cokes Blast furnace slags	• Combustion air preheating • Boiler feed water preheating • Load preheating • Power generation • Steam generation for use in: power generation mechanical power process steam • Space heating • Water preheating • Transfer to liquid or gaseous process streams

Waste Heat Sources and End Uses [4]

Above waste heat sources have definite temperature range & key factor for determining waste heat recovery feasibility. It is necessary that the waste heat source temperature is higher than the surrounding temperature. The magnitude of the temperature difference between the heat source and surrounding temperature is an important determinant of waste heat's utility or quality.

II. Literature Survey

Hussam Jouhara et.al (2018) -It had been concluded that industrial waste heat is the energy lost in industrial processes to the environment. Waste heat recovery in industry covers methods of collection and re-use of the lost heat of industrial processes that can then be used to provide useful energy and reduce the overall energy consumption. Heat loss is mainly classified into high temperature, medium temperature and low temperature grades and waste heat recovery systems are correspondingly introduced for each range of waste heat. The selection of heat recovery methods and techniques largely depends on key factors such as the quality, quantity and the nature of heat source in terms of suitability and effectiveness. The identification of the waste sources is an important aspect when looking into waste heat recovery methods for industrial processes in order to achieve optimum results and efficiency. In this regard, a comprehensive review is presented for waste heat recovery methodologies and state of the art technologies used in industrial processes. It was investigated that, there are many different heat [1]

MA Guang-yua , et.al (2012)- As energy crisis become increasingly prominent, the energy consumption has become the main problem which restricts the sustainable development of China's iron & steel industry. The recovery and utilization of different kinds of waste heat can effectively reduce energy consumption, the research of the scientifically recovery and utilization of waste heat become very important. The current situation and status of recovery and utilization of waste heat in the China's iron & steel industry will be analysed from some aspects such as the quality and the source process of waste heat, Based on them the potential and develop directions will be pointed out, combining with the analysis of the basic principle using energy scientifically, the mode of the recovery and utilization of waste heat is given, it is hoped that it can promote the scientifically and rapid development of recovery and utilization of waste heat of any Industry.[2]

A.D.Pitale,et.al (2017) It had been concluded that, recovering Waste heat is the need of the day for the industries of developing countries. Extent of literature available shows a continuously increasing interest of researchers, managements and engineers in recovering the heat. Many big industrial plants have already realized the importance of heat recovery and they are effectively utilizing it in one or other way. Efforts are being done to improve the recovery efficiencies by using the latest technological advancements and optimization methods.[3]

Ashok Reddy (2017) : A detailed review of waste heat recovery systems used in power generation units and utility of heat from other sources like cement, internal combustion engines, paper, chemical industries were been discussed . Flow diagrams of utilization of waste heat recovery system, conventional and cogeneration power utility systems have been drawn. Supercritical Carbon Dioxide cycle , Gasification and internal combustion engine coupled to an organic rankine cycle from biomass, heat recovery system with organic rankine cycle in cement industry, organic rankine cycle heat recovery in PEM fuel cell, and air conditioning integrated Hot water system have been discussed . [4]

Cecilia Arzbaecher,**et.al (2007)** Industrial facilitates with significant energy use should conduct site-wide energy efficiency assessments to identify opportunities to reduce energy intensity and identify waste heat recovery and reuse opportunities. Incentive programs from utilities and federal and state agencies are available to offset all or part of the cost of a site-wide energy-efficiency assessment. The site-wide energy-efficiency assessment should:

• Start with an energy balance of energy sources and uses (loads);
• Identify waste-heat recovery and reuse opportunities;
• Utilize pinch analysis, if applicable;
• Consider new technology options, such as energy-efficient motors, adjustable speed drives, advanced controls, heat exchangers, heat pumps, electric boilers, energy-efficient lighting, combined heat and power, cogeneration, energy storage and distributed generation;
• Identify and implement cost-effective projects that minimize energy intensity. [5]

Amir K. Deshmukh,et.al (2017) - Waste heat is defined as heat which is rejected from the process at a temperature above the ambient temperature to permit the extraction of additional useful energy from it.The recovery of waste heat is the most beneficial single energy conservation technique which can significantly help to conserve fuel and bring about substantial cost reduction in energy intensive industries. Waste heat is the heat which is produced in a process by combustion of fuel or exothermic chemical reaction and then rejected into the environment even though it can still be utilized for some useful and economic purpose. [6]

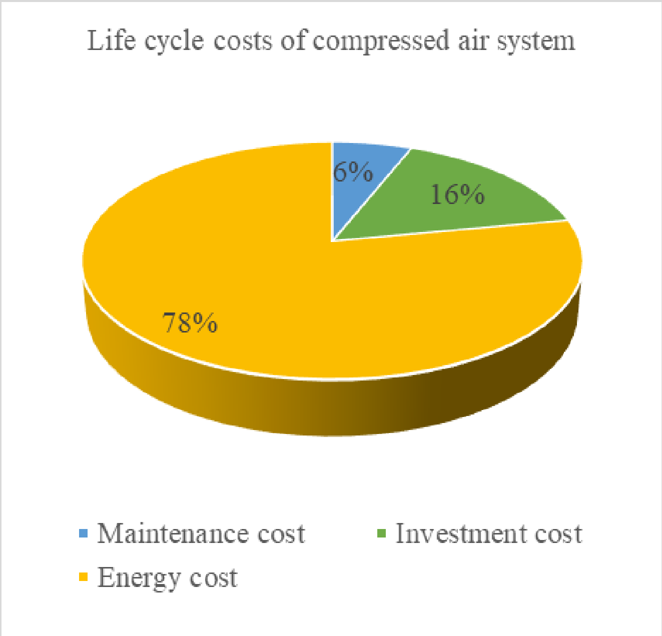
Mariusz Broniszewski ,et.al (2018)- Research study focused on recovering heat form air compressors are profitable and can be successfully implemented in industrial area, in companies that use compressed air in their production processes. Additional advantage of implementing this kind of solution for improving energy efficiency is possibility for gaining significantly shorten payback period of investment.

Sami Kara ,et.al (2014) - Compressed Air (CA) systems have a significant impact on the energy consumption and efficiency of manufacturing systems. These may be composed of a single compressor or include several compressors that work together in a logical manner. Compressors with fixed or variable drive systems have dynamic energy consumption profiles. In addition, they require complicated logic to control multiple compressors as a system. The control system reacts to the flow and pressure of the air output and determines which compressors need to be loaded and which ones to be unloaded. This paper provides an overview of techniques to model energy consumption as well as various approaches used to control the CA system. A state-base modelling technique is used to develop a simulation model that includes both fixed and variable speed drive compressors. [8]

Abdul Hadi Mahmoud Ayoub (2018) - Compressed air systems are very popular and widely used in industrial facilities. They are used for providing compressed air to the systems, such as machines, pneumatics, tools, and transportation. Compressed air usage varies depending on the type of industry. Compressed air systems are known to be one of the biggest energy consumer systems in a facility, usually 10% - 30% of the electricity consumption.[9]

2.1 Objectives:

1. **To study the use of compressed air in industry**
2. **Possibilities of the waste heat recovery from the compressed air.**



Typical Lifetime Compressed Air Utilisation & its cost [8].

Compressed air is considered to be cheap, or even free source of energy. However, this is a wrong approach. About 10-20% of electricity transferred to the compressor is used for production of compressed air,

For the needs of Proper utilization of Compressed Air , proposals of savings in compressed air systems were the rest is lost due to lack of tightness and heat losses developed, with determination of savings potential according to index of possibility to apply, given as percentage values. The following operations were highlighted:

• Reduction of air leaks,
• Reduction of pressure losses that result from friction,
• Appropriate designing of new compressed air systems,
• More frequent changes of filters,
• Compressors upgrading,
• Variable rotary drives,
• High performance electric motors,
• Application of advanced Control systems,
• Waste heat recovery,
• Improvement of cooling, drying and filtration systems,

Energy costs during the utilization time of a compressor may reach more than 75% of the total cost during life cycle (as shown in Figure). It has been claimed that improvements within energy efficiency of compressors can bring energy savings in amount of 20-50% energy used for their running.

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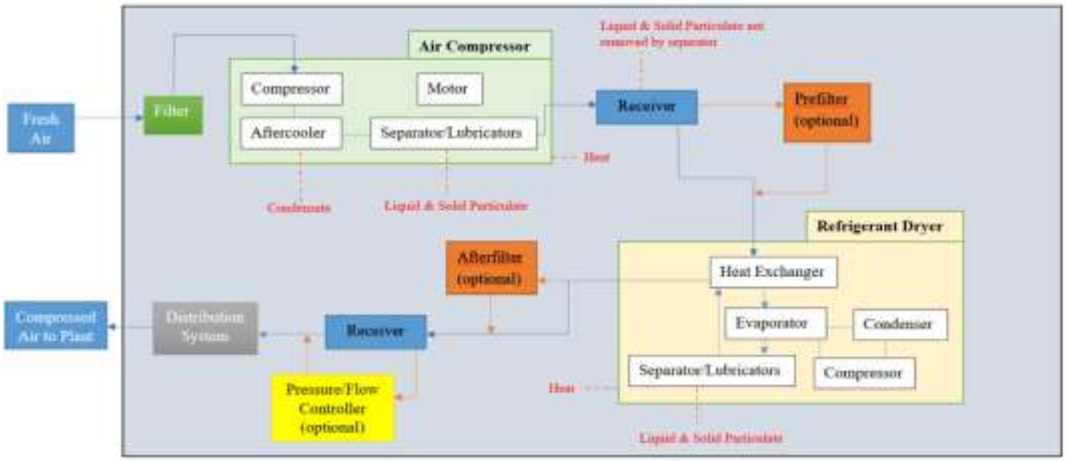
2.2 Compressed Air System Diagram.



Compressed Air System Diagram. [9]

Above Figure shows a typical air compressor system diagram. The fresh air intake flows into a filter before entering the compressor. Many of the industrial air compressors come in a closure that will include multiple components such as compressor, motor, after cooler and a separator. Then, air flows into a wet receiving tank. The wet receiving tank helps store the air and drain any liquid and solid particulate that was not removed by the separator. A common practice is to place a filter between the receiver and air dryer. Refrigerant air dryers come in closures similar to air compressors. These closures include the main component of a refrigerant cycle, and that would be a heat exchanger, evaporator, condenser, and a compressor. Finally, air will flow through an optional filter before being stored in a dryer receiver tank. Pressure Flow Controller plays an important role in distributing the air to the plant side based on the required air demand.

2.3 Air Dryers

Air dryers are one of the most common methods used to modify air quality. Their main purpose is to convert air into a form that can be used for different applications. Compressed air must be kept free of moisture. Without air dryers, wet compressed air running through the system would negatively impact the machines. Parts of the machines would rust and tear due to the wetness of the air passing through. However, excessively dry compressed air would result in unnecessary energy and costs.

2.4 Air Receivers

Air receivers, or compressed air storage tanks, is a crucial part in compressed air systems. They are used as temporary storage for compressed air to meet peak demand from systems and optimizes the efficiency of the plant. It also helps control the system pressure by controlling the rate of change in a system. Receivers should be properly sized to meet the required demand. There are several factors that should be considered when sizing a receiver. These factors are: minimizing pressure fluctuations/drops, meeting short term peak air demands, energy considerations, and safety consideration.

2.5 Pressure/Flow Controller

A pressure/flow controller is a device that serves to separate the supply side of a compressed air system from the demand side. Most plant air systems have an ever changing fluctuation of demand, and changes in plant air pressure. Peak air demands will draw from the air system, and tend to disrupt the air capacity. These changes inevitably lead to inconsistent production, poor product quality, and wasted energy. The system will utilize the supply-side storage tank installed with the compressors operating at an appropriately set control pressure, and the controller will deliver the desired plant air pressure set point. Peak air consumption will be drawn from storage, and less compressor horsepower is required for peak events.

A pressure/flow controller is used to:

- Stabilize of the plant production quality by stabilizing the compressed air.
- Optimize operations of the Air Compressors.
- Make constant adjustments to stabilize the system air pressure in responses to the ever-changing fluctuations of demand.

2.6 Air Inlet Filters

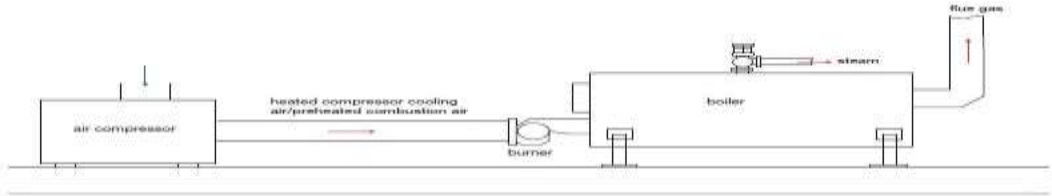
An air inlet filter protects the compressor from any atmospheric particles such as dust and dirt. It is the most important filter on the compressor. It will prevent the dust from getting sucked into the oil, oil filter, and oil separator. Any of these issues could lower the compressors performance and increase both maintenance costs and energy bills. Filtration only to the level required by each compressed air application will minimize pressure drop and resultant energy consumption.

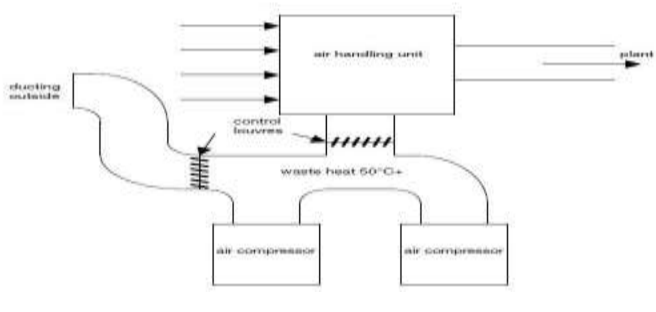
2.7 Aftercoolers

Aftercoolers are installed to cool the discharge from the compressor. They also reduce the moisture and water vapour in the compressed air system. After coolers are placed after the final stage of the air compression. The air is cooled below its dew point converting the water vapour into liquid and drained from the system

2.8 Heat recovery from an air compressor.

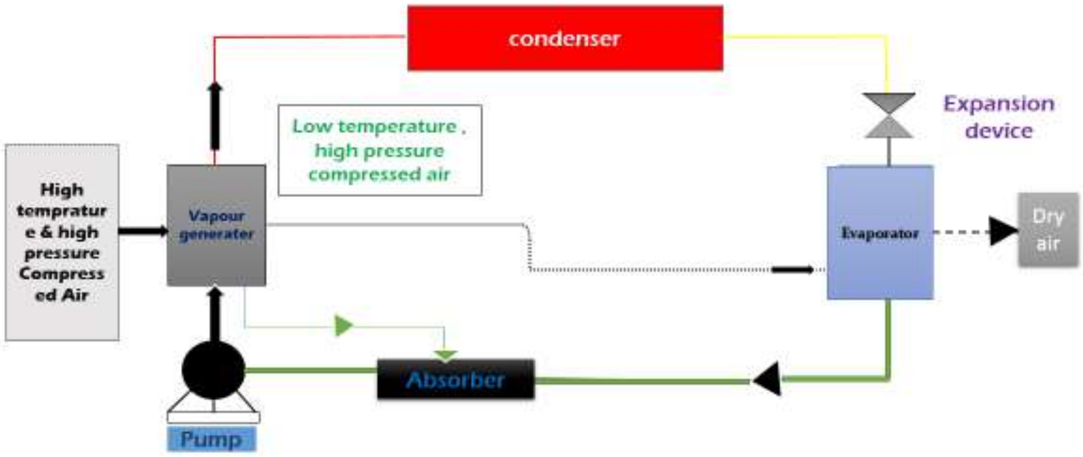
Air compressors are widely used in industry for supplying compressed air to run machinery and equipment. Unfortunately, only around 15% of the electrical energy supplied to the compressor is available to do useful work – most of the supplied energy is lost as heat and will need to be removed by the compressor’s cooling system. If the compressor is water-cooled, then recovery of the waste heat can be fairly straight forward with perhaps only a heat exchanger and pump required. If the compressor is not water-cooled, many compressor manufacturers can supply heat exchangers to transfer this heat to water. Air may be a good option A possible layout is shown as below





2.9 Problem Statement. Using compressor cooling air as preheated boiler combustion air[10]

In above study, waste heat recovery from compressed air is utilized for preheating of air for boiler and space heating for centralized air conditioning plant but one can utilized the waste heat recovery for preparation of compressed dry air in place of refrigerated air dryer. We can supply waste heat for vapour absorption refrigerating system and save input power.



Proposed Set up for Heat recovery from Compressed Air

III. Conclusion

1. All the researchers have claimed that recovering the waste heat is need of the day for the industries of developing countries. This is continuous work of researcher, management and engineers in recovering the heat.
2. Many big industrial plants have already realized the importance of heat recovery and they are effectively utilizing it in one or other way.
3. Some are taking efforts for improve the existing recovery efficiencies by using technological advancements and optimization techniques.
4. Some papers have provided an overview of current research trends in compressed Air Energy Demand and storage and also new updated technology in the view of betterment in terms of sustainability, low maintenance and long life time.
5. In this current energy scenario we all are focused towards the awareness of planning activities that would be aiming at increase the energy efficiency in production plants and secondary processes such as production of compressed air.
6. The industry that have to produce compressed air in their operational activity, should maintain entire compressed air system requirements. Because it has great potential for application in heat systems for their other applications.

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