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Combined Refrigeration Cycle for Thermal Power Plant Using Low Grade Waste Steam

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Abstract
Now a days, In most of the thermal power plant, where low-pressure steam is being exhausted to the atmosphere as a waste steam. This waste heat could be use to operate many small preheating or cooling equipments or small scale plants. There are many refrigeration systems present for refrigeration and air condition purpose. Such as air refrigeration, vapour compression, vapour absorption etc. In this paper we have presented the concept of combined vapour absorption and vapour compression refrigeration system. We present about the idea discuss here that how a vapour absorption and vapour compression can be used together as one complete working refrigeration plant. By using such concept of refrigeration we can improve the co-efficient of performance of whole plant by minimizing the input. We can also named the system as waste heat recovery refrigeration system.
Keywords: waste heat recovery; Combined cooling plant; combined absorption-compression refrigeration; Primary energy.

I. Introduction

There are wide range of low-grade recovery technologies and design options for the recovery of low grade heat, including heat pump, organic Rankine cycle, energy recovery from exhaust gas, absorption refrigeration and boiler feed water heating. Simulation models have been developed for techno-economic analysis of the design options for each technology and to evaluate the performance of each with respect to quantity and quality of low grade heat produced on the site. [1] In order to utilize the waste heat efficiently for a steam turbine driven heat pump running in cooling mode, this paper studied two combined vapour absorption and vapour compression refrigeration cycle using ammonia and water as a working fluid. By analyzing the operating characteristics of the combined cycle that make efficient use of waste heat output of the turbine in any steam turbine power plant. Analysis of result indicates that optimization can make the combined cycle fully achieve the saught-after energy saving advantage. It was also found that the PERs (primary-energy ratio) of the combined cycles increase considerably compared with a conventional engine driven compression cycle working with pure ammonia. The combined cycle, with two solution circuits, is the best.

In large installations particularly where high pressure steam is available for power generation and heat is rejected in the condenser to circulating cooling water, it is advantageous to harness the objectable heat for vapour absorption refrigeration system in combination high grade energy from the steam prime mover being used for vapour compression refrigeration system as shown in figure. [2] The high pressure steam first expand in a turbine which supplies the power for the compressor of vapour compression refrigeration system. The exhaust steam from the turbine goes to the generator of the vapour absorption system. The water to be chilled to provide refrigeration goes in series through the evaporators of the two refrigeration systems. This concept is similar to the concept of co-generation or combined heat power system.

Need. As we discuss above that from a thermal power station a large amount of heat is rejected to the atmosphere which is generally useless, on other hand there a possible way to utilise this waste heat i.e waste heat powered refrigeration system. Because of requirement of various cooling application in the plant such as office cabines, drinking water etc. The waste heat obtained from various sections of the plant could be used to operate the small scale refrigeration systems. In this way it might be possible to run refrigeration systems without any additional investment. Hence waste heat recovery in such a way give additional advantage in a large scale thermal power station.

II. System Description

The figure shows the arrangement of various components used in combined vapour absorption/compression refrigeration system. The first part of cycle consists of a vapour compression cycle powered by the high pressure steam turbine (this steam is bled from the main power generating high pressure steam turbine). [3] Rest of the part is working in same manner as normal compression cycle. In vapour compression refrigeration cycle compressor is the main part which required work input to operate the whole system. There are two possible ways to run the compressor with minimum input. One is thermo-compressor and other one is compressor driven by low grade high pressure waste steam of a large scale thermal plant. Thermo-compressor uses high pressure steam to compress low or intermediate pressure waste steam into medium pressure steam. Figure shows a thermo-compressor where high pressure steam enters as a high velocity fluid, which entrains the low pressure steam by suction. The resulting mixture is compressed and discharged as a medium pressure steam from the divergent section of the thermo-compressor. The main advantage of thermo compressor is high reliability and less compression power requirement.

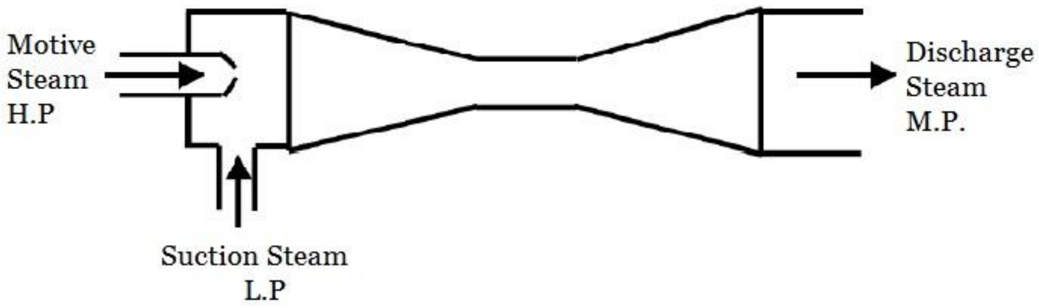

Figure : Thermo-compressor.

In second way, Vapour is passed through turbine for generation of electricity. Vapour is condensed in condenser at lower temperature and releases heat to the outside atmosphere. Organic fluid is raised from lower pressure to high pressure in the pump. The amount of energy consumed in pumping the fluid is considerably low. During operation of a thermal power plant, blade steam from high pressure turbine and medium pressure turbine being used for drive the small scale turbine which is used to drive the compressor of vapour compression refrigeration unit. The steam for this purpose might also be obtain from the condenser of the plant because in condenser low pressure steam lost its latent heat and get condensed. This latent heat is used to vaporize the water which is supplied to condenser for condensation process. From these ways, obtained steam is sufficient to drive the turbine of vapour compression unit.

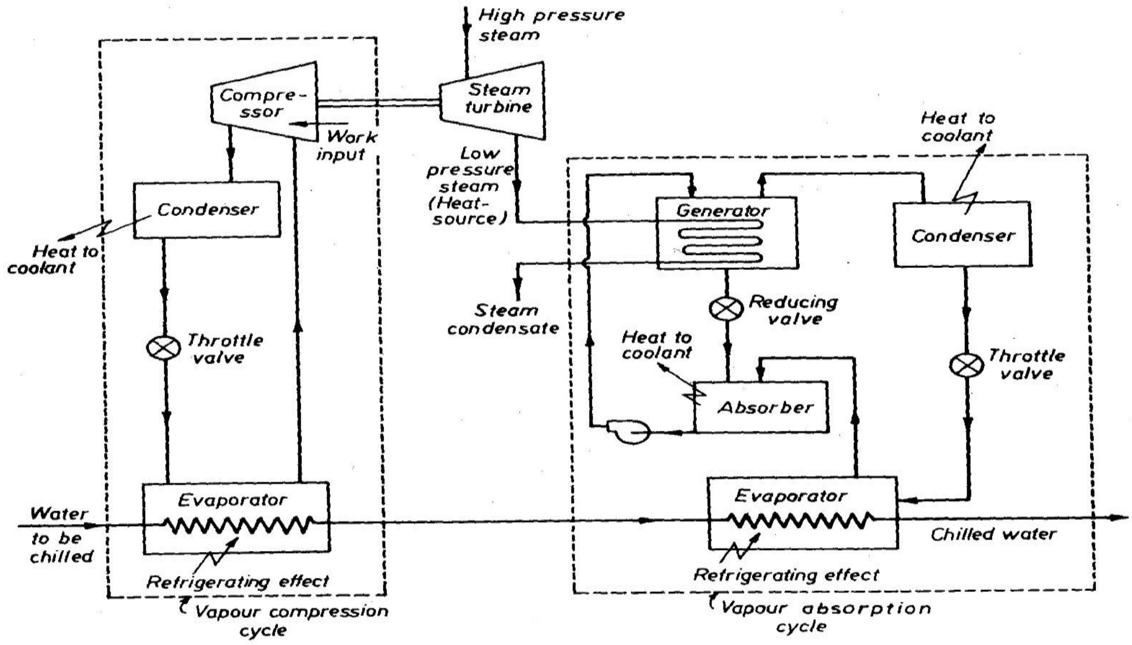

Figure: Combined vapour absorption/compression system

In a Rankine cycle, after expansion of steam in turbine, a low pressure steam is obtained. This low pressure steam operates the vapour absorption system (shown in fig). [4,5] Ammonia vapour at high pressure transfers heat to neighborhood in the condenser. Liquid ammonia from the condenser is passed through an expansion valve to reach the evaporator pressure. Heat is transferred from the low temperature heat source to convert liquid ammonia to vapour state. Ammonia vapour is absorbed by a weak solution of water and ammonia to form a concentrated solution of ammonia-water at the bottom of absorber. This concentrated solution is passed to the generator for the production of ammonia vapour while the lean solution from the generator is passed back to the absorber unit. Low grade heat is used in the generator for the production of ammonia vapour. Lean ammonia solution from the generator exchanges heat with the high concentration ammonia solution from the absorber. [6] The given by the low pressure steam is sufficient to operate the generator of the absorption cycle. After the generator the steam is supplied to the condenser and passed towards the power generation cycle.

Key features of the system:

- Compressor is operated by steam turbine.
- Generator is operated by low pressure steam, obtained after expansion in steam turbine.
- Both the evaporators gives more refrigerating effect comparatively.

In this way it can be concluded that whole cycle is operated by the heat which was waste heat before using such refrigeration cycle. As there is a waste heat recovery system hence getting maximum co-efficient of performance.

Refrigerant Background.

For vapour compression system: 134a (1,1,1,2-Tetrafluoroethane)

1-1-1-2-tetrafluoroethane (R134a) is one of the most commonly used refrigerants. Its thermo physical properties are important for evaluating the performance of refrigeration cycles. These can be obtained via computer simulation, with an insight into the microscopic structure of the liquid, which is not accessible to experiment. [7]

Physical Properties.

Chemical Formula CH2FCF3
Molecular Weight 102.03
Boiling Point at
One Atmosphere –14.9°F (–26.06°C)
Critical Temperature 213.9°F (101.08°C)
Critical Pressure 588.9 psi (4060.3 kPa [abs])
Critical Density 32.17 lb/ft_3 (515.3 kg/m^3)
Critical Volume 0.031 ft^3/lb (0.00194 m^3/kg)

III. For vapour absorption system

Ammonia-water. Anhydrous ammonia is a clear liquid that boils at a temperature of -28°F. In refrigeration systems, the liquid is stored in closed containers under pressure. When the pressure is released, the liquid evaporates rapidly, generally forming an invisible vapour or gas. The rapid evaporation causes the temperature of the liquid to drop until it reaches the normal boiling point of -28°F, a similar effect occurs when water evaporates off the skin, thus cooling it. This is why ammonia is used in refrigeration systems. Ammonia has a number of benefits, which has been proven by many decades of application of ammonia refrigeration systems.

1. Energy Efficiency

Ammonia is one of the most efficient applications out there, with the application range from high to low temperatures. With the ever increasing focus on energy consumption, ammonia systems are a safe and sustainable choice for the future. Typically a flooded ammonia system would be 15-20 % more efficient than a DX R404A counterpart. Recent developments of NH3 and CO2 combination contributed to increase the efficiency further. NH3/CO2 cascaded is extremely efficient for low and very low temperature applications (below -40'C), while NH3/CO2 brine systems are around 20% more efficient than traditional brines. [8]

2.Environment

Ammonia is the most environmentally friendly refrigerant. It belongs to the group of so called "natural" refrigerants, and it has both GWP (Global Warming Potential) and ODP (Ozone Depletion Potential) equal to zero. [9]

IV. Conclusion

It is an approach towards energy saving by utilization of waste heat of any thermal power plant. This paper represents the concept of waste heat recovery and use it to obtain some useful work output. As we discuss previous that the refrigeration system operated by high pressure steam blade from the high pressure steam turbine. This system can also be operated by the exhaust low pressure steam obtained from low pressure steam turbine of a thermal power plant or waste heat (latent heat) obtain from the condenser. The waste heat obtained from various sections of the plant could be used to operate the small scale refrigeration systems. By using such refrigeration system there is no need to supply any external power or heat to operate it and hence increase the COP of the refrigeration system

Drinking water chilling and air conditioning are the advantageous applications of such combined refrigeration system.

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