REFRIGERANTS PERFORMANACE MEASUREMENT FOR COOLING EFFECT UNDER TRANS-CRITICAL SYSTEM: A CASE RESERACH

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Abstract
The refrigerant in the high temperature circuit gets evaporated in trans-critical unit and passes through the HTC compressor. The refrigerant then passes through the HTC condenser where heat is released causing the refrigerant to cool. The refrigerant then passes through the HTC throttling valve, where the fluid expands losing temperature. In the presented research work, the two-stage CO_2 refrigerants performance has been measured for cooling effect under trans-critical system. A two-stage CO_2 trans-critical unit for supermarket refrigeration has been built. COP values are calculated to be 22-72% greater over the particular ambient temperature range than for single stage compression. In both medium and low temperature belongings the COP improvement is greater given high ambient conditions.
Keywords: Refrigerant, Trans-Critical System, Performance Valuation.

I. INTRODUCTION

Due to global environmental concerns, the usage of natural working fluid is becoming more interesting theme to be discussed. Transcritical CO2 cycle is recently considered as one of the most influential refrigerant for its characteristics such as non-ODP, negligible GWP, non-flammability and non-toxicity, despite the drawback of high working pressure. The refrigeration system is a freezing system that uses two kinds of refrigerants having different boiling points, which run through their own independent freezing cycle and are joined by a heat exchanger. In a refrigeration system, the higher-temperature side uses a normally used refrigerant (R404A, ammonia, etc.), and the lower-temperature side uses R23, which is an HFC refrigerant. A refrigeration system employs 2 or more individual refrigeration cycles operating at different pressure and temperature levels. The lower temperature cycle provides the desired refrigeration effect at a relatively low temperature

II. LITERATURE REVIEW

Investigation study of recovery the low waste heat which can generate electricity for saving energy and reducing pollutant and CO2 emission. In order to improve the waste energy recover rate and energy utilization efficiency, it is concluded that heat transfer analysis, thermal heat exploitation is indeed **[1]**. Described the design of three unique thermoelectric generators developed to supply electric power in natural gas fields. This generator used in the gas field as the first generator (1948), described uses the difference in temperature between the hot and cold legs of the glycol l natural gas dehydrator cycle to produce power for cathodic protection of the well. The second system uses waste heat from the pilot light of the gas dehydrator boiler to produce power for electronic instruments. The third system used waste heat from the gas dehydrator boiler stack to provide power for instruments, communications, and other uses around the well site **[2].** Designed the energy recovery technology of aquatic products processing plant, including refrigeration heat recovery and ice-making cooling recovery. Three heat recovery plans are compared and analyzed, and two ways about cooling recovery of ice-melting pool are compared. The results of analysis show that different heat recovery modes have different energy efficiency [3]. Proposed a theoretical research to work out the basic key theory of fluidized bed, the Eulerian Eulerian continuum model was adopted to research the fluidized bed, which focuses the complex heat and mass transfer accompanied by the process that high-temperature blast furnace slag particles were cooled by air stream, and the theoretical research was carried out to gain the optimized parameter matches of the fluidized bed. The simulation was carried out from the size of particle and the gas supply velocity, and showed that for the particle of 3mm and 4mm size, v=2.68m/s is the best condition for the both size particle [4].

Expressed an analytical framework to predict the j and f factor for laminar and turbulent flow from experimental and analytical work [5]. Suggested a liquid coolant instead of using previous air cooled models in an experimental set up to evaluate heat transfer and pressure drop of offset fin heat exchanger. It shows that the liquid cooled apparatus Prandtl number has a large effect on Nusselt number and numerical analysis examines the surface temperature distribution. Related to CFD work [6]. Calculated the Colburn factor j and friction factor f for an Aluminum- oil-air Plate Fin Heat Exchanger (PFHE) with serrated fins at low Reynolds No. (Between10-200) both experimentally, with constant air flow rate and 6 different oil flow rates and numerically, with 3D geometric analysis. One of the objectives of this paper is also to propose a procedure for the ANFIS model and an Artificial Neural Network (ANN) model alongside a few experiments so as to predict the performance of fins with new configuration in PFHE [7]. Developed the successful utilization of Genetic Algorithm (GA) combined with the Back Propagation (BP) algorithm of Artificial Neural Network that is more efficient and advanced than the traditional GA method for the optimal design of PFHE, and showed that this method is also applicable to various PFHEs [8]. The performance of the carbon dioxide Tran critical power cycle has been simulated and compared with the other supreme commonly employed power cycles in truncated grade heat source. At the beginning of this study, basic CO2 power cycles, namely carbon dioxide transcritical power cycle, carbon dioxide Brayton cycle and carbon dioxide cooling and power joined cycle were simulated and studied to see their potential in different applications (e.g. low-grade heat cradle applications, commercial applications and heat and power cogeneration applications). During the study, the work also involved studies in other parallel and related topics such as component design for COP. By identifying the strength and weakness facts in CO2 system solutions it is possible to apply and test modifications to optimize the system for its best cooling effect. By comparing the experimental and theoretical it is possible to point out potential improvements in the experimental rigs, and thereafter, conclude upon good CO2 system. The study subsequently focused essentially on carbon dioxide Tran critical power cycle, which has a wide range of applications [9].

Library is given and the Modeling of CO2-Heat exchangers are described. A comparison with steady state results of heat exchangers is presented showing a very good agreement. The presented transient simulation results slow the expected trends, but the models have not yet been validated with transient experimental data [10]. Focused on the evaluation of the performance of a single stage CO2 reciprocating compressor working on a beverage cooler application. A glass door merchandiser (GDM) was tested to develop a procedure to determine the best combination of capillary tube and refrigerant charge. Fin and tube heat exchangers were used both for the evaporator and the gas cooler. The criteria are choosing the combination was the total energy consumption of the system. The theoretical optimum discharge pressure was determined point by point during the "ON" period of the cycle and was compared to the experimental discharge pressure. The results showed that the closer profile to the optimum profile was the best in terms of energy consumption. The system was also tested with R134a and the results were compared showing 26% of energy savings in favor of the CO2 system [11].

Obtained results allow the collection of detailed information on air and COs across the coil. The results have been compared with those obtained on our laboratory test bench and the agreement between the predictions and experimental data is very satisfactory. The analysis has been limited to the evaporator coil from the thermal hydraulics point of view. The recirculation ratio, N has been varied in the range

1 to 4 and corresponding heat transfer coefficients, internal pressure drop and saturation temperature variations have been obtained. Despite a substantial improvement in heat transfer due to recirculation (in the order of 180% for N=4), the coil capacity remained almost unchanged while pressure drop has considerably increased and the corresponding saturation temperature dropped. **[12]**

III. OBJECTIVE OF WORK

The performance of the carbon dioxide Tran critical power cycle has been simulated and compared with the other supreme commonly employed power cycles in truncated grade heat source. By identifying the strength and weakness facts in CO_2 system solutions it is possible to apply and test modifications to optimize the system for its best cooling effect. By comparing the experimental and theoretical it is possible to point out potential improvements in the experimental rigs, and thereafter, conclude upon good CO_2 system. The study subsequently focused essentially on carbon dioxide Tran critical power cycle, which has a wide range.

IV. TRANS-CRITICAL SYSTEM

It is a transcritical expansion device. A system based on the transcritical CO2 cycle uses a high pressure expansion valve (HPEV). Rather than controlling refrigerant metering from the low-pressure side of the system, modulation control comes from the high side of the system Trans-critical CO2 systems will bypass the essential for a cascade condenser which may improve the COP. In order to evaluate the CO2 trans-critical system solution against other alternatives an efficient CO2 system should first be defined. Calculations have been performed in order to proposal different CO2 trans-critical system solutions.

V. TRANSCRITICAL SYSTEM DESCRIPTION

A transcritical cycle differs from a conventional phase-change vapour compression cycle as for the heat rejection phase in the high temperature cycle section, which is not operated through a condenser, being replaced by a gas cooler, where the CO2 temperature decreases over a large temperature range. The use of a gas cooler may offer some advantages over the constant temperature vapour condensation phase, especially if a heat recovery has to be accounted for. Indeed, when compared with other refrigerants, the CO2 heat rejection phase may begin at higher temperature levels, possibly exceeding 100 °C. This paper deals with the feasibility of using such waste heat as powering source for a thermally activated cooling machine, as an absorption system, which adds further cooling capacity to the basic cooling cycle. The two main possibilities for system solutions where CO2 can be used in applications as the only refrigerant are the parallel and centralized arrangements. The parallel solution consist circuits which serve the medium temperature level cabinets and, the other serves low temperature level cabinets. Cascade is applied at both temperature levels and two-stage compression is used for the low temperature circuit. This will decrease the discharge temperature, minimize losses in compression, and reduce the enthalpy difference across the compressors. Since the temperature lift is presumed to be small in the medium temperature circuit then single stage compression is used. Fig. 1 showed the parallel system solution with single stage compression on low temperature

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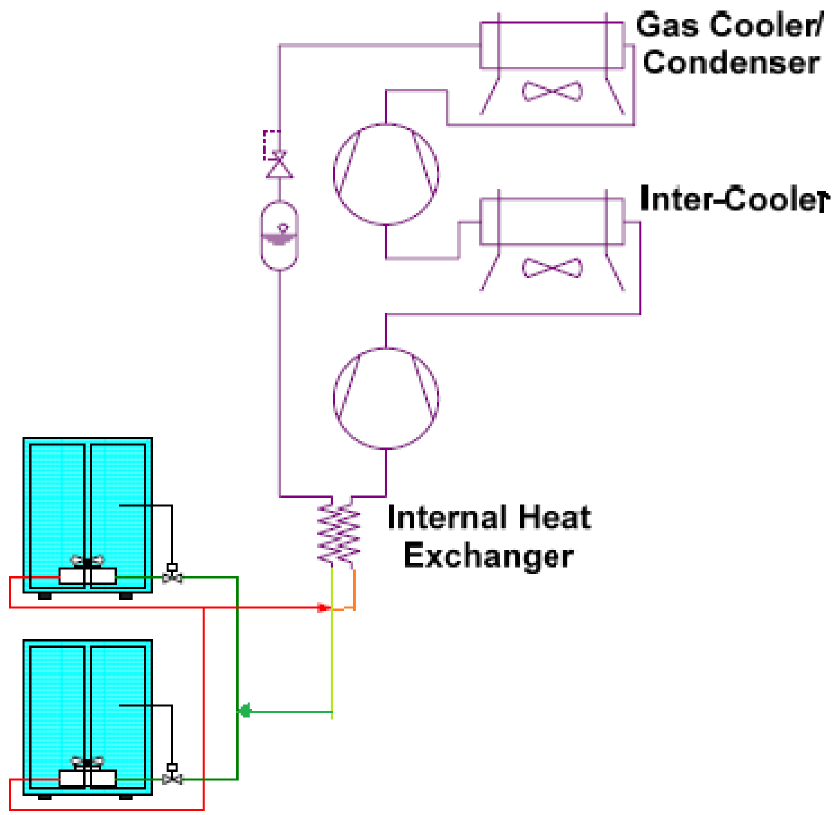

Fig. 1: Parallel system solution with single stage compression on low temperature

VI. CALCULATION MODEL

The same models used for the components of the cascade system, are applied to the trans-critical solution. Further components used in the trans-critical system are modeled using the effectiveness as the input variable, which is calculated as:

$$\varepsilon = \frac{(m.C_p)_c * (T_{c.o} - T_{c,i})}{(m.C_p)_{min} * (T_{h,i} - T_{c,i})}$$

The inlet conditions of the heat exchanger are used as the input constraints where the exit temperature from the cold side is calculated. Using temperatures and pressures after the exit of the cold side of the IHE, the enthalpy is calculated and the enthalpy difference at the cold flank is assumed to be the same as at the hot side; enthalpy and pressure are then used to calculate the temperature at the exit on the hot side. The assumed effectiveness value of the IHE used in the models is 50%.

VII. SYSTEM OPTIMIZATION

At high ambient temperatures and when the exit temperature of CO_2 in the gas cooler gets higher than the precarious temperature of CO_2, then the operating pressure becomes independent of the gas cooler exit temperature. For different temperatures, the shape of the isotherm will change and this suggests that the optimum functional pressure will depend on the ambient temperature. Therefore, it is essential to find a correlation between ambient temperature and discharge pressure in order to run the system under optimum conditions and obtain the highest COP. When CO_2 functions in the trans-critical region it loses COP compared to other refrigerants at the same temperature levels. A way to improve the COP, particularly when high temperature lift is needed, is to introduce two-stage compression using an intercooler.

VIII. CONCLUSION

After testing with the two-stage compressor it has been modified to work as single stage system and further tests have been performed. The CO_2 trans-critical unit will be compared to the performance of the NH_3 unit in the cascade system and the operating conditions will be kept comparable. The heat sink temperature is controlled in a similar way to the NH_3 system. The supply water temperature was varied between 15, 20, 25 and 30°C. Temperature and pressure measuring themes are placed before and after each component in the system. A mass flow meter is installed at the brine flank of the evaporator where the cooling capacity is calculated. An energy balance is performed around the evaporator to obtain the CO_2 mass flow rate, and thereafter, capacities of the gas cooler and intercooler are calculated from the refrigerant side. COP of Trans Critical System is shown in Table 1 and Fig. 2 showed the COP of Trans Critical System

Table 1 COP of Trans Critical System

Ambient Temperature °C	*COP of Single Stage Compression*		*COP of Double Stage Compression*	
	Low	*High*	*Low*	*High*
10	5.2	5.8	5.4	6.2
15	4	4.2	4.6	4.9
20	3.2	3.4	3.5	4.1
25	2.4	2.7	2.5	3.1
30	2.1	2.1	2.2	2.4
35	1.7	1.8	1.9	2.1
40	1.2	1.4	1.4	1.6

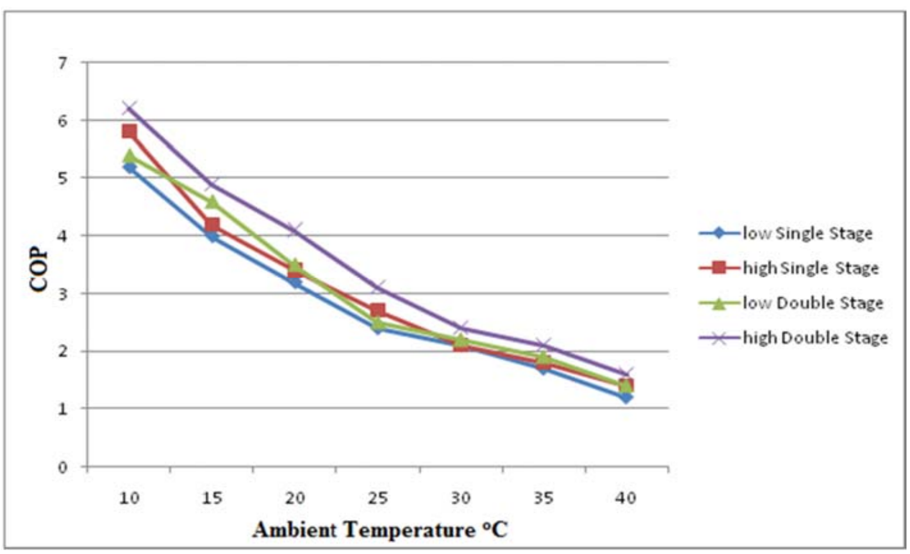

Fig. 2 COP of Trans Critical System

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