Chapter 44
Enhancing Heat Transfer Rate by Optimization of Commercial Refrigeration Condenser and Its Design Metrics

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Abstract Optimization of heat transfer rate and size of heat money changer (condenser) by significant tests met by Refrigeration structure proposals. The heat transfer rate problem is concerned with the determination of total heat transfer rate, and the sizing issue is concerned with the determination of the aggregate high temperature exchange surface range. The key element helping for higher heat exchange rate and base high-temperature exchange zone may be those refrigerant streams out in the condenser coil, likewise those framework lies over indoor of a bureau. The objective of the available task will streamline those outlined of a commercial refrigeration condenser to enhance the heat transfer rate. CFD (Computational Fluid Dynamics) and Condenser software will be used to optimize the design of the components. Structural dissection about parts will be also will be performed to dissect the deformations and anxieties happening because of the weights and temperatures of the stream. The necessary modifications are made to improve the heat transfer rate & reduce the size of the condenser that enhances the overall heat transfer rate.

44.1 Introduction

The main objective of this project is to reduce the size of the condenser and enhance the heat transfer rate. The Condenser is a device used to exchange the heat absorbed to ambient. It rejects heat to an external cooling medium (air or water) [1, 2] be those procedure of evacuating high temperature from an encased space, or from

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V. V. Rao et al. (eds.), *Computational and Experimental Methods in Mechanical Engineering*, Smart Innovation, Systems and Technologies 239,
https://doi.org/10.1007/978-981-16-2857-3_45

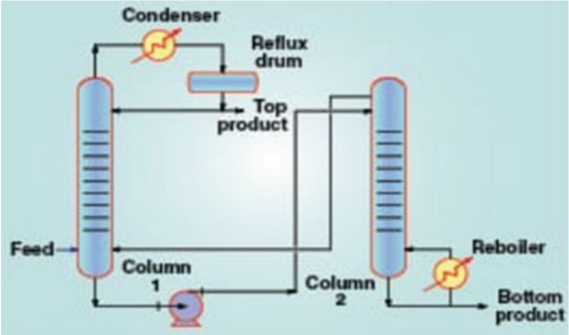


Fig. 44.1 Detailed explanation of condenser with phase change

A substance, furthermore moving it will a spot the place it cam wood a chance to be excluded in high face area, low FPI & optimum refrigerant flow through condenser coil and air flow over the condenser coil are the key for effective condenser performance [3, 4].

In the present study, the condenser coil circuit is optimized so that the refrigerant flow through the condenser flows via two tubes parallels and the heat exchange between the refrigerant and the external surface occurs very quickly [5–7] (Fig. 44.1).

44.2 Experimental Setup of Condenser Optimization

The issues that mainly affect the heat transfer rate in a required convection type condenser.

44.2.1 Air-Cooled Condenser Selection

Air-cooled condenser might be a common convection sort alternately to constrained convection sort. On practically as a relatable point, we utilize air-cooled condenser [8, 9]. In front of measuring a condenser, cautious assessment of the necessities for a particular establishment will be fundamental. The assessment ought to include, attention from claiming starting cost, operating cost, administration and aggregation, furthermore the kind about load [10–12]. A condenser that is excessively little camwood make unreasonable What's more make operating issues in easier encompassing states a under-size condenser camwood make working issues in higher encompassing states [13]. It is, therefore, paramount to think about those taking after factors in front of measuring a condenser:

- Terrible heat dismissal.
- Encompassing temperature.
- Consolidating temperature.

- Temperature distinction (TD).
- Wind stream.

Condenser ability is the capacity of the essential high-temperature exchange equation [14].

$$Qc = U \times A \times LMTD$$

here

$$\begin{aligned} \text{Qc} \; &= \text{Condenser capacity in Cal/h} \\ &\quad (\text{Ref.effect} \; + \text{Heat of Comp} \; + \text{Motor winding heat}) \end{aligned}$$

$$U = \text{Overall heat transfer coefficient K Cal/m}^2\text{h.}$$
$$CA = \text{Effective surface area in m}^2$$

$$\begin{aligned} \text{LMTD} \; &= \text{Log mean temperature difference between the} \\ &\quad \text{condensing refrigerant and the condensing medium in} \,^\circ\text{C} \end{aligned}$$

Face area = Air quantity/Air velocity

The greatest speed happens between those tubes since the tubes block An and only those streams acceptably [15]. If B is those dividing among tubes in the face and c may be the tube dividing among rows, also d may be those tube breadths. The Reynolds and Nusselt number are defined as follows for this case:

$$\text{Re} = (\rho \times do \times U\infty)/\mu$$

The Grimson's correlation is as follows:

where the constants C and n are dependent upon Reynolds number (Tables 44.1 and 44.2).

Enthalpy values taken from P-h chart

$H_1 = 400$ kJ/kg $H_4 = 270$ kJ/kg $H_2 = 430$ kJ/kg $H_5 = 245$ kJ/kg $H_3 = 420$ kJ/kg $H_6 = 245$ kJ/kg

Refrigerant Effect = $H_1 - H_6$

= 155 kJ/kg

Table 44.1 Constant for Grimson's equation

Reynolds no, Re	Constant C	Constant n
0.4–4	0.978	0.44
4–40	0.920	0.358
40–4000	0.698	0.477
4000–40000	0.189	0.600
40000–400000	0.0315	0.852

Table 44.2 Observation for condenser

Design of condenser	Design consideration
Tube size	3/8th
Outside diameter of the condenser tube:	0.0080
Inside diameter of the condenser tube	0.0068
Refrigerant used	R404A
Evaporator temperature (°C)	7.2
Condenser temperature (°C)	54
Subcooling temperature (°C)	10
Superheating temperature (°C)	10.8
Compressor power (W)	678
Cooling capacity (Btu/h)	5460
Ambient temperature (°C)	43

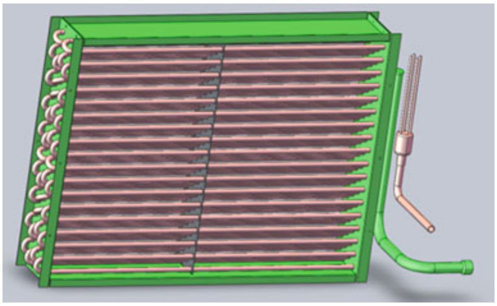


Fig. 44.2 Existing design with 12 tube single circuit

Heat Rejection Capacity (HRC) = (**Refrigeration capacity * power of compressor) * FOS**

$= ((1.6) + (678/1000)) \times 1.05 = 2.392$ KW

Overall heat transfer coefficient

$1/Uo = (At/Ai) \times (1/hi\ \text{condensation}) + 1/ho\ U_o = 47.46\ \text{W/m}^2\ \text{K}$

LMTD condensation = 7.61 °C

44.2.2 CAD Modeling

See Figs. 44.2, 44.3, 44.4, 44.5 and 44.6.

44.2.3 ANALYSIS-Structural Analysis

Boundary Conditions:

Fig. 44.3 New design with 11 tube

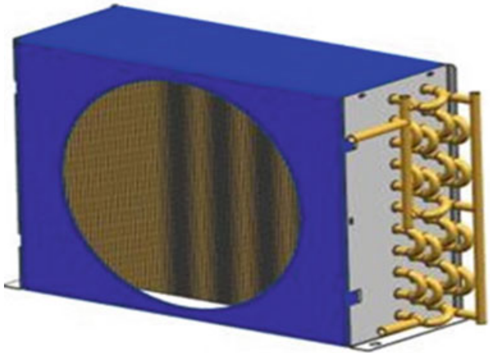


Fig. 44.4 Condenser coil with fins

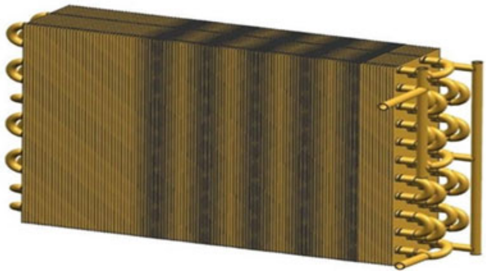
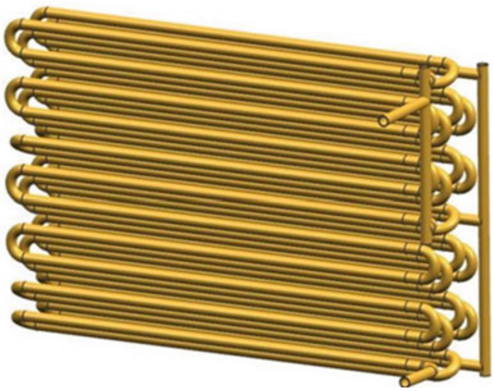


Fig. 44.5 Condenser coil without fins



Inlet: Temperature: 85 [°C]
Outlet: Mass flow rate = 0.0137(kg/s) Ref. Pressure: 14.7 [PSI] Assumptions: Steady state single phase analysis (Figs. 44.7 and 44.8, Table 44.3).

Fig. 44.6 Physical model of the design

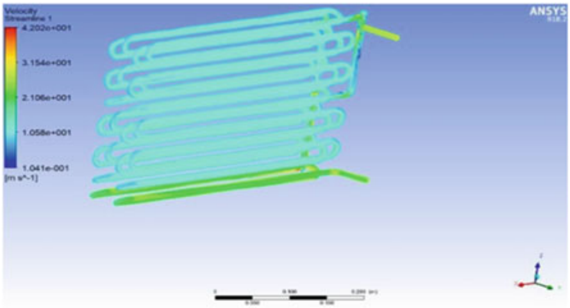


Fig. 44.7 11 *4 row condenser velocity streamlines

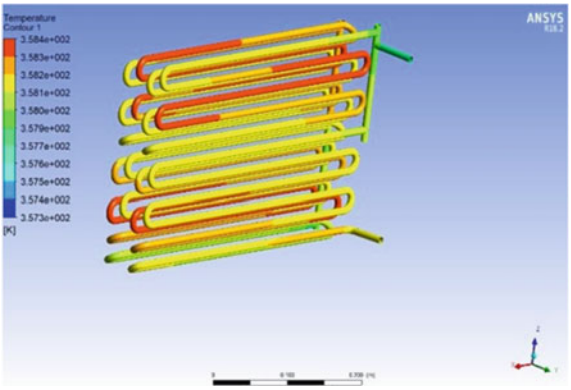


Fig. 44.8 Temperature contour

Table 44.3 Velocity and temperature

	Inlet	Outlet
MFR	1.380e02 [kg s6ˆ−1]	−1.380e02 [kg s6ˆ−1]
Velocity	2.691e+01 [m sˆ−1]	2.458e+01 [m sˆ−1]
Temperature	3.621e+02 [K]{85.32 °C}	3.228e+02 {50.32 °C}

44.3 Results and Discussion

By comparing the two models the outlet temperature of the new design is better. By optimizing the circuit design from one circuit to two circuit the heat transfer rate of the condenser is improved by 6% though the height of the condenser is decreased by 9% by reducing one row of the tube. The capacity increased from 3.17 to 3.37 KW. With this achievement, the higher capacity of the compressor can be used for the same refrigeration system and can be used in very compact-sized refrigeration units. The above data is calculated from the LUVATA Thest. Condenser design Software and the images of the same are shown below (Figs. 44.9 and 44.10).

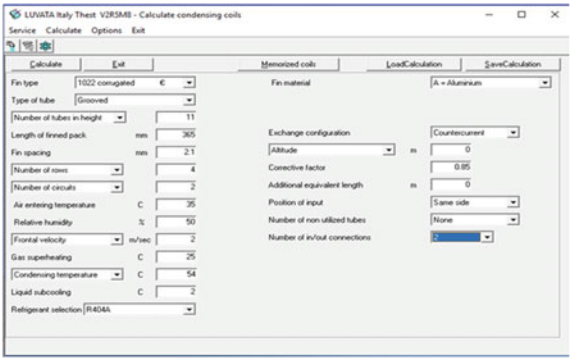


Fig. 44.9 Input for 11 tubes condenser

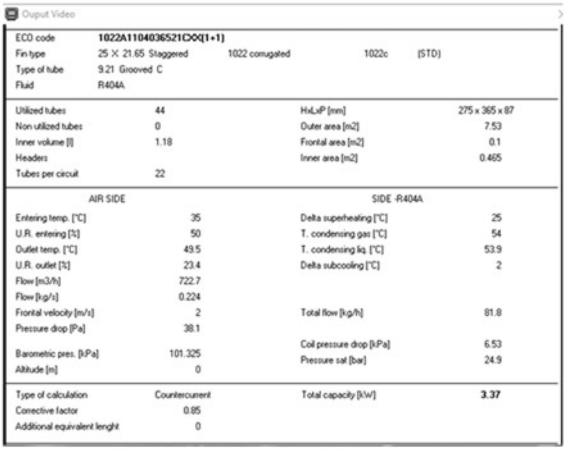


Fig. 44.10 Output for 11 tubes condenser

44.4 Conclusion

By optimizing the circuit designs from one circuit to two circuits the heat transfer rate of the condenser is improved by 6% though the size of the condenser is decreased by 9% by reducing one row of the tube. The capacity increased from 3.17 to 3.37 KW. With this achievement, the higher capacity of the compressor can be used for the same refrigeration system and can be used in very compact-sized refrigeration units. With this new design, the cost of the unit can be reduced by about 5–6%. In conclusion, by optimizing the circuit design the performance of the condenser can be improved.

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