# A Comparison of heat transfer coefficient of R-12, R-134a and R-409a for condensation based on existing correlation: A Review

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***Abstract*: Heat transfer coefficient is reported for condensation and evaporation of R134a and R12 is compared for different conditions found in heat exchanger used for refrigeration and air conditioning. Various existing correlation used to calculate the heat transfer coefficient for single phase and two phase heat transfer. These correlations are previously verified for R12 and for some other refrigerant. Single phase correlation and two phase correlation for evaporation and condensation predict the heat transfer coefficient of R134a is higher than R12.**

***Keywords*: Condensation, Heat transfer coefficient, Refrigerant, R12, R134a, R409a.**

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## I. INTRODUCTION

Heat transfer evaluation of HFC134a and other alternative refrigerants have become important as reductions in CFCs. As the thermo-physical properties of the two refrigerants are similar, HFC134a is considered a potential replacement for CFC12. HFC134a is more environmentally acceptable with a zero ODP. This paper reviewed the comparison of experimental results for HFC134a and CFC 12 with predicted heat transfer coefficients obtained from the some existing correlation. The predicted heat transfer coefficient can be use for two purposes. First, as a heat transfer fluid, the effectiveness of R134a as a replacement refrigerant for system that use R12 can be assessed. Second, the heat transfer coefficient presented herein can help in the design of new systems that employ R134a as working fluid.

## II. LITERATURE REVIEW

**[1] M. Mostaqur Rahman et al**

This paper describe that the experimental study and development of new correlation for condensation heat transfer in horizontal rectangular multiport mini-channel with and without fins using R134a. A new experimental apparatus has been fabricated in order to obtain explicit local condensation heat transfer coefficient measurements over a range of test conditions. The test section is an 852 mm long horizontal rectangular multiport mini-channel with and without fins having 20 channels with a hydraulic diameter of 0.64 mm and 0.81 mm. The measurements were done over a range of saturation temperature from 30 to 35℃ with mass fluxes ranging from 50 to 200 kg/m2 s. The effects of vapor quality, mass fluxes, channel geometry, and saturation temperature on the heat transfer coefficient have been clarified and analyzed. The experimental results were compared with the well-known condensation heat transfer models available in the open literature. All of the existing correlations were failed to capture the present experimental heat transfer coefficient with a high degree of accuracy. As a consequence, a new condensation heat transfer correlation was developed based on the present experimental data and validated with 750 data points collected from the available journal.

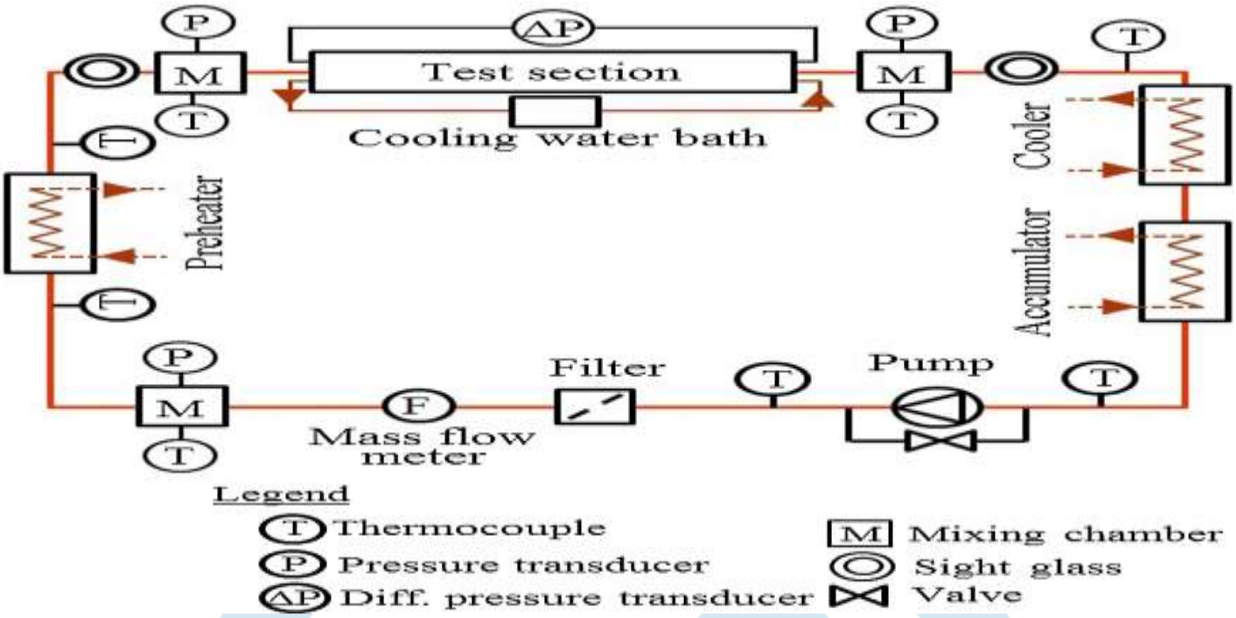


Fig: Schematic diagram of experimental apparatus

**[2] Sung-Min Kim et al**

In this paper a new universal approach to predicting the condensation heat transfer coefficient for mini/micro-channel flows is proposed that is capable of tackling many fluids with drastically different thermo-physical properties and very broad ranges of all geometrical and flow parameters of practical interest. This is accomplished by first amassing a consolidated database consisting of 4045 data points from 28 sources. The database consists of single-channel and multi-channel data, 17 different working fluids, hydraulic diameters from 0.424 to 6.22 mm, mass velocities from 53 to 1403 kg/m2 s, liquid-only Reynolds numbers from 276 to 89,798, qualities from 0 to 1, and reduced pressures from 0.04 to 0.91. An exhaustive assessment of prior correlations shows only two correlations, that are actually intended for macro-channels, provide relatively fair predictions, while mini/micro-channel correlations generally show poor predictions. Two new correlations are proposed, one for predominantly annular flows, and the second for slug and bubbly flows. This approach shows very good predictions of the entire consolidated database, with an overall MAE of 16.0%. It is shown this accuracy is fairly even for different working fluids, and over broad ranges of hydraulic diameter, mass velocity, quality and pressure, and for single and multiple mini/ micro-channels. Correlation used in this paper is

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|---|---|
| Haraguchi et al. (1994) | $\frac{h_{tp}D_h}{k_f} = 0.0152(1+0.6\mathrm{Pr}_f^{0.8})\frac{\phi_g}{X_{tt}}\mathrm{Re}_f^{0.77}\, X_{tt} = \left(\frac{\mu_f}{\mu_g}\right)^{0.1}\left(\frac{1-x}{x}\right)^{0.9}\left(\frac{\upsilon_f}{\upsilon_g}\right)^{0.5}\, \phi_g = 1+0.5\left[\frac{G}{\sqrt{g\rho_g(\rho_f-\rho_g)D_h}}\right]^{0.75}X_{tt}^{0.35}$ |
| Dobson and Chato (1998) | $\frac{h_{tp}D_h}{k_f} = 0.023\mathrm{Re}_f^{0.8}\mathrm{Pr}_f^{0.4}\left(1+\frac{2.22}{X_{tt}^{0.89}}\right)$ |
| Moser et al. (1998) | $\frac{h_{tp}D_h}{k_f} = \frac{0.0994^{C_1}\mathrm{Re}_f^{C_2}\mathrm{Re}_{eq}^{1+0.875C_1}\mathrm{Pr}_f^{0.815}}{(1.58ln\mathrm{Re}_{eq}-3.28)(2.58ln\mathrm{Re}_{eq}+13.7\mathrm{Pr}_f^{2/3}-19.1)} C_1 = 0.126\mathrm{Pr}_f^{-0.448}, C_2 = -0.113\mathrm{Pr}_f^{-0.563}, \mathrm{Re}_{eq} = \phi_{fo,Friedel}^{8/7}\mathrm{Re}_{fo}$ |
| Wang et al. (2002) | $\frac{h_{tp}D_h}{k_f} = 0.0274\mathrm{Pr}_f\mathrm{Re}_f^{0.6792}x^{0.2208}\frac{\phi_g}{X_{tt}}\, \phi_g^2 = 1.376+8X_{tt}^{1.665}$ |
| Koyama et al. (2003) | $\frac{h_{tp}D_h}{k_f} = 0.0152(1+0.6\mathrm{Pr}_f^{0.8})\frac{\phi_g}{X_{tt}}\mathrm{Re}_f^{0.77}\, \phi_g^2 = 1+21[1-exp(-0.319D_h)]X_{tt}+X_{tt}^2$ |
| Huang et al. (2010) | $\frac{h_{tp}D}{k_f} = 0.0152(-0.33+0.83\mathrm{Pr}_f^{0.8})\frac{\phi_g}{X_{tt}}\mathrm{Re}_f^{0.77}\quad \phi_g = \phi_{g,Haraguchi}$ |
| Bohdal et al. (2011) | $\frac{h_{tp}D}{k_f} = 25.084\mathrm{Re}_f^{0.258}\mathrm{Pr}_f^{-0.495}P_R^{-0.288}\left(\frac{x}{1-x}\right)^{0.266}$ |
| Park et al. (2011) | $\frac{h_{tp}D}{k_f} = 0.0055\mathrm{Pr}_f^{1.37}\frac{\phi_g}{X_{tt}}\mathrm{Re}_f^{0.7}\, \phi_g^2 = 1+13.17\left(\frac{\rho_g}{\rho_f}\right)^{0.17}\left[1-exp\left(-0.6\sqrt{\frac{g(\rho_f-\rho_g)D_h^2}{\sigma}}\right)\right]X_{tt}+X_{tt}^2$ |

**[3] Akintunde**

This paper describe that the experimental study of the performance of mixture of three eco-friendly refrigerants namely: R600a (n-butane), R134a (1,1,1,2,tetra-fluoro-ethane) and R406A (55%R22/4%R600a/41%R142b). These refrigerants were mixed in various ratios, studied and compared with R-12 (dichlorodifluoromethane) which was used as the control for the experimentation. The rig used in the experimentation is a 2 hp (1.492 kW) domestic refrigerator, designed based on 40℃ condensing and -10℃ evaporating temperatures. The rig was tested with R-12, and blends of the three refrigerants. During the experimentation, both evaporator and condenser temperatures were measured. These were used to determine the heat absorbed in evaporator and the heat rejected in condenser. The results show that R134a/R600a mixture in the ratio 50:50 can be used as alternative to R-12 in domestic refrigerators, without the necessity of changing the compressor lubricating oil. At evaporator temperature of -5℃ and condenser temperature of 40℃, R-12 gives a COP of 2.08 while 50:50 blend of R134a/R600a gives a COP of 2.30 under the same operating conditions.

**[4] Robert Santa**

This paper describe that the analysis of two phase condensation heat transfer models based on the comparison of the boundary condition. The heat transfer models are analyzed for condensation in horizontal smooth tubes. The final aim of the analysis is to select the optimal model from the examined two phase condensation heat transfer models. The selection of the condensing refrigerant two phase heat transfer model is based on the boundary condition. The applied method of analysis is numerical graphical

**[5] Suhayla Younis Hussain**

This paper describe that the experimental investigation of refrigerants R134a and R12 in air cooled horizontal condenser. In this study, the experimental result of heat rejected at condenser, COP, the experimental condensing heat transfer coefficients of R-12 and R-134a, in a horizontal copper finned tube with an outer diameter of 10mm are presented at different mass flux and different ambient temperatures during condensation under annular flow. A correlation has been developed from the data obtained. the refrigerant side heat transfer coefficients obtained from experimental study is different by 5% to 12% from that computed from the Shah correlation. This paper use a Shah correlation for condensation to find heat transfer coefficient which is-

$$h_{tp} = h_l \left[ (1-x)^{0.8} + \frac{3.8x^{0.76}(1-x)^{0.04}}{pr^{0.38}} \right]$$

**[6] Bhavesh M. Rawat et al**

This paper describe that the comparative study of refrigerant and heat transfer during film condensation of eco-friendly refrigerant R-407C and R-22 on horizontal finned tubes in bundles. Heat transfer data is obtained during condensation of horizontal of R-407C and R-22 on staggered bundles of horizontal finned tube with vertical vapor flow down and compares the effect of various fin parameters during the condensation process for effective heat transfer coefficient and compares the enhancement ratio for both the fluids and find out the optimum fin dimensions using the theoretical model proposed by Honda and Nozu (1987).

**S. N. Sapali**

This paper describe that Two phase heat transfer coefficients and pressure drops of R-404A in a smooth (8.56 mm ID) and micro-fin tube (8.96 mm ID) are experimentally investigated. Different from previous studies, the present experiments are performed for different condensing temperatures, with superheating and sub cooling and using hermetically sealed compressor. The test runs are done at average saturated condensing temperatures ranging from 35oC to 60oC. The mass fluxes are between 90 and 800 kg m-2s-1 . The experimental results from both smooth and micro-fin tubes show that the average heat transfer coefficient and pressure drop increases with mass flux but decreases with increasing condensing temperature. The average heat transfer coefficient is 30-210% higher for micro-fin tube than that of smooth tube, with moderate increase in pressure drop ranging from 10-55%. New correlations based on the data gathered during the experimentation for predicting condensation heat transfer coefficients are proposed for wide range of practical applications.

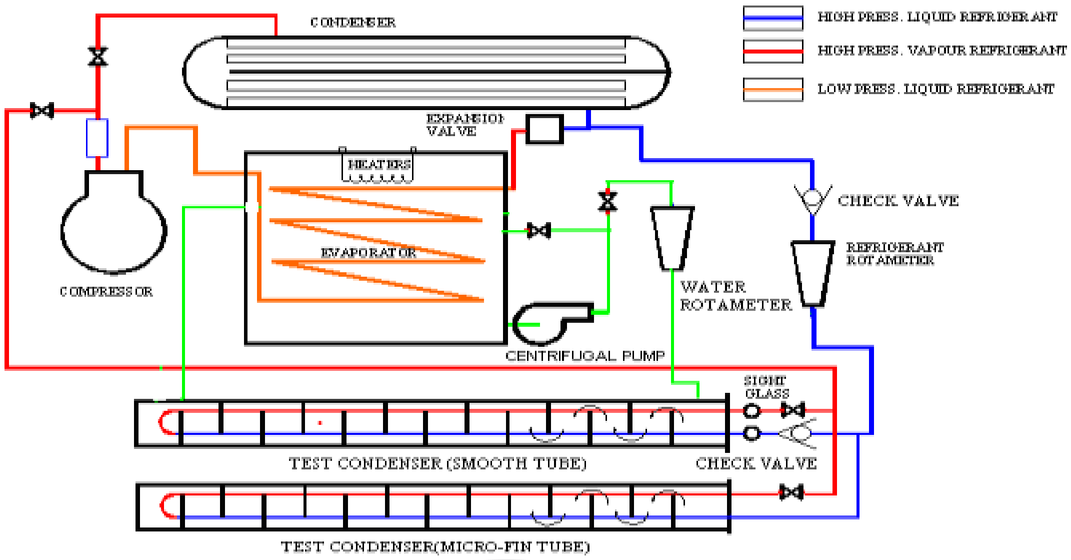


Fig: Experimental test facility

**[7] S. J. Eckels et al**

This paper describe that an experimental comparison of evaporation and condensation heat transfer coefficient for HFC-134a and CFC-12. Evaporation test were performed for a refrigerant temperature range of 5-15°C with quality range 10%-90%. Condensation test were performed for a temperature range 30-50°C.For both test tube inner diameter is 8mm, tube length is 3.67m and mass flux varied from 125 to 400 kgm$^{-2}$s$^{-1}$. For similar mass fluxes, the evaporation and condensation heat transfer coefficient for HFC-!34a were higher than CFC-12.HFC-134a showed a 35-45% increase over CFC-12 for evaporation and 25-35% increase over CFC-12 for condensation.

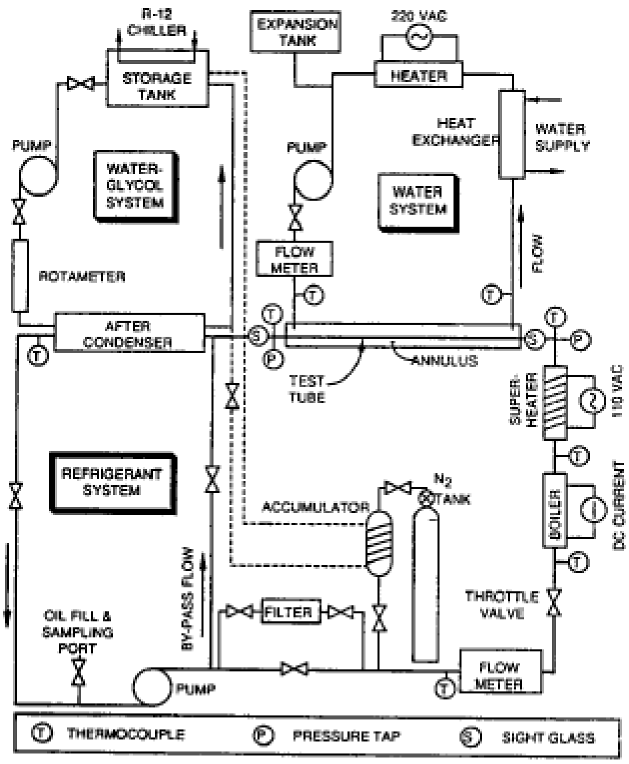


Fig: Experimental test facility

**[8] M. B. Pate et al**

This paper describe that a comparison of R-134a and R-12 in tube heat transfer coefficients based on existing correlations. single phase heat transfer coefficient for R-134a are shown to be significantly higher than those for R-12. Depending on the liquid refrigerant temperature, the predicted increase is from 27%-38% and for vapor, the predicted increase is from 37% to 45%. Two phase heat transfer coefficients for R-134a are higher than those for R-12.Evaporation correlations predict increases from 28% to 40%, depending on the refrigerant temperature, tube length,. Condensation correlations predict increases from 33% to 38%, depending on the refrigerant temperature. The correlation used in this paper is

| Correlation for Heat Transfer Coefficient | | | | |
|---|---|---|---|---|
| For Single Phase Heat Transfer | | For Two Phase Heat Transfer i.e. Condensation | | |
| Dittus Boelter Correlation | Petukhov Popov Correlation | Cavallini Zecchin Correlation | Shah Correlation | Traviss et al Correlation |
| h = $0.023Re^{0.8}Pr^{n}\frac{K_l}{D}$<br>where, n = 0.4 (for heating)<br>n = 0.3 (for cooling) | h = $\frac{\left(\frac{f}{8}\right)RePr}{1.07+12.7\left(\frac{f}{8}\right)^{0.5}(Pr^{0.67}-1)}\left(\frac{K_l}{D}\right)$<br>where, f = $[1.82\log_{10}Re - 1.64]^{-2}$ | $h_{TP}$ = $0.05Re_{eq}^{0.8}Pr_l^{0.33}\left(\frac{K_l}{D}\right)$<br>where,<br>$Re_{eq} = Re_l + \left(\frac{\mu_g}{\mu_l}\right)\left(\frac{\rho_l}{\rho_g}\right)^{0.5}Re_g$ | $\Psi = \frac{h_{TP}}{h_l} = 1 + \frac{3.8}{Z^{0.95}}$<br>where,<br>$Z = \left(\frac{1}{x} - 1\right)^{0.8}P_{rd}^{0.4}$<br>$h_1 = h_l(1 - x)^{0.8}$<br>$h_l = 0.023\left(\frac{GD}{\mu_l}\right)^{0.8}Pr^{0.4}\left(\frac{K_l}{D}\right)$ | $h_{TP} = \left(\frac{Pr_l Re_l^{0.9}}{F_2}\right)F_{tt}$<br>For $0.15<F_{tt}<15$<br>where,<br>$Ftt = 0.015(X_{tt}^{-1} + 2.85X_{tt}^{-0.467})$<br>$X_{tt} = \left(\frac{\mu_l}{\mu_g}\right)^{0.1}\left(\frac{1-x}{x}\right)^{0.9}\left(\frac{\rho_g}{\rho_l}\right)^{0.5}$<br>$F_2$ can be determine as follows<br>If $Re_l < 50$, then $F_2 = 0.707Pr_l Re_l^{0.5}$<br>If $50 < Re_l < 1125$, then $F_2 = 5Pr_l + 5\ln(1 + Pr_l(0.09636Re_l^{0.585} - 1))$<br>If $Re_l > 1125$, then $F_2 = 5Pr_l + 5\ln(1 + 5Pr_l) + 2.5\ln(0.00313Re_l^{0.812})$ |

**[9] Alberto Cavallini et al**

This paper describe that experimental heat transfer coefficient during condensation of R-134a and R407C in a micro-fin tube. Heat transfer measurement are compared against performance of an equivalent smooth tube under the same operating conditions, to show advantages of the micro-fin tube as compared to the smooth tube. Experimental tests are carried out in a broad range of operating temperatures to enlighten the influence of saturation temperature on the heat transfer coefficient. Comparison with three models cavallini et al, Yu and Koyama and Kedzierki are available in this research paper.

**[10] N. Austin**

This paper describe that the performance comparison and analysis of refrigerants used in domestic compression refrigeration systems in the premises of steady state.R134a and R600a are the two refrigerants considered for comparison. Refrigerators used for domestic as well as household uses were chosen for conducting the experiments. The achieved results show that 50g of R600a produces the same output as produced by R134a.Based on the results, R600a performance compressor coefficient, charge amount and condenser evaporator were chosen for the analytical design. Out of the various outcomes, the variance result supported the view that R600a charge amount was the most notable parameter. At conditions which are optimal the charging amount necessary for R600a was found to be 60g which was 68% lesser than R134a.Other working parameters include heat transfer performance and capillary tube dimensions. Comparison and review results show that R600a performs better than R134a.

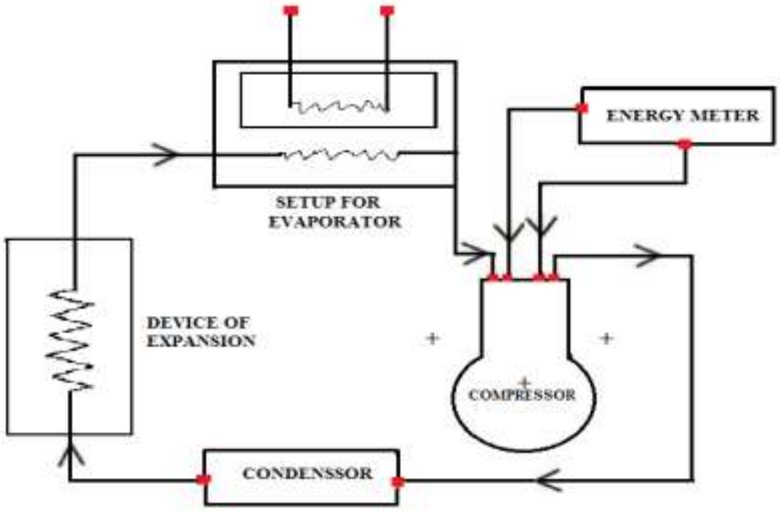


Fig: Experimental setup design layout

## III. CONCLUSION

From above literature survey we conclude that many researcher compare heat transfer coefficient of CFC12 and HFC 134a refrigerant by experiment and by using existing correlation in condensation and evaporation mode and find that heat transfer coefficient of HFC134a is higher than CFC12 in both mode.
Then I have decided to compare the heat transfer coefficient of HCFC409a and HFC 134a as an alternative of R12 during condensation based on existing correlation.

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