RESEARCH ARTICLE OPEN ACCESS

A Comparative Study of the Effect of Variation of Inside Diameter of Condenser and Mass Flow Rate on the Heat Transfer Coefficient in a Domestic Refrigerator.

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ABSTRACT
The performance of a domestic refrigerator is affected by the Surface roughness of condenser, evaporator and associated piping. The heat transfer in a domestic refrigerator is a complex phenomenon as it involves two phase flow inside the condenser, evaporator and the tubing. Various equations had been developed in the past by different Researchers to calculate the heat transfer for fluid flow inside tubes. In the present study Boyko and Kurzhillin equation is being used to determine the heat transfer coefficient for two phase flow in the condenser of a domestic refrigerator using R134a as refrigerant. For this an experimental setup has also been developed containing different condensers having different inside tube diameters varying in the range of 6.25mm to 12mm and the mass flow rate of refrigerant is varied in the range of 0.002kg/s to 0.02 kg/s.
Key words: Domestic refrigerator, condenser, heat transfer coefficient, Reynolds number, mass flow rate.

I. INTRODUCTION

The heat transfer in a domestic refrigerator involves two phase flow and the refrigerant undergoes change of phase as it flows through the condenser, and evaporator of the refrigerator. Determination of heat transfer is thus a complex process and researchers in the past have developed different equations[1] for predicting the heat transfer for two phase flow. *Boyko and Kurzhillin equation*[2] is being used in the present study to determine the heat transfer in the domestic refrigerator for two phase flow. The theoretical heat transfer through the condenser calculated using the above stated equation would be compared with the actual heat transfer. For this an experimental test setup had been fabricated.

Boyko and Kurzhillin proposed the following equation to determine the heat transfer coefficient in two phase flow inside tubes;

$hi = 0.024(K/d)Re^{0.8}\,Pr^{0.43}\{(\rho_l/\rho_v)^{0.5}+1\}/2$ …(1)

where, hi= heat transfer coefficient
k= thermal conductivity of liquid inside the tubes.
d= pipe inside diameter
Re=Reynolds number for liquid
Pr= Prandtl number for liquid [8]
ρ_l = liquid phase density
ρ_v = vapour phase density .

II. EXPERIMENTAL SETUP

An experimental set up has been developed to determine the effect of relative roughness of condenser piping material on the friction factor, pressure drop and heat transfer in a domestic refrigerator. The set up is equipped with a number of condensers having different relative roughness values and inside pipe diameters mounted in parallel with flow control valves to vary the flow conditions. The heat transfer coefficient is determined using the *Boyko and Kurzhillin* equation. The actual heat transfer can be compared with the theoretically computed results obtained by using the above specified equation.

III. DATA USED

Refrigerant used R134a
Mean Condensing temperature=60^0c
Liquid phase density = 1052.85 kg/m^3
Vapour phase density= 87.719 kg/m^3
Thermal conductivity of R134a =0.01144 W/m-k
Prandtl number for liquid= 0.769
Condensers inside diameters selected as 6.25mm, 8mm, 10mm and 12mm respectively.
Mass flow rate of refrigerant varied from 0.002kg/s to 0.02 kg/s. in step of 0.001 kg/s.

IV. TABLES AND FIGURES

The following tables were prepared using the different mass flow rate conditions with different pipe inside diameters for condensers. The heat transfer coefficient was then determined using the *Boyko and Kurzhillin* equation for two phase flow of refrigerant.

Table 1(6.25mm diameter pipe)

Mass flow rate(kg/s)	Reynolds number	Mass flow rate(kg/s)	Reynolds number
0.002	29300.2	0.012	175801.2
0.003	43950.2	0.013	190451.3
0.004	58600.3	0.014	205101.4
0.005	73250.4	0.015	219751.5
0.006	87900.5	0.016	234401.6
0.007	102550.7	0.017	249051.7
0.008	117200.8	0.018	263701.8
0.009	131850.9	0.019	278351.9
0.01	146501	0.02	293002
0.011	161151.1		

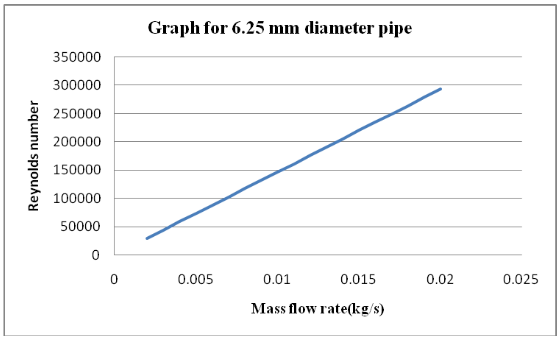

Figure 1

Table 2 (8 mm diameter pipe)

Mass flow rate(kg/s)	Reynolds number	Mass flow rate(kg/s)	Reynolds number
0.002	22890.78	0.012	137344.7
0.003	34336.17	0.013	148790.1
0.004	45781.56	0.014	160235.4
0.005	57226.95	0.015	171680.8
0.006	68672.33	0.016	183126.2
0.007	80117.72	0.017	194571.6
0.008	91563.11	0.018	206017
0.009	103008.5	0.019	217462.4
0.01	114453.9	0.02	228907.8
0.011	125899.3		

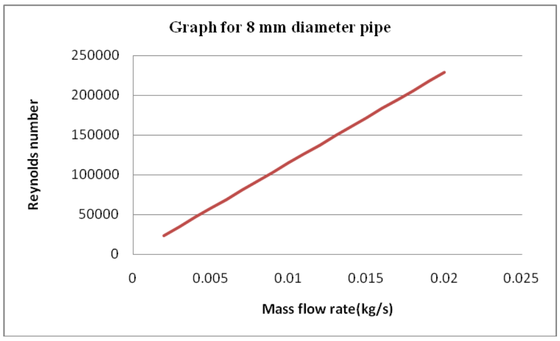

Figure 2

Table 3 (10 mm diameter pipe)

Mass flow rate(kg/s)	Reynolds number	Mass flow rate(kg/s)	Reynolds number
0.002	18312.6	0.012	109875.7
0.003	27468.9	0.013	119032
0.004	36625.2	0.014	128188.4
0.005	45781.5	0.015	137344.7
0.006	54937.8	0.016	146501
0.007	60944.1	0.017	155657.3
0.008	73250.4	0.018	164813.6
0.009	82406.8	0.019	173969.9
0.01	91563.1	0.02	183126.2
0.011	100719.4		

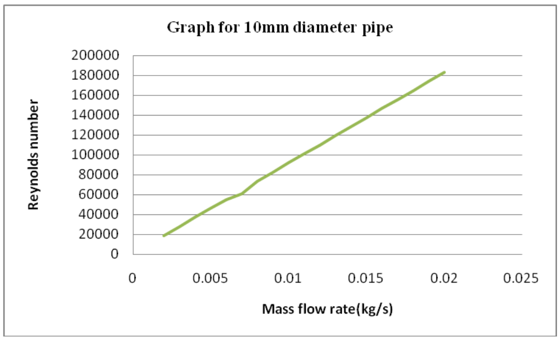

Figure 3

Table 4 (12 mm diameter pipe)

Mass flow rate(kg/s)	Reynolds number	Mass flow rate(kg/s)	Reynolds number
0.002	15260.52	0.012	91563.11
0.003	22890.78	0.013	99193.37
0.004	30521.04	0.014	106823.6
0.005	38151.3	0.015	114453.9
0.006	45781.56	0.016	122084.2
0.007	53411.82	0.017	129714.4
0.008	61042.08	0.018	137344.7
0.009	68672.33	0.019	144974.9
0.01	76302.59	0.02	152605.2
0.011	83932.85		

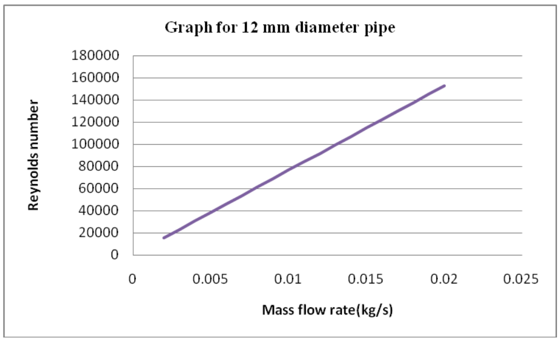

Figure 4

Table 5 (6.25mm diameter pipe)

Mass flow rate(kg/s)	Heat transfer coefficient (w/m^2-K)	Mass flow rate(kg/s)	Heat transfer coefficient (w/m^2-K)
0.002	328.05	0.012	1375.56
0.003	453.74	0.013	1466.46
0.004	571.17	0.014	1556.03
0.005	682.8	0.015	1644.33
0.006	790.02	0.016	1731.46
0.007	893.7	0.017	1817.51
0.008	994.46	0.018	1902.54
0.009	1092.72	0.019	1986.64
0.01	1188.82	0.02	2069.86
0.011	1283.01		

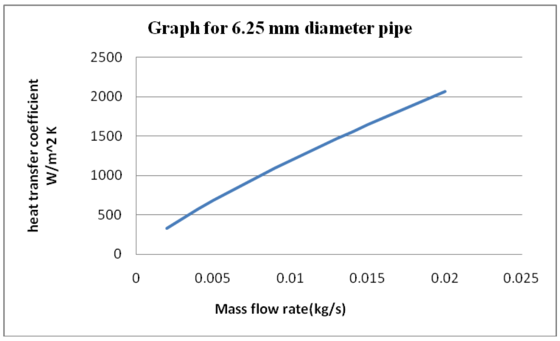

Figure 5

Table 6(8 mm diameter pipe)

Mass flow rate(kg/s)	Heat transfer coefficient (w/m^2-K)	Mass flow rate(kg/s)	Heat transfer coefficient (w/m^2-K)
0.002	210.36	0.012	882.03
0.003	290.96	0.013	940.36
0.004	366.25	0.014	997.79
0.005	437.84	0.015	1054.41
0.006	506.59	0.016	1110.28
0.007	573.08	0.017	1165.46
0.008	637.69	0.018	1219.99
0.009	700.7	0.019	1273.92
0.01	762.32	0.02	1327.28
0.011	822.72		

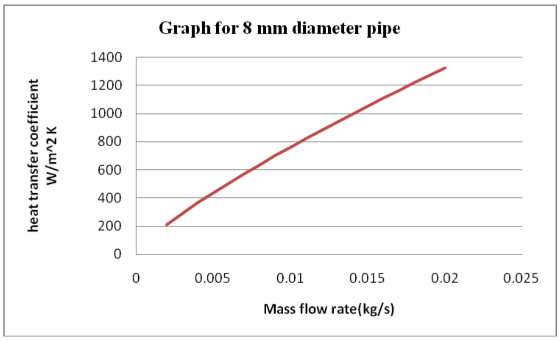

Figure 6

Table 7 (10 mm diameter pipe)

Mass flow rate(kg/s)	Heat transfer coefficient (w/m^2-K)	Mass flow rate(kg/s)	Heat transfer coefficient (w/m^2-K)
0.002	140.77	0.012	590.26
0.003	194.71	0.013	629.29
0.004	245.1	0.014	667.73
0.005	293	0.015	705.62
0.006	339.01	0.016	743.01
0.007	383.51	0.017	779.93
0.008	426.75	0.018	816.43
0.009	468.91	0.019	852.52
0.01	510.15	0.02	888.23
0.011	550.57		

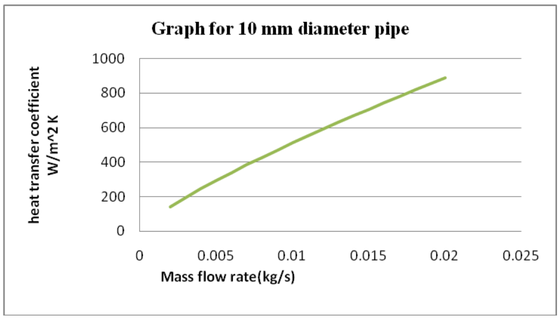

Figure 7

Table 8 (12 mm diameter pipe)

Mass flow rate(kg/s)	Heat transfer coefficient (w/m^2-K)	Mass flow rate(kg/s)	Heat transfer coefficient (w/m^2-K)
0.002	101.39	0.012	425.12
0.003	140.24	0.013	453.24
0.004	176.53	0.014	480.92
0.005	211.03	0.015	508.21
0.006	244.17	0.016	535.14
0.007	276.21	0.017	561.73
0.008	307.36	0.018	588.02
0.009	337.73	0.019	614.01
0.01	367.43	0.02	639.73
0.011	396.54		

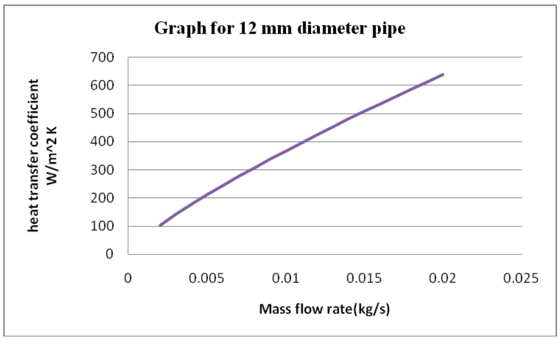

Figure 8

Table 9 (comparative performance)

Mass flow rate (kg/s)	Reynolds number			
	Pipe diameter 6.25mm	Pipe diameter 8mm	Pipe diameter 10 mm	Pipe diameter12 mm
0.002	29300.2	22890.78	18312.6	15260.5
0.003	43950.2	34336.17	27468.9	22890.7
0.004	58600.3	45781.56	36625.2	30521.0
0.005	73250.4	57226.95	45781.5	38151.3
0.006	87900.5	68672.33	54937.8	45781.5
0.007	102550.7	80117.72	60944.1	53411.8
0.008	117200.8	91563.11	73250.4	61042.0
0.009	131850.9	103008.5	82406.8	68672.3
0.01	146501	114453.9	91563.1	76302.5
0.011	161151.1	125899.3	100719	83932.8
0.012	175801.2	137344.7	109875	91563.1
0.013	190451.3	148790.1	119032	99193.3
0.014	205101.4	160235.4	128188	106823
0.015	219751.5	171680.8	137344	114453
0.016	234401.6	183126.2	146501	122084
0.017	249051.7	194571.6	155657	129714
0.018	263701.8	206017	164813	137344
0.019	278351.9	217462.4	173969	144974
0.02	293002	228907.8	183126	152605

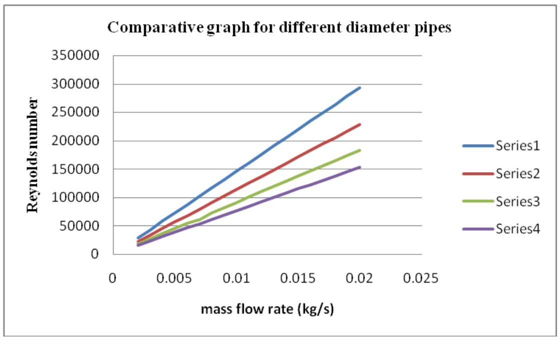

Figure 9

Table 10 (comparative performance)

Mass flow rate (kg/s)	Heat transfer coefficient (w/m^2-K)			
	6.25mm	8 mm	10 mm	12 mm
0.002	328.05	210.36	140.77	101.39
0.003	453.74	290.96	194.71	140.24
0.004	571.17	366.25	245.1	176.53
0.005	682.8	437.84	293	211.03
0.006	790.02	506.59	339.01	244.17
0.007	893.7	573.08	383.51	276.21
0.008	994.46	637.69	426.75	307.36
0.009	1092.72	700.7	468.91	337.73
0.01	1188.82	762.32	510.15	367.43
0.011	1283.01	822.72	550.57	396.54
0.012	1375.56	882.03	590.26	425.12
0.013	1466.46	940.36	629.29	453.24
0.014	1556.03	997.79	667.73	480.92
0.015	1644.33	1054.4	705.62	508.21
0.016	1731.46	1110.2	743.01	535.14
0.017	1817.51	1165.4	779.93	561.73
0.018	1902.54	1219.9	816.43	588.02
0.019	1986.64	1273.9	852.52	614.01
0.02	2069.86	1327.2	888.23	639.73

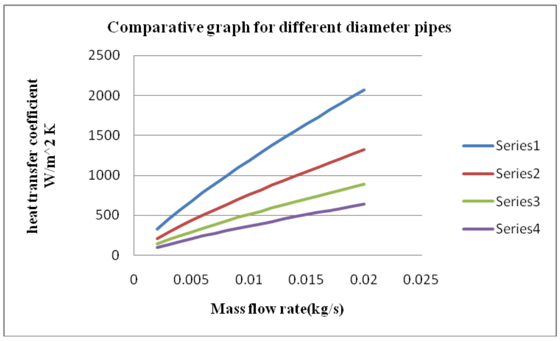

Figure 10

Series 1, 2, 3 and 4 marked in the Fig.9 and Fig. 10 corresponds to the respective pipe diameters of 6.25mm, 8mm, 10mm and 12mm.

V. CONCLUSIONS

It can be concluded from the above tables and figures that

a) For a specified mass flow rate of refrigerant; as the pipe diameter increases, the Reynolds number decreases.
b) For a specified pipe diameter; the Reynolds number increases with increase in mass flow rate.
c) The heat transfer coefficient increases with increase in mass flow rate for a specified value of pipe diameter.
d) The heat transfer coefficient decreases with increase in pipe diameter for a specified value of mass flow rate.

References

[1] D. M. Admiraal and C. W. Bullard, *Heat Transfer in Refrigerator Condensers and Evaporators*, (Air Conditioning and Refrigeration Center, University of Illinois, Mechanical & Industrial Engineering Dept.1206 West Green Street Urbana, IL 61801), August 1993

[2] Heat transfer and pressure drop inside tubes. *Wolverine Tube Heat transfer Data Book.* 2006

[3] D.M. Graham, J. C. Chato and T. A. Newell, *Heat transfer and pressure drop during condensation of refrigerant 134a in an axially grooved tube*, (Air Conditioning and Refrigeration Center, University of Illinois, Mechanical & Industrial Engineering

Dept.1206 West Green Street Urbana, IL 61801, March 1997)

[4] Raja Balakrishnan, Joseph Sekhar Santhappan, and Mohan Lal Dhasan, *Heat Transfer Correlation for a Refrigerant Mixture in a Vertical Helical Coil Evaporator*, (THERMAL SCIENCE: Vol. 13 (2009), No. 4, pp. 197-206)

[5] S. N. Sapali and Pradeep A. Patil, *A new experimental technique to determine heat transfer coefficient and pressure drop in smooth and micro-fin tube,* (Journal of Mechanical Engineering Research Vol. 2(4), pp. 71-84, September 2010)

[6] Lap Mou Tam, Hou Kuan Tam and Afshin A Ghajar, *Simultaneous Heat Transfer and Pressure Drop Measurements for a Horizontal Micro-Tube*, (Proceedings of AJTEC2011 ASME/JSME 2011 8th Thermal Engineering Joint Conference March 14-17, 2011, Honolulu, Hawaii, USA)

[7] K. S. Patil, K. V. Mali & Prabhat Ojha, *Simulation Of Wire And Tube Condenser Of Domestic Refrigerator*, (International Journal of Engineering & Science Research, IJESR/July 2012/ Volume-2/Issue-7/Article No-11/613-620)

[8] A.V. Domkundwar & Dr. V.M. Domkundwar, *Heat and Mass Transfer Data Book*, (Dhanpatrai and company Pvt. Ltd., 2008)