A SIMPLIFICATION OF READING FLUID PROPERTIES USING MICROSOFT EXCEL

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Report submitted in partial fulfillment of the requirements
for the award of Bachelor of Mechanical Engineering

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FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled *"A Simplification of Reading Fluid Properties Using Microsoft Excel"* is written by *Mohd Asri bin Ibrahim.* I have examined the final copy of this project and in my opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering.

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Examiner   Signature

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project report and in my opinion this project is adequate in terms of scope and quality for the award of the Degree of Bachelor of Mechanical Engineering.

Signature:
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Date: 21 JUNE 2012

STUDENT'S DECLARATION

I hereby declare that the work in this report is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature:

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ABSTRACT

This project deals with simplification reading fluid properties using Microsoft Excel. The objective of this project to develop an excel file to easily obtain fluid properties without manual reading from table. The types of fluid are saturated water, saturated refrigerant-134a, saturated ammonia, saturated propane and air at 1 atm pressure while the fluid properties are density, dynamic viscosity, kinematic viscosity and friction factor. The formula in Microsoft Excel, INDEX, MATCH, INDIRECT, IF, AND, ISBLANK, NA and DROPDDOWLIST are used to build a combine formula that can obtain fluid properties from property tables. The combined formula was constructed step by step starting the listed value, followed by listed and unlisted value for SI units only and then the listed and unlisted value for SI units and English units in the property tables. Finally, one more combined formula was constructed to obtain friction factor based on Colebrook equation by using bisection method to solve that equation. Validation results were conducted where compared the results from manual reading and excel file. The error from both results was observed where all the error results are below 5 % and can be accepted. The different results from manual reading and excel file only occur for result in value decimal places. It can be comprehend that, to obtain fluid properties from property tables can be using Microsoft Excel by constructed a excel file. The developed excel file for future work is highly recommended for adding more properties, more type of fluid and using Visual Basic for Applications for advance editing.

ABSTRAK

Projek ini berkaitan meringkaskan cara membaca sifat-sifat bendalir menggunakan Microsoft Excel. Objektif projek ini untuk membangunkan satu fail Microsoft Excel untuk memudahkan mendapat sifat-sifat bendalir tanpa membaca secara manual dari jadual. Jenis-jenis bendalir adalah air tepu, bahan pendingin-134a tepu, ammonia tepu, propana tepu dan udara pada tekanan 1 atm manakala sifat-sifat bendalir adalah ketumpatan, kelikatan dinamik, kelikatan kinematik dan faktor geseran. Formula dalam Microsoft Excel, INDEX, MATCH, INDIRECT, IF, AND, ISBLANK, NA dan DROPDDOWLIST digunakan untuk membina satu gabungan fomula untuk mendapatkan sifat-sifat bendalir dari jadual sifat-sifat bendalir. Gabungan fomula dibina peringkat demi peringkat dimulakan dengan nilai tersenarai, diikuti dengan nilai tersenarai dan tidak tersenarai untuk SI unit dan kemudiannya nilai tersenarai dan nilai tidak tersenarai untuk SI unit dan English unit dalam jadual sifat-sifat bendalir. Akhir sekali, satu lagi gabungan formula dibina untuk mendapatkan faktor geseran berdasarkan persamaan Colebrook dengan menggunakan kaedah pembahagian dua sama bagi menyelesaikan persamaan itu. Pengesahan keputusan telah dijalankan di mana membandingkan keputusan dari bacaan secara manual dan keputusan dari fail excel. Ralat dari kedua-dua keputusan telah diperhatikan di mana semua ralat adalah di bawah 5 % dan boleh diterima. Keputusan yang berbeza dari bacaan secara manual dan fail excel hanya berlaku pada nila tempat perpuluhan. Ia boleh difahami bahawa, untuk mendapatkan sifat-sifat bendalir dari jadual sifat-sifat bendalir boleh menggunakan Microsoft Excel dengan membina satu fail excel. Bagi penambahbaikkan projek ini pada masa hadapan, disyorkan menambah lebih banyak sifat-sifat bendalir, jenis-jenis bendalir dan menggunakan Visual Basic for Applications (VBA) untuk penambaikkan yang lebih baik.

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LIST OF SYMBOLS

f	Friction factor
f_D	Darcy friction factor
f_F	Fanning friction factor
ε	Roughness
D	Diameter
Re	Reynolds number
ρ	Density
μ	Dynamic viscosity
ν	Kinematic viscosity
T	Temperature
V	Velocity

LIST OF ABBREVIATIONS

ASME	American Society of Mechanical Engineers
IST	International Skeleton Tables
ICPS	International Conference on the Properties of Steam
IFC	International Formulating Committee
IAPS	International Association for the Properties of Steam
IAPWS	International Association for the Properties of Water and Steam
SI	International System of Units
atm	Atmosphere
VBA	Visual Basic for Applications

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Fluid property tables are important to be referred by engineer to obtain the properties value to solve engineering problems. This project is simplification reading fluid properties without manually reading from table for some of the properties in the fluid property tables. Easier read the property table will shorten the time to solve problems.

Microsoft Excel is the software to simplification reading property tables. An excel file will construct where properties of fluid can be easily read simply by inserting the value of temperature in a certain cell and various fluid properties will automatically appear on any designated cells. The formulas in excel such as Match, Index, Indirect, If, And, Isblank, Na and Dropdownlist and other will use to obtain the properties.

1.2 PROBLEM STATEMENT

For manual reading property tables, it is quite difficult when interpolation is required if the value of the parameter is unlisted in the table and the time is very short. Interpolation calculation for unlisted value in property tables will cause the longer time taken to obtain that value in order to solve engineering task and problem. For Moody Chart, it is difficult to read manually because the Moody Chart is complicated that will increase the possibility to read the wrong value.

1.3 OBJECTIVE

The objective of this project is:

i. To develop an excel file to easily obtain fluid properties without manual reading from table

1.4 SCOPE OF THE PROJECT

The scopes of this project are limited to:

i. Fluid will be used are water, ammonia, refrigerant 134a, propane and air
ii. Fluid properties such as density, dynamic viscosity, kinematic viscosity and friction factor
iii. Based on table of fluid properties (McGraw Hill, 2006, Cengel Y.A and Cimbala J.M)
iv. Use Microsoft Excel 2007 software
v. Validation of results

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discuss about literature review of the history of property tables, Moody Chart and Microsoft excel. Besides that, this chapter also discusses the existing software or calculator to obtain value from property tables and friction factor.

2.2 HISTORY OF PROPERTY TABLES

Property tables are important tool in the engineering field. Thermodynamics property tables and Fluid Mechanics property tables are the common use in mechanical engineering. The history of fluid property table is difficult to find compare to the history of steam table. The main used of property tables is for the industrial application and to solve the engineering problems especially in education.

In the history of steam table, James Watt in 1763 probably constructed the first steam table where he constructed a curve relating temperature and saturation pressure of water. There are four major steam tables were available in the middle of 1920s by Mark and Davis, by Goodenough, by Moiler and by Callendar where each table constructed density of steam as a function of temperature and pressure. Those four major steam tables had difference in published data and became a problem in the industry equipment performance. (Sifner, 2004)

Thus, to counter this problem, American Society of Mechanical Engineers (ASME) had a program of research that addresses the problem properties of steam in 1921. The program joined by Professor Callendar and followed by the German Research Authority. In the first World Power Conference, the country Czechoslovakia immediately invited after knowing Czechoslovakia had the research of properties of steam. (Sifner, 2004)

In 1929, the First International Steam-Table Conference was held in London, the second conference in Berlin in 1930 and in 1934, the third conference was held in Washington. In 1934, after many discussions and debates, engineers and scientist agreed the first International Skeleton Tables, IST'34 where this table only for limited range of temperature and pressure. This table become an important tool for engineer and famous as steam tables. (Sifner, 2004)

World war two was interrupted the international cooperation about 20 years. The steam tables needed to be extended due to increasing pressure and temperature of the power generating equipment. The fourth conference was renamed to the International Conference on the Properties of Steam (ICPS) was held in Philadelphia in 1954 while fifth conference in London in 1956 and sixth conference in New York in 1963. These conferences were discussed and developed of new standards for water and steam properties. (Sifner, 2004)

The seventh conference ICPS was held in Tokyo adopted two final versions namely The 1967 IFC Formulation for Industrial Use for simpler equations but sufficient accuracy and The 1968 IFC Formulation for Scientific and General Use for accurate description of properties. International Association for the Properties of Steam (IAPS) was established at the seventh conference and now known as International Association for the Properties of Water and Steam (IAPWS). (Tremaine et al., 2008)

The eighth conference was held in Giens, France in 1974 to construct new tables of viscosity and thermal conductivity. In that conference, it also discussed to prepare the surface tension formulation. Ninth conference was held in Munich in 1979 to discuss new tables and new thermodynamic formulations. In 1984, the tenth conference was held in Moscow adopted a new thermodynamic standard for general and scientific use. (Sifner, 2004)

Eleventh conference was held in Prague, Czechoslovakia in 1989 while the twelfth conference was held in Orlando, USA in 1994. In 1995, the new Formulation for Industrial Use known as IAPWS-95 was adopted to replace previous version while in 1997 the new Formulation for Scientific and General Use was adopted known as IAPWS-IFC97. The thirteenth conference was held in Toronto, Canada in 1999, fourteenth conference was held in Kyoto in 2004 and fifteenth conference was held in Berlin in 2008. (Tremaine et al., 2008)

Properties of saturated water

Temp.	Saturation Pressure	Density ρ, kg/m³		Enthalpy of Vaporization	Specific Heat c_p, J/kg · K		Thermal Conductivity k, W/m · k		Dynamic Viscosity μ, kg/m · s		Prandtl Number Pr		Volume Expansion Coefficient β, 1/K
T, °C	P_{sat}, kPa	Liquid	Vapor	h_{fg}, kJ/kg	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid
0.01	0.6113	999.8	0.0048	2501	4217	1854	0.561	0.0171	1.792×10^{-3}	0.922×10^{-5}	13.5	1.00	-0.068×10^{-3}
5	0.8721	999.9	0.0068	2490	4205	1857	0.571	0.0173	1.519×10^{-3}	0.934×10^{-5}	11.2	1.00	0.015×10^{-3}
10	1.2276	999.7	0.0094	2478	4194	1862	0.580	0.0176	1.307×10^{-3}	0.946×10^{-5}	9.45	1.00	0.733×10^{-3}
15	1.7051	999.1	0.0128	2466	4185	1863	0.589	0.0179	1.138×10^{-3}	0.959×10^{-5}	8.09	1.00	0.138×10^{-3}
20	2.339	998.0	0.0173	2454	4182	1867	0.598	0.0182	1.002×10^{-3}	0.973×10^{-5}	7.01	1.00	0.195×10^{-3}
25	3.169	997.0	0.0231	2442	4180	1870	0.607	0.0186	0.891×10^{-3}	0.987×10^{-5}	6.14	1.00	0.247×10^{-3}
30	4.246	996.0	0.0304	2431	4178	1875	0.615	0.0189	0.798×10^{-3}	1.001×10^{-5}	5.42	1.00	0.294×10^{-3}
35	5.628	994.0	0.0397	2419	4178	1880	0.623	0.0192	0.720×10^{-3}	1.016×10^{-5}	4.83	1.00	0.337×10^{-3}
40	7.384	992.1	0.0512	2407	4179	1885	0.631	0.0196	0.653×10^{-3}	1.031×10^{-5}	4.32	1.00	0.377×10^{-3}
45	9.593	990.1	0.0655	2395	4180	1892	0.637	0.0200	0.596×10^{-3}	1.046×10^{-5}	3.91	1.00	0.415×10^{-3}
50	12.35	988.1	0.0831	2383	4181	1900	0.644	0.0204	0.547×10^{-3}	1.062×10^{-5}	3.55	1.00	0.451×10^{-3}
55	15.76	985.2	0.1045	2371	4183	1908	0.649	0.0208	0.504×10^{-3}	1.077×10^{-5}	3.25	1.00	0.484×10^{-3}
60	19.94	983.3	0.1304	2359	4185	1916	0.654	0.0212	0.467×10^{-3}	1.093×10^{-5}	2.99	1.00	0.517×10^{-3}
65	25.03	980.4	0.1614	2346	4187	1926	0.659	0.0216	0.433×10^{-3}	1.110×10^{-5}	2.75	1.00	0.548×10^{-3}
70	31.19	977.5	0.1983	2334	4190	1936	0.663	0.0221	0.404×10^{-3}	1.126×10^{-5}	2.55	1.00	0.578×10^{-3}
75	38.58	974.7	0.2421	2321	4193	1948	0.667	0.0225	0.378×10^{-3}	1.142×10^{-5}	2.38	1.00	0.607×10^{-3}
80	47.39	971.8	0.2935	2309	4197	1962	0.670	0.0230	0.355×10^{-3}	1.159×10^{-5}	2.22	1.00	0.653×10^{-3}
85	57.83	968.1	0.3536	2296	4201	1977	0.673	0.0235	0.333×10^{-3}	1.176×10^{-5}	2.08	1.00	0.670×10^{-3}
90	70.14	965.3	0.4235	2283	4206	1993	0.675	0.0240	0.315×10^{-3}	1.193×10^{-5}	1.96	1.00	0.702×10^{-3}
95	84.55	961.5	0.5045	2270	4212	2010	0.677	0.0246	0.297×10^{-3}	1.210×10^{-5}	1.85	1.00	0.716×10^{-3}
100	101.33	957.9	0.5978	2257	4217	2029	0.679	0.0251	0.282×10^{-3}	1.227×10^{-5}	1.75	1.00	0.750×10^{-3}
110	143.27	950.6	0.8263	2230	4229	2071	0.682	0.0262	0.255×10^{-3}	1.261×10^{-5}	1.58	1.00	0.798×10^{-3}
120	198.53	943.4	1.121	2203	4244	2120	0.683	0.0275	0.232×10^{-3}	1.296×10^{-5}	1.44	1.00	0.858×10^{-3}
130	270.1	934.6	1.496	2174	4263	2177	0.684	0.0288	0.213×10^{-3}	1.330×10^{-5}	1.33	1.01	0.913×10^{-3}
140	361.3	921.7	1.965	2145	4286	2244	0.683	0.0301	0.197×10^{-3}	1.365×10^{-5}	1.24	1.02	0.970×10^{-3}
150	475.8	916.6	2.546	2114	4311	2314	0.682	0.0316	0.183×10^{-3}	1.399×10^{-5}	1.16	1.02	1.025×10^{-3}
160	617.8	907.4	3.256	2083	4340	2420	0.680	0.0331	0.170×10^{-3}	1.434×10^{-5}	1.09	1.05	1.145×10^{-3}
170	791.7	897.7	4.119	2050	4370	2490	0.677	0.0347	0.160×10^{-3}	1.468×10^{-5}	1.03	1.05	1.178×10^{-3}
180	1,002.1	887.3	5.153	2015	4410	2590	0.673	0.0364	0.150×10^{-3}	1.502×10^{-5}	0.983	1.07	1.210×10^{-3}
190	1,254.4	876.4	6.388	1979	4460	2710	0.669	0.0382	0.142×10^{-3}	1.537×10^{-5}	0.947	1.09	1.280×10^{-3}
200	1,553.8	864.3	7.852	1941	4500	2840	0.663	0.0401	0.134×10^{-3}	1.571×10^{-5}	0.910	1.11	1.350×10^{-3}
220	2,318	840.3	11.60	1859	4610	3110	0.650	0.0442	0.122×10^{-3}	1.641×10^{-5}	0.865	1.15	1.520×10^{-3}
240	3,344	813.7	16.73	1767	4760	3520	0.632	0.0487	0.111×10^{-3}	1.712×10^{-5}	0.836	1.24	1.720×10^{-3}
260	4,688	783.7	23.69	1663	4970	4070	0.609	0.0540	0.102×10^{-3}	1.788×10^{-5}	0.832	1.35	2.000×10^{-3}
280	6,412	750.8	33.15	1544	5280	4835	0.581	0.0605	0.094×10^{-3}	1.870×10^{-5}	0.854	1.49	2.380×10^{-3}
300	8,581	713.8	46.15	1405	5750	5980	0.548	0.0695	0.086×10^{-3}	1.965×10^{-5}	0.902	1.69	2.950×10^{-3}
320	11,274	667.1	64.57	1239	6540	7900	0.509	0.0836	0.078×10^{-3}	2.084×10^{-5}	1.00	1.97	
340	14,586	610.5	92.62	1028	8240	11,870	0.469	0.110	0.070×10^{-3}	2.255×10^{-5}	1.23	2.43	
360	18,651	528.3	144.0	720	14,690	25,800	0.427	0.178	0.060×10^{-3}	2.571×10^{-5}	2.06	3.73	
374.14	22,090	317.0	317.0	0	—	—	—	—	0.043×10^{-3}	4.313×10^{-5}			

Figure 2.1: Sample of fluid property tables

Source: Cengel and Cimbala (2006)

Figure 2.1 show the sample of fluid property tables that are important tool as the reference in industry for engineer to solve engineering problem. International Association for the Properties of Water and Steam (IAPWS) is the association that concern with the properties of water and steam.

2.3 HISTORY OF MOODY CHART

Moody Chart or Moody Diagram was used by engineering worker and engineering student since 1940s. Lewis F. Moody was the responsible person which had developed Moody Chart in 1944 and this Moody Chart was published by American Society of Mechanical Engineers (ASME). Moody Chart is semi-empirical that related to the Darcy friction factor, relative roughness and Reynolds number. (McGovern, 2003)

Cyril F. Colebrook in 1939 was developed Colebrook equation where that equation comes from combined available data for transition and turbulent flow in smooth. The Colebrook equation is:

$$\frac{1}{\sqrt{f}} = -2\log\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{Re\sqrt{f}}\right) \tag{2.1}$$

The American engineer, Hunter Rouse in 1942 had verified Colebrook equation and developed a graphical plot of friction factor, f as a function of Reynolds number, Re. From Rouse diagram, Lewis F. Moody redrew that diagram and produced the Moody Chart. (Cengel and Cimbala, 2006)

There are two common of friction factor which the first Darcy friction factor, f_D and the second Fanning friction factor f_F. Fanning friction factor equal to one quarter of the Darcy friction factor shows in equation below: (McGovern, 2003)

$$f_F = \frac{f_D}{4} \tag{2.2}$$

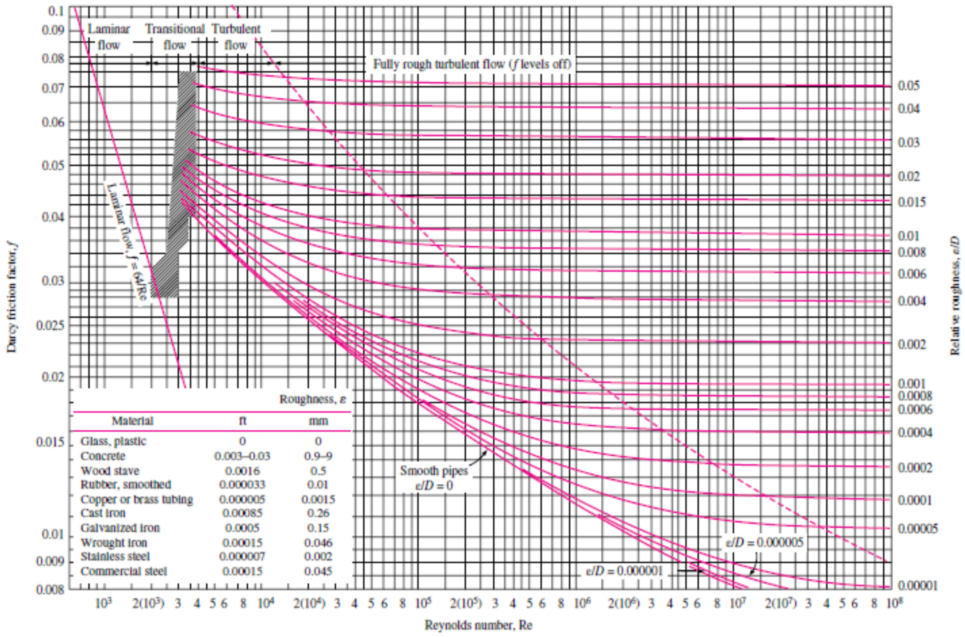


FIGURE A–20

The Moody chart for the friction factor for fully developed flow in circular pipes for use in the head loss relation $\Delta P_L = f\frac{L}{D}\frac{\rho V^2}{2}$. Friction factors in the turbulent flow are evaluated from the Colebrook equation $\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{Re\sqrt{f}}\right)$.

Figure 2.2: Moody Chart

Source: Cengel and Cimbala (2006)

Figure 2.2 show the Moody Chart that was included in many mechanical engineering books like Fluid Mechanics and Heat Transfer. From Moody Chart, known the value of Reynolds number and relative roughness, the friction value can be obtained.

2.4 HISTORY OF MICROSOFT EXCEL

Microsoft Excel is one of the spreadsheet program that allow user to organize, format, calculate data with formula, graphing tools, pivot tables and macro programming language called visual basic for application. Once an excel file was constructed, the contents can modified by adding and deleting where the result recalculated automatically. In 1979, Dan Bricklin constructed the first spreadsheet program on a personal computer was called visible interactive calculator (VisiCalc). (Martin, 2010)

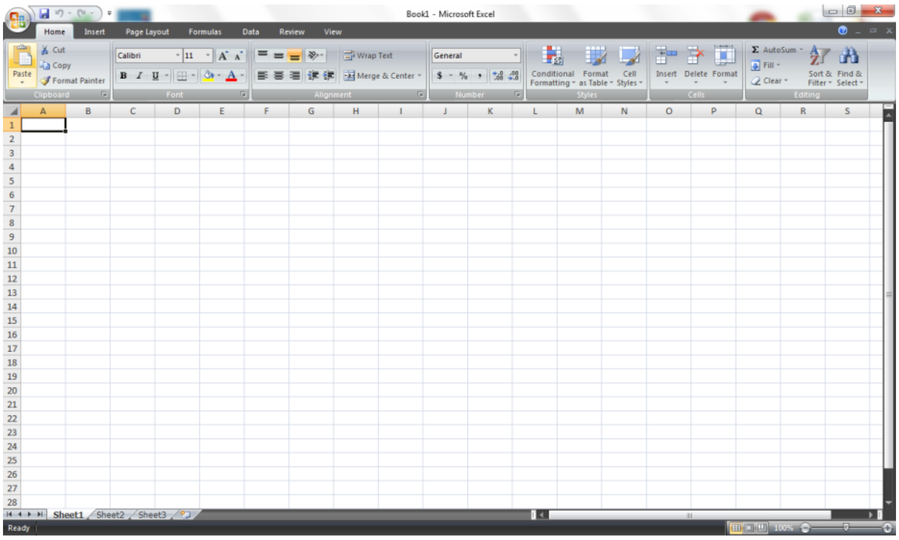


Figure 2.3: View of Microsoft Excel 2007

Figure 2.3 show view of Microsoft Excel 2007 that developed by Microsoft. In 1975, Paul Allen and Bill Gates formed a company namely Microsoft. In 1982, Microsoft released spreadsheet program known as Multiplan. Then, Microsoft was released first version of excel in 1985 but for Macintosh operating system only. In 1987, second version of excel was released for the first Windows operating system. (Pearson, 2011)

Excel third version was released in 1990 with new features included worksheets. In 1992, Excel fourth version was released with included lots of usability features and become the first popular version. Excel fifth version was released in 1993 with new features included multiple worksheets and support visual basic for applications. (Power, 2004)

New version of Excel was rebranded as Excel 95 in 1995 along with other Microsoft Office 95 programs. Excel 95 was the seventh version where there was no sixth version of excel. This Excel 95 was the 32 bit version. Then, Excel 97 was released in 1997 with new visual basic for applications and new features included user forms and data validation. In 1999, new excel was released known as Excel 2000. Excel 97 was the eighth version and Excel 2000 was the ninth version. (Pearson, 2011)

Excel 2002 was released in 2001 while Excel 2003 was released in 2003 where Excel 2002 was the tenth version and Excel 2003 was the eleventh version. Excel 2007 was released in 2007 with a lot of improvements. Excel 2010 was the latest Excel version builds on Excel 2007 with not any major changes. Excel 2007 was the twelfth version and Excel 2010 was the fourteenth version where there was no thirteenth version of excel. Table 2.1 shows the various versions of Microsoft Excel. (Pearson, 2011)

Table 2.1: The various versions of Microsoft Excel

Version	Released	Comments
1	1985	For Macintosh operating system
2	1987	First for Windows operating system
3	1990	Features included worksheets, toolbar, outlining and drawing capabilities
4	1992	Lots of usability features and first popular version
5	1993	Included multiple worksheets and visual basic for applications
6	-	There was no sixth version
7	1995	32-bit first version, rebranded as Excel 95
8	1997	New visual basic for applications, user forms and data validation interface namely as Excel 97
9	1999	Known as Excel 2000
10	2001	A lot of new features namely as Excel 2002
11	2003	Namely as Excel 2003
12	2007	A lot of improvements namely as Excel 2007
13	-	There was no thirteenth version
14	2010	Builds on Excel 2007 with not any major changes namely as Excel 2010

Source: Pearson (2011)

2.5 EXISTING SOFTWARE OR CALCULATOR FOR FLUID PROPERTY TABLES AND MOODY CHART

There are a lot of software or calculator to obtain fluid property tables and Moody Chart in the market. However, majority of the software is commercial that require user to buy the software. Some of the software must be paid before download or utilize for trial version and use it for certain period. For the calculator, internet connection is required to use it because there is no requirement to download and install it into the computer. This software or calculator has their own advantages and disadvantages. There is the several existing software or calculator for fluid in property tables and Moody Chart:

i. Fluid Properties Calculator

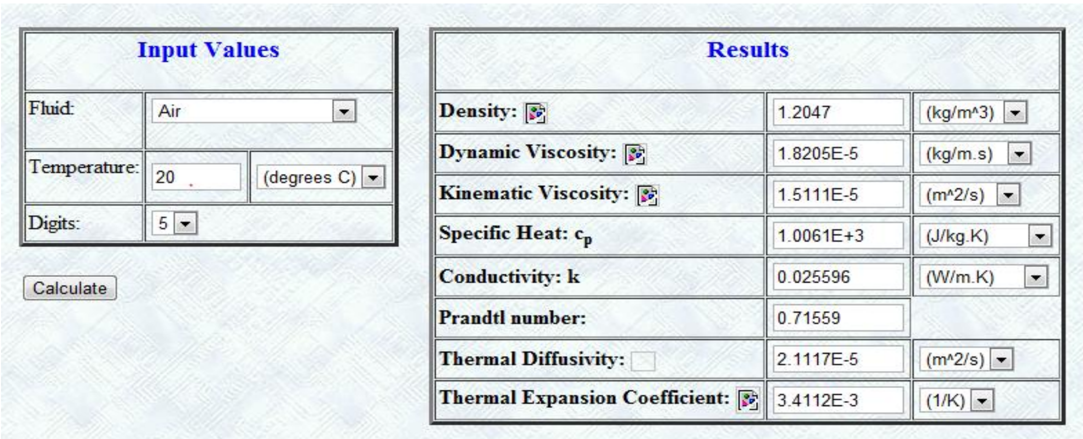


Figure 2.4: View of fluid properties calculator

Source: Yovanovich et al. (1998)

Figure 2.4 shows the fluid properties calculator was developed by Microelectronics Heat Transfer Laboratory. For properties of air, argon, nitrogen and hidrogen, it calculated based on correlations developed by F. McQuillan while for properties of carbon dioxide, water and the ethylene glycols it calculated based on the correlations developed by Tom Lemczyk. The temperature is use as the input and requires internet connection to use this calculator. The advantage of this calculator is it can be used either in International units or English units.

ii. Fluid Property Calculator

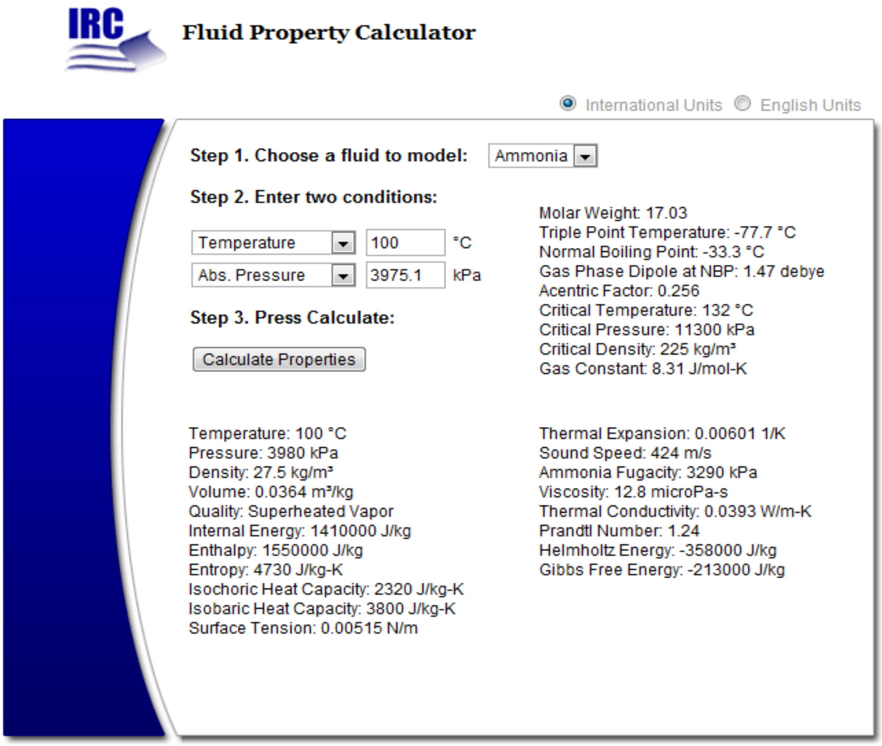


Figure 2.5: View of fluid property calculator

Source: Reindl et al. (2009)

Figure 2.5 shows the property fluid calculator that was developed by Industrial Refrigeration Consortium, IRC. Types of fluid available in this calculator are ammonia, carbon dioxide, R134a, R22, R404a, R410a, R507a, water. The range of temperature is between 195.5 K until 700 K as the input. The source of this calculator based on the most accurate pure fluid and mixture models. Internet connection is required and the user is able to choose either using International units or English units.

iii. Steam97 v4.0 Demo

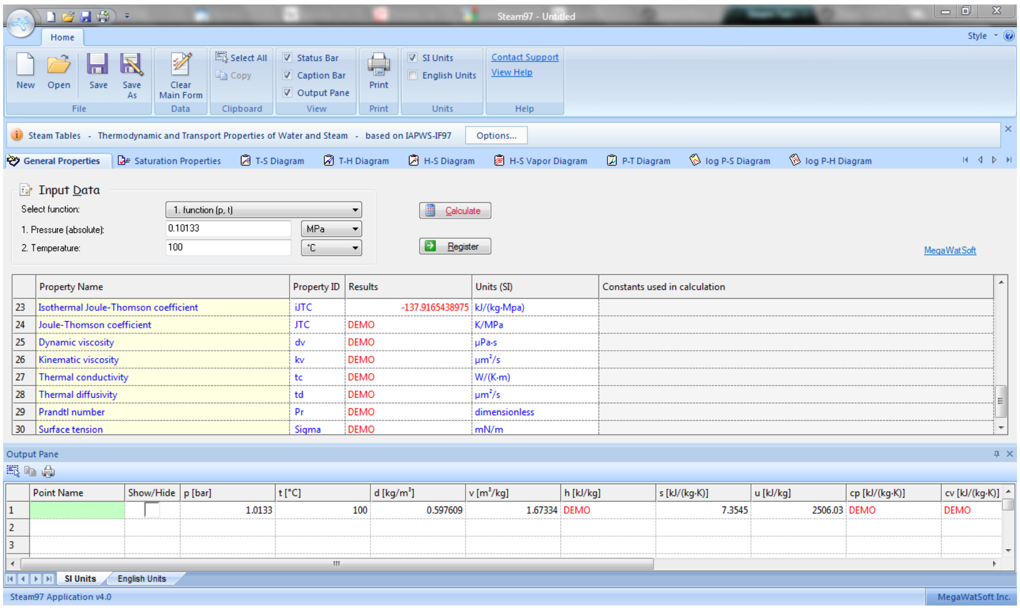


Figure 2.6: View of steam97 v4.0 demo software

Source: Steam97 v4.0 demo software

Figure 2.6 shows the steam97 v4.0 demo property table software was developed by Mega WatSoft Inc. IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam (IAPWS-IF97) is used as the source of calculated in this software. The advantage of this software is able to choose either using in International units or English units.

The disadvantage of this software is required the user to buy this software while for demo version, only certain results value appear. However, this software suitable for Thermodynamics properties although, some fluid properties such as density, dynamic viscosity and kinematic viscosity available in this software.

iv. StmProps (Steam Properties)

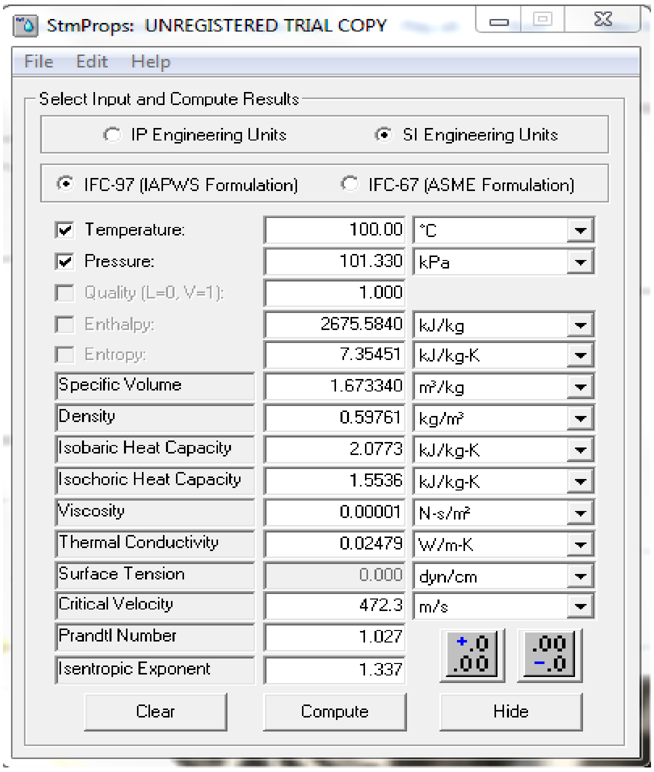


Figure 2.7: View of StmProps

Source: StmProps (Steam Properties) software

Figure 2.7 shows the StmProps property table software was developed by G&P Engineering Software for Windows based computer systems. The results calculation based on IFC-97 and IFC-67 formulations and the user is able to choose either using one of these formulations. The input parameters can be temperature, pressure, quality, enthalpy or entropy.

The advantage of this software is the ability to choose either using in International units (SI) or US Imperial (IP) units. However, this is a commercial software where only allow the user to use as trial version for 14 days. Besides that, this software is suitable for Thermodynamics properties although, only some fluid properties are available.

v. Moody Chart Calculator

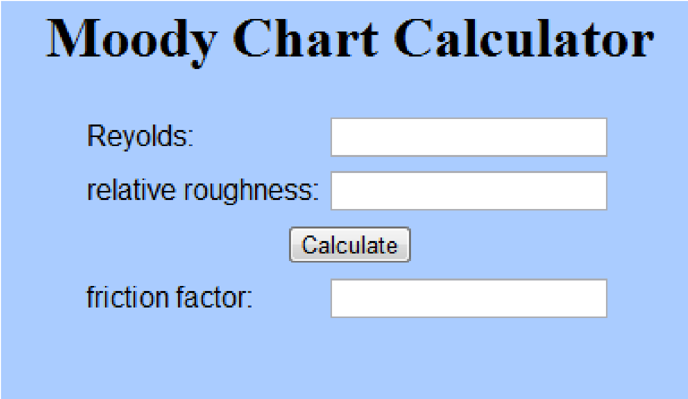


Figure 2.8: View of moody chart calculator

Source: Maley (undated)

Figure 2.8 shows the Moody Chart calculator was developed by Michael Maley's Engineering Site. The user is required to key in Reynolds number and relative roughness value to obtain friction factor. Friction factor calculation based on Colebrook equation and requires internet connection to use this calculator.

vi. Darcy Friction Factor Calculator

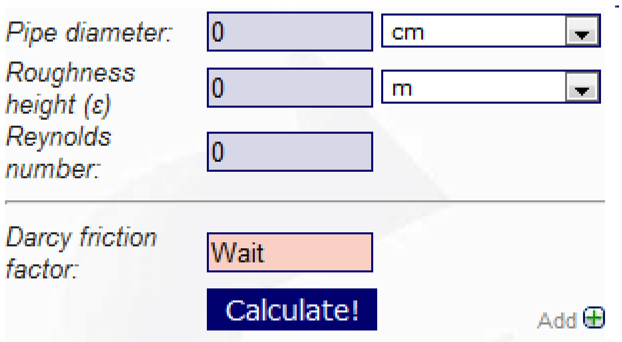


Figure 2.9: View of Darcy friction factor calculator

Source: Andy and Steve (2008)

Figure 2.9 shows the Darcy friction factor calculator was developed by CalcTool. The user is required to key in pipe diameter, roughness and Reynolds number value. Friction factor calculation based on Colebrook equation and requires internet connection to use this calculator. The advantage of this calculator is able to choose either using in International units or English units.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter discusses and explains about the method use and the flow progress of this project. Methodology is the most important element to be considered to make sure the smoothness of the project. Throughout this chapter, it explains how the formulas of Microsoft Excel work to obtain the properties from fluid property tables of saturated water, saturated refrigerant 134-a, saturated ammonia, saturated propane and air at 1 atm pressure. Besides that, this chapter explains how to obtain friction factor based on Colebrook equation.

3.2 FLOW CHART

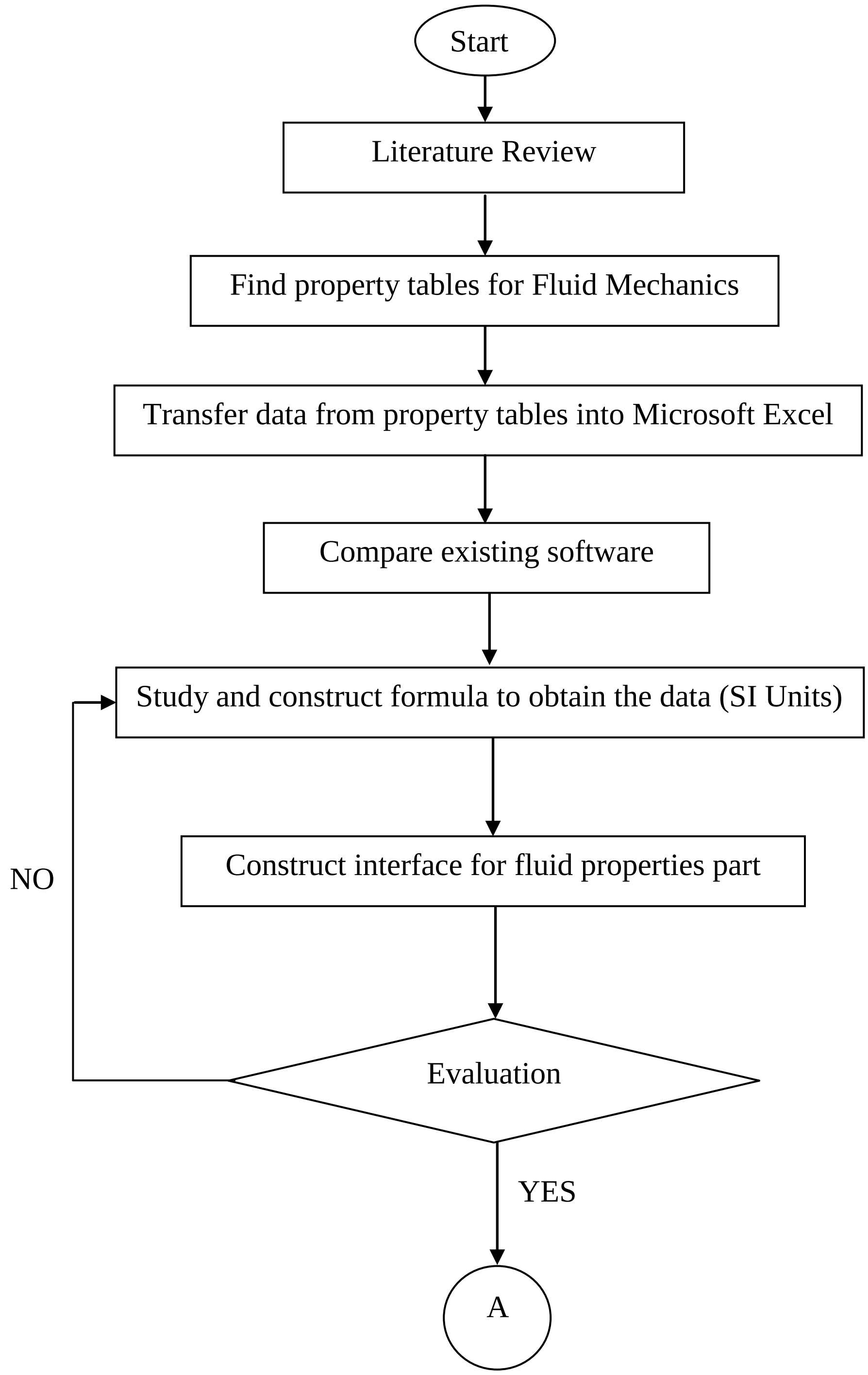


Figure 3.1: Process flow chart final year project 1

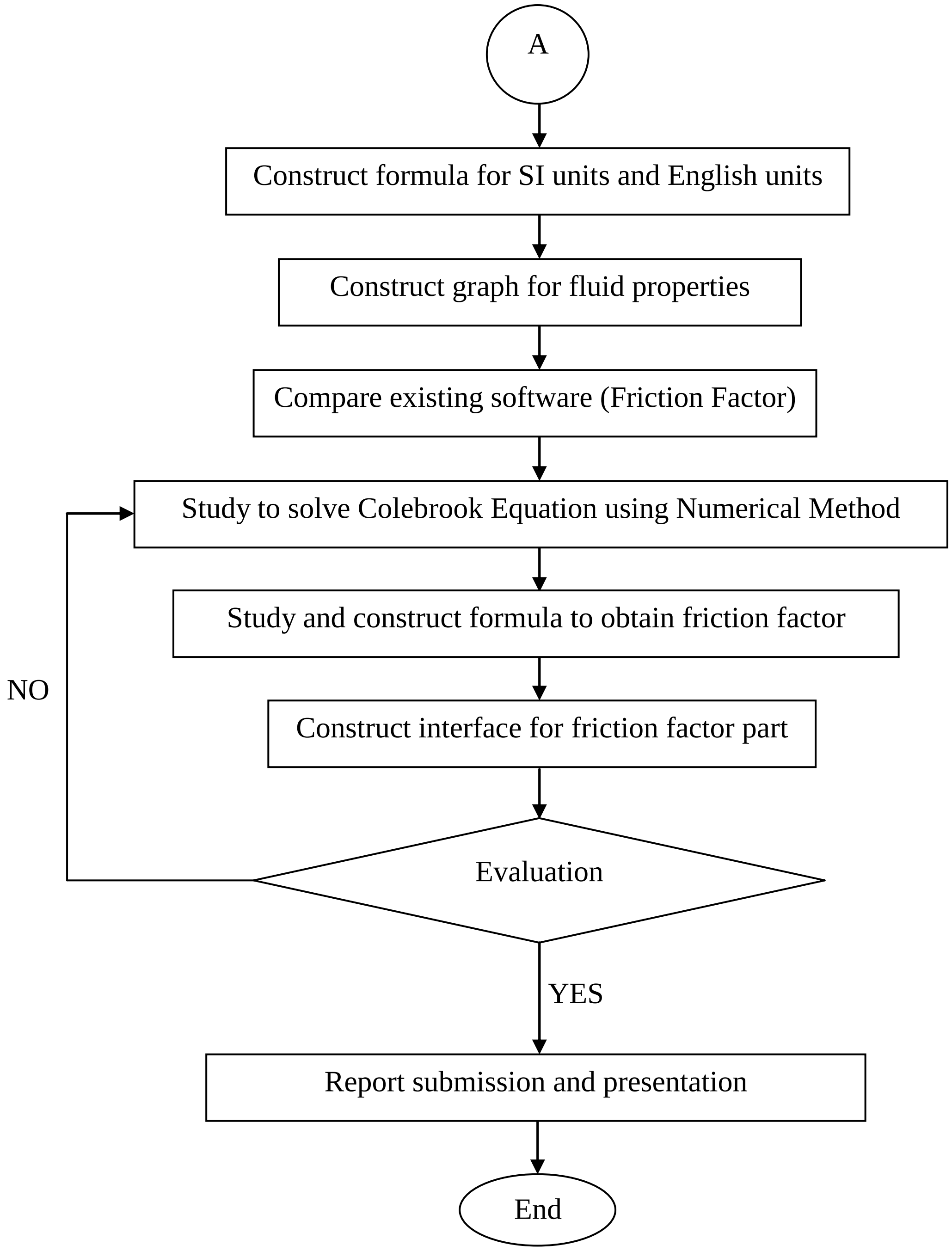


Figure 3.2: Process flow chart final year project 2

3.3 FORMULA CONSTRUCTION

3.3.1 Formula in Microsoft Excel

In Microsoft Excel, there are a lot of formulas that has their own function. This formulas can be combined together to construct a new function. In this project, several numbers of formulas is used to obtain data from property tables and obtain friction factor based on Colebrook equation. Table 3.1 shows the description of the formulas that use in this project.

Table 3.1: Formula in Microsoft Excel

Formula	Description
MATCH	Locate specified item in a range cells to tell that item from which row or column number.
INDEX	Returns value based on row and column number.
INDIRECT	Locate the specified item in a cell from a range of data.
IF	Returns true value if condition evaluates true and returns false value if condition evaluates to false.
AND	Returns true if all arguments evaluate to true and returns false if have arguments evaluate to false.
NA	Returns the error value that means no available value.
ISBLANK	To avoid function refer as zero value for blank cell.
DROP-DOWN LIST	To make easier to choose value from a list.

Source: Microsoft Excel 2007 software

3.4 HOW THE FORMULA WORK

In Microsoft Excel, formula should be constructed to obtain data from property tables for SI units and English units. There are some steps starting with the listed value in the table and followed by listed and unlisted value in the table for SI units only. Then, for value listed and unlisted for SI units and English units. After that, continue plot the graph for fluid properties and finally to obtain Darcy friction factor based on Colebrook equation.

3.4.1 Formula for Exact Value in Data Sheet for SI Units Only

This formula only obtains the value listed in the property tables for SI units only. If the temperature value inserted by user is unlisted in the property tables, the results shows #N/A mean not available which is shown in figure 3.4. For example, the formula for density (liquid) is:

=INDEX(INDIRECT(C5&"!B6:I45"),MATCH(B5,INDIRECT(C$5&"!B6:B45"),0),3)

For figure 3.3, the temperature equal to 5°C that is listed in property tables which translated into data sheet shown in figure 3.5, so the results appear for density, dynamic viscosity and kinematic viscosity. For figure 3.4, the temperature equal to 5.5°C that is unlisted in property tables and the results show #N/A that mean not available in the data sheet.

Temperature (T°C)	Type of Fluid	Density (ρ, kg/m^3)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (υ, m^2/s)	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
5	Water	999.9	0.0068	1.519E-03	9.340E-06	1.519E-06	1.374E-03

Figure 3.3: The result for listed value for temperature equal to 5°C and type of fluid is water

Temperature (T°C)	Type of Fluid	Density (ρ, kg/m^3)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (υ, m^2/s)	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
5.5	Water	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

Figure 3.4: The result for unlisted value for temperature equal to 5.5°C and type of fluid is water

Table 3.2 shows how the formula works to obtain properties for listed value while table 3.3 shows how the formula works for unlisted value. These tables show steps of formula evaluation which show how Microsoft Excel read the formula. This formula refers the data of water fluid properties shown in figure 3.5.

Table 3.2: Steps of formula evaluation for water at 5°C (liquid density)

Evaluate Formula	Description
Evaluation: INDEX(INDIRECT(C5&"!B6:I45"), Water	Cell C5 = Water, so the formula refers water worksheet between B6:I45. To be select by user
Evaluation: INDEX(Water!$B$6:$I$45,MATCH(B5,I 5	Cell B5 = 5, this is temperature value. User defined
Evaluation: INDEX(Water!$B$6:$I$45,MATCH(5,INDIRECT("Water!B6:B45") ,0),3)	T (°C) = 5, so INDIRECT function refer water worksheet between B6:B45
Evaluation: INDEX(Water!$B$6:$I$45,MATCH(5,Water!$B$6:$B$45,0),3)	MATCH function refer value for T (°C) = 5 and match at row number 2. Refer figure 3.5
Evaluation: INDEX(Water!$B$6:$I$45,2,3)	So, INDEX function refers row number 2 and column number 3. Column number 3 is set in the formula.
Evaluation: 999.9	So, the answer for ρ (liquid) = 999.9 kg/m^3 in row number 2 and column number 3. Refer figure 3.5

Table 3.3: Steps of formula evaluation for water at 5.5°C (liquid density)

Evaluate Formula	Description
Evaluation: INDEX(INDIRECT(C5&"!B6:I45"), *Water*	Cell C5 = Water, so the formula refers water worksheet between B6:I45. To be select by user
Evaluation: INDEX(Water!$B$6:$I$45,MATCH(B5, *5.5*	Cell B5 = 5.5, this is temperature value. User defined
Evaluation: INDEX(Water!$B$6:$I$45,MATCH(5.5,INDIRECT(*"Water!B6:B45"*),0),3)	T (°C) = 5.5, so INDIRECT function refer water worksheet between B6:B45
Evaluation: INDEX(Water!$B$6:$I$45,MATCH(5.5, *Water!$B$6:$B$45*,0),3)	MATCH function refer value for T (°C) = 5.5 and not match at any row. Refer figure 3.5
Evaluation: INDEX(Water!$B$6:$I$45, *#N/A*,3)	So, INDEX function for column is #N/A
Evaluation: *#N/A*	So, the answer for ρ (liquid) = #N/A (not available).

Temp. T, °C	Saturation Pressure Psat, kPa	Density ρ, kg/m³		Dynamic Viscosity μ, kg/m · s		Kinematic Viscosity υ, m²/s	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
0.01	0.6113	999.8	0.0048	1.792E-03	9.220E-06	1.792E-06	1.921E-03
5	0.8721	999.9	0.0068	1.519E-03	9.340E-06	1.519E-06	1.374E-03
10	1.2276	999.7	0.0094	1.307E-03	9.460E-06	1.307E-06	1.006E-03
15	1.7051	999.1	0.0128	1.138E-03	9.590E-06	1.139E-06	7.492E-04
20	2.339	998.0	0.0173	1.002E-03	9.730E-06	1.004E-06	5.624E-04
25	3.169	997.0	0.0231	8.910E-04	9.870E-06	8.937E-07	4.273E-04
30	4.246	996.0	0.0304	7.980E-04	1.001E-05	8.012E-07	3.293E-04
35	5.628	994.0	0.0397	7.200E-04	1.016E-05	7.243E-07	2.559E-04
40	7.384	992.1	0.0512	6.530E-04	1.031E-05	6.582E-07	2.014E-04
45	9.593	990.1	0.0655	5.960E-04	1.046E-05	6.020E-07	1.597E-04
50	12.35	988.1	0.0831	5.470E-04	1.062E-05	5.536E-07	1.278E-04
55	15.76	985.2	0.1045	5.040E-04	1.077E-05	5.116E-07	1.031E-04

Figure 3.5: Data of fluid properties for water

3.4.2 Formula to Obtain Properties for Listed and Unlisted Value for SI Units Only

In property table, not all values are listed. To find a value for unlisted temperature, interpolation is required to find the properties. Interpolation is a method to estimate the value between two known values. In this project, linear interpolation is adapted where the unlisted temperature is estimated to the straight line between two adjacent values.

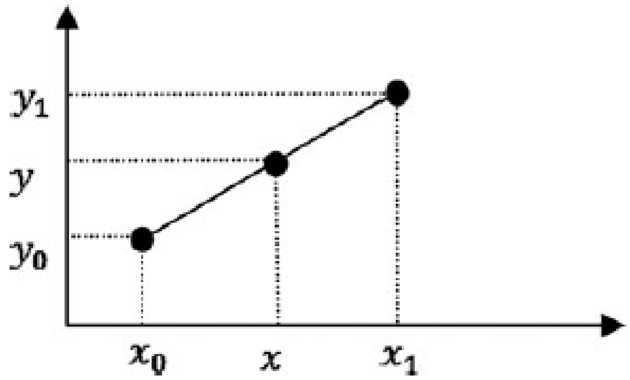


Figure 3.6: Linear interpolation graph

Source: Ahmad et al., (2011)

In linear interpolation, the gradient of unlisted temperature is considered equal for two adjacent temperatures. To make it simpler, table 3.4 constructed to describe the symbol of the following formula. From figure 3.6, point y0, x0, y1 and x1 is known values from the property table while point x and y is new value. The equation to known y value is:

$$\frac{y-y0}{x-x0} = \frac{y1-y0}{x1-x0} \tag{3.1}$$

$$(y-y0) = (x-x0)\frac{y1-y0}{x1-x0} \tag{3.2}$$

$$y = y0 + (x-x0)\frac{y1-y0}{x1-x0} \tag{3.3}$$

Table 3.4: Description of the symbol

Symbol	Description
y	The value either density, dynamic viscosity or kinematic viscosity
y0	Value either density, dynamic viscosity or kinematic viscosity that lower than y value
y1	Value either density, dynamic viscosity or kinematic viscosity that higher than y value
x	Temperature value (Define by user)
x0	Temperature value that slightly lower than x value listed in data sheet
x1	Temperature value that slightly higher than x value listed in data sheet

Equation 3.3 is required to construct the formula in Microsoft Excel to obtain the listed or unlisted value from property tables. For figure 3.7, it shows the result of unlisted value for temperature equal to 7.5°C and type of fluid is ammonia. For example, the formula for density (liquid) is:

```
=IF(D16="NO","Out of Range",INDEX(INDIRECT(D15&"!B6:I47"),MATCH(C15,INDIRECT(D15&"!B6:B47"),1),3)+(C15-INDEX(INDIRECT(D15&"!B6:I47"),MATCH(C15,INDIRECT(D15&"!B6:B47"),1),1))*(INDEX(INDIRECT(D15&"!B6:I47"),MATCH(C15,INDIRECT(D15&"!B6:B47"),1)+1,3)-INDEX(INDIRECT(D15&"!B6:I47"),MATCH(C15,INDIRECT(D15&"!B6:B47"),1),3))/(INDEX(INDIRECT(D15&"!B6:I47"),MATCH(C15,INDIRECT(D15&"!B6:B47"),1)+1,1)-INDEX(INDIRECT(D15&"!B6:I47"),MATCH(C15,INDIRECT(D15&"!B6:B47"),1),1)))
```

Table 3.5 shows description of symbol based on equation 3.3 and the excel formula. In this method, formula INDEX, INDIRECT, MATCH is used.

Table 3.5: Description of the formula

Actual Formula	Excel Formula
y0	INDEX(INDIRECT(D15&"!B6:I47"),MATCH(C15,INDIRECT(D15&"!B6:B47"),1),3)
x	C15
x0	INDEX(INDIRECT(D15&"!B6:I47"),MATCH(C15,INDIRECT(D15&"!B6:B47"),1),1)
y1	INDEX(INDIRECT(D15&"!B6:I47"),MATCH(C15,INDIRECT(D15&"!B6:B47"),1)+1,3)
y0	INDEX(INDIRECT(D15&"!B6:I47"),MATCH(C15,INDIRECT(D15&"!B6:B47"),1),3)
x1	INDEX(INDIRECT(D15&"!B6:I47"),MATCH(C15,INDIRECT(D15&"!B6:B47"),1)+1,1)
x0	INDEX(INDIRECT(D15&"!B6:I47"),MATCH(C15,INDIRECT(D15&"!B6:B47"),1),1)

When temperature equal to 7.5°C and type of fluid is ammonia:

y = y0 + (x-x0) x (y1-y0) / (x1-x0)

y = 631.7 + (7.5-5) x ((624.6-631.7) / (10-5))

y = 628.15 kg/m^3

y for liquid density result

Temperature (T°C)	Type of Fluid	Density (ρ, kg/m^3)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (υ, m^2/s)	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
7.5	Ammonia	628.1500	4.4930	1.746E-04	9.689E-06	2.778E-07	2.170E-06

Figure 3.7: The result for unlisted value for temperature equal to 7.5°C and type of fluid is ammonia

Table 3.6 shows how the formula works for interpolation in excel. This table shows steps of formula evaluation which show how Microsoft Excel read the formula. This formula refers data of ammonia fluid properties shown in figure 3.8.

Table 3.6: Steps of formula evaluation for ammonia at 7.5°C (liquid density)

Evaluate Formula	Description
Evaluation: IF(FALSE,"Out of Range",INDEX(INDIRECT(D15 — *Ammonia*	Cell D15 = Ammonia, so the formula refers Ammonia worksheet between B6:I47. To be select by user
Evaluation: IF(FALSE,#N/A,INDEX(Ammonia!$B$6:$I$47,MATCH(C15, — *7.5*	Cell C15 = 7.5, this is temperature value and refer as x value. User defined
Evaluation: IF(FALSE,#N/A,*631.7*+	y0 = 631.7, this is density (liquid) value that lower and nearest y value. Refer figure 3.8
Evaluation: IF(FALSE,#N/A,631.7+(*7.5*-	x = 7.5, this is temperature value. Refer figure 3.7
Evaluation: IF(FALSE,#N/A,631.7+(7.5-*5*)	x0 = 5, this is temperature value that lower and nearest than x value. Refer figure 3.8
Evaluation: IF(FALSE,#N/A,631.7+2.5*(624.6-	y1 = 624.6, this is density (liquid) value that higher and nearest y value. Refer figure 3.8
Evaluation: IF(FALSE,#N/A,631.7+2.5*(624.6-*631.7*),	y0 = 631.7, this is density (liquid) value that lower and nearest y value. Refer figure 3.8
Evaluation: IF(FALSE,#N/A,631.7+-17.7500000000001/(*10*-	x1 = 10, this is temperature value that higher and nearest x value. Refer figure 3.8
Evaluation: IF(FALSE,#N/A,631.7+-17.7500000000001/(10-*5*))	x0 = 5, this is temperature value that lower and nearest x value. Refer figure 3.8

Table 3.6: Continued

Evaluate Formula	Description
Evaluation: 628.1500	So, the answer for ρ (liquid) = 628.15 kg/m^3

PROPERTIES OF SATURATED AMMONIA

SI unit

Temp. T, °C	Saturation Pressure P_{sat}, kPa	Density ρ, kg/m^3		Dynamic Viscosity μ, kg/m · s		Kinematic Viscosity υ, m^2/s	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
-40	71.66	690.2	0.6435	2.926E-04	7.957E-06	4.239E-07	1.237E-05
-30	119.4	677.8	1.037	2.630E-04	8.311E-06	3.880E-07	8.014E-06
-25	151.5	671.5	1.296	2.492E-04	8.490E-06	3.711E-07	6.551E-06
-20	190.1	665.1	1.603	2.361E-04	8.669E-06	3.550E-07	5.408E-06
-15	236.2	658.6	1.966	2.236E-04	8.851E-06	3.395E-07	4.502E-06
-10	290.8	652.1	2.391	2.117E-04	9.034E-06	3.246E-07	3.778E-06
-5	354.9	645.4	2.886	2.003E-04	9.218E-06	3.104E-07	3.194E-06
0	429.6	638.6	3.458	1.896E-04	9.405E-06	2.969E-07	2.720E-06
5	516	631.7	4.116	1.794E-04	9.593E-06	2.840E-07	2.331E-06
10	615.3	624.6	4.870	1.697E-04	9.784E-06	2.717E-07	2.009E-06
15	728.8	617.5	5.729	1.606E-04	9.978E-06	2.601E-07	1.742E-06
20	857.8	610.2	6.705	1.519E-04	1.017E-05	2.489E-07	1.517E-06
25	1003	602.8	7.809	1.438E-04	1.037E-05	2.386E-07	1.328E-06
30	1167	595.2	9.055	1.361E-04	1.057E-05	2.287E-07	1.167E-06
35	1351	587.4	10.46	1.288E-04	1.078E-05	2.193E-07	1.031E-06
40	1555	579.4	12.03	1.219E-04	1.099E-05	2.104E-07	9.135E-07
45	1782	571.3	13.8	1.155E-04	1.121E-05	2.022E-07	8.123E-07
50	2033	562.9	15.78	1.094E-04	1.143E-05	1.944E-07	7.243E-07
55	2310	554.2	18.00	1.037E-04	1.166E-05	1.871E-07	6.478E-07
60	2614	545.2	20.48	9.846E-05	1.189E-05	1.806E-07	5.806E-07
65	2948	536.0	23.26	9.347E-05	1.213E-05	1.744E-07	5.215E-07
70	3312	526.3	26.39	8.879E-05	1.238E-05	1.687E-07	4.691E-07
75	3709	516.2	29.90	8.440E-05	1.264E-05	1.635E-07	4.227E-07
80	4141	505.7	33.87	8.030E-05	1.292E-05	1.588E-07	3.815E-07
85	4609	494.5	38.36	7.646E-05	1.322E-05	1.546E-07	3.446E-07
90	5116	482.8	43.48	7.284E-05	1.354E-05	1.509E-07	3.114E-07
95	5665	470.2	49.35	6.946E-05	1.389E-05	1.477E-07	2.815E-07
100	6257	456.6	56.15	6.628E-05	1.429E-05	1.452E-07	2.545E-07

Figure 3.8: Data of ammonia fluid properties

3.4.3 Formula to Obtain Value for Listed and Unlisted Value for SI Units and English Units

The formula to obtain the value for SI units and English units in property tables was constructed based on formula for listed and unlisted value for SI units. Some change are conducted which is adding new function to the formula to obtain value from either table SI units or English units. In this section, user is free to choose which unit they would refer. Figure 3.9 shows the result for temperature equal to 7.5°C and type of fluid is ammonia for English units. For example, the formula for liquid density is:

```
=IF(C17="SI unit",IF(D18="NO","Out of
Range",INDEX(INDIRECT(E17&"!B9:I51"),MATCH(D17,INDIRECT(E17&"
!B9:B51"),1),3)+(D17-
INDEX(INDIRECT(E17&"!B9:I51"),MATCH(D17,INDIRECT(E17&"!B9:B5
1"),1),1))*(INDEX(INDIRECT(E17&"!B9:I51"),MATCH(D17,INDIRECT(E17
&"!B9:B51"),1)+1,3)-
INDEX(INDIRECT(E17&"!B9:I51"),MATCH(D17,INDIRECT(E17&"!B9:B5
1"),1),3))/(INDEX(INDIRECT(E17&"!B9:I51"),MATCH(D17,INDIRECT(E17
&"!B9:B51"),1)+1,1)-
INDEX(INDIRECT(E17&"!B9:I51"),MATCH(D17,INDIRECT(E17&"!B9:B5
1"),1),1))),IF(D19="NO","Out of
Range",INDEX(INDIRECT(E17&"!L9:S51"),MATCH(D17,INDIRECT(E17&"
!L9:L51"),1),3)+(D17-
INDEX(INDIRECT(E17&"!L9:S51"),MATCH(D17,INDIRECT(E17&"!L9:L5
1"),1),1))*(INDEX(INDIRECT(E17&"!L9:S51"),MATCH(D17,INDIRECT(E1
7&"!L9:L51"),1)+1,3)-
INDEX(INDIRECT(E17&"!L9:S51"),MATCH(D17,INDIRECT(E17&"!L9:L5
1"),1),3))/(INDEX(INDIRECT(E17&"!L9:S51"),MATCH(D17,INDIRECT(E17
&"!L9:L51"),1)+1,1)-
INDEX(INDIRECT(E17&"!L9:S51"),MATCH(D17,INDIRECT(E17&"!L9:L5
1"),1),1))))
```

For the above formula, the IF function was added to choose either SI units or English units. If choose SI units, it refer to value if true and if choose English units, it refer value if false in syntax IF shown below.

IF(logical_test, value_if_true, [value_if_false])

From syntax IF above, logical test refer to:

C17="SI unit"

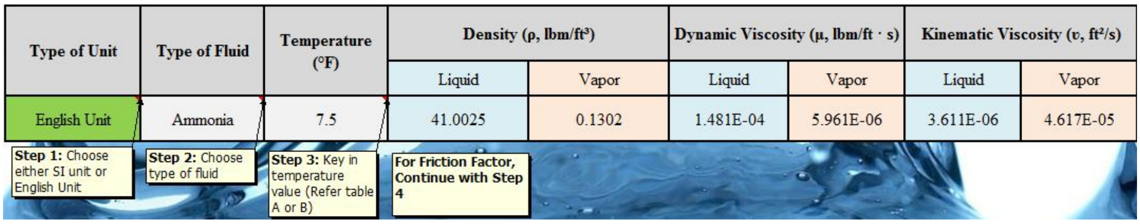
From syntax IF above, value if true refer to:

IF(D18="NO","Out of Range",INDEX(INDIRECT(E17&"!B9:I51"),MATCH(D17,INDIRECT(E17&"!B9:B51"),1),3)+(D17-INDEX(INDIRECT(E17&"!B9:I51"),MATCH(D17,INDIRECT(E17&"!B9:B51"),1),1))*(INDEX(INDIRECT(E17&"!B9:I51"),MATCH(D17,INDIRECT(E17&"!B9:B51"),1)+1,3)-INDEX(INDIRECT(E17&"!B9:I51"),MATCH(D17,INDIRECT(E17&"!B9:B51"),1),3))/(INDEX(INDIRECT(E17&"!B9:I51"),MATCH(D17,INDIRECT(E17&"!B9:B51"),1)+1,1)-INDEX(INDIRECT(E17&"!B9:I51"),MATCH(D17,INDIRECT(E17&"!B9:B51"),1),1)))

From syntax IF above, value if false refer to:

IF(D19="NO","Out of Range",INDEX(INDIRECT(E17&"!L9:S51"),MATCH(D17,INDIRECT(E17&"!L9:L51"),1),3)+(D17-INDEX(INDIRECT(E17&"!L9:S51"),MATCH(D17,INDIRECT(E17&"!L9:L51"),1),1))*(INDEX(INDIRECT(E17&"!L9:S51"),MATCH(D17,INDIRECT(E17&"!L9:L51"),1)+1,3)-INDEX(INDIRECT(E17&"!L9:S51"),MATCH(D17,INDIRECT(E17&"!L9:L5

1"),1),3))/(INDEX(INDIRECT(E17&"!L9:S51"),MATCH(D17,INDIRECT(E17&"!L9:L51"),1)+1,1)-INDEX(INDIRECT(E17&"!L9:S51"),MATCH(D17,INDIRECT(E17&"!L9:L51"),1),1))))



Type of Unit	Type of Fluid	Temperature (°F)	Density (ρ, lbm/ft³)		Dynamic Viscosity (μ, lbm/ft · s)		Kinematic Viscosity (υ, ft²/s)	
			Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
English Unit	Ammonia	7.5	41.0025	0.1302	1.481E-04	5.961E-06	3.611E-06	4.617E-05

Figure 3.9: Interpolation result for temperature equal to 7.5°C and type of fluid is ammonia

Table 3.7 shows how the formula works for SI units and English units based on data sheet shown in figure 3.10. This table shows steps of formula evaluation which show how Microsoft Excel read the formula. This formula refers data of ammonia fluid properties for English units shown in figure 3.11.

Table 3.7: Steps of formula evaluation for ammonia at 7.5°F (liquid density)

Evaluate Formula	Description
Evaluation: IF(C17="SI unit", English Unit	From syntax IF, IF(logical_test, value_if_true, [value_if_false]), for formula, cell C17 = SI unit, but cell C17 = English unit, it shows false for cell C17 = SI unit, so it refer English unit table. To be select by user
Evaluation: IF(FALSE,#N/A,IF(E17&"!L9:S51"),MA +(D17-INDEX(INDIF INDIRECT(E17&"!L9 L9:S51"),MATCH(D1 Ammonia	Cell E17 = Ammonia, so the formula refers Ammonia worksheet between L9:S51. To be select by user

Table 3.7: Continued

Evaluate Formula	Description
Evaluation: IF(FALSE,#N/A,IF(F ,MATCH(D17,INDIR (INDIRECT(E17&"!L :L51"),1),1))*(INDE (D17,INDIRECT(E1 7.5	Cell D17 = 7.5, this is temperature value and refer as x value. User defined
Evaluation: IF(FALSE,#N/A,IF(FALSE,#N/A,41.34+(D17-	y0 = 41.34, this is density (liquid) value that lower and nearest y value. Refer figure 3.11
Evaluation: IF(FALSE,#N/A,IF(FALSE,#N/A,41.34+(7.5-	x = 7.5, this is temperature value. Refer figure 3.11
Evaluation: IF(FALSE,#N/A,IF(FALSE,#N/A,41.34+(7.5-0)	x0 = 0, this is temperature value that lower and nearest than x value. Refer figure 3.11
Evaluation: IF(FALSE,#N/A,IF(FALSE,#N/A,41.34+7.5*(40.89-	y1 = 40.89, this is density (liquid) value that higher and nearest y value. Refer figure 3.11
Evaluation: IF(FALSE,#N/A,IF(FALSE,#N/A,41.34+7.5*(40.89-41.34)	y0 = 41.34, this is density (liquid) value that lower and nearest y value. Refer figure 3.11
Evaluation: IF(FALSE,#N/A,IF(FALSE,#N/A,41.34+-3.37500000000002/(10	x1 = 10, this is temperature value that higher and nearest x value. Refer figure 3.11
Evaluation: IF(FALSE,#N/A,IF(FALSE,#N/A,41.34+-3.37500000000002/(10 -0))	x0 = 0, this is temperature value that lower and nearest x value. Refer figure 3.11
Evaluation: 41.0025	So, the answer for ρ (liquid) = 41.0025 kg/m^3

SI unit

Temp. T, °C	Saturation Pressure P_{sat}, kPa	Density ρ, kg/m³		Dynamic Viscosity μ, kg/m · s		Kinematic Viscosity υ, m²/s	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
-40	71.66	690.2	0.6435	2.926E-04	7.957E-06	4.239E-07	1.237E-05
-30	119.4	677.8	1.037	2.630E-04	8.311E-06	3.880E-07	8.014E-06
-25	151.5	671.5	1.296	2.492E-04	8.490E-06	3.711E-07	6.551E-06
-20	190.1	665.1	1.603	2.361E-04	8.669E-06	3.550E-07	5.408E-06
-15	236.2	658.6	1.966	2.236E-04	8.851E-06	3.395E-07	4.502E-06
-10	290.8	652.1	2.391	2.117E-04	9.034E-06	3.246E-07	3.778E-06
-5	354.9	645.4	2.886	2.003E-04	9.218E-06	3.104E-07	3.194E-06
0	429.6	638.6	3.458	1.896E-04	9.405E-06	2.969E-07	2.720E-06
5	516	631.7	4.116	1.794E-04	9.593E-06	2.840E-07	2.331E-06
10	615.3	624.6	4.870	1.697E-04	9.784E-06	2.717E-07	2.009E-06
15	728.8	617.5	5.729	1.606E-04	9.978E-06	2.601E-07	1.742E-06
20	857.8	610.2	6.705	1.519E-04	1.017E-05	2.489E-07	1.517E-06
25	1003	602.8	7.809	1.438E-04	1.037E-05	2.386E-07	1.328E-06
30	1167	595.2	9.055	1.361E-04	1.057E-05	2.287E-07	1.167E-06
35	1351	587.4	10.46	1.288E-04	1.078E-05	2.193E-07	1.031E-06
40	1555	579.4	12.03	1.219E-04	1.099E-05	2.104E-07	9.135E-07
45	1782	571.3	13.8	1.155E-04	1.121E-05	2.022E-07	8.123E-07
50	2033	562.9	15.78	1.094E-04	1.143E-05	1.944E-07	7.243E-07
55	2310	554.2	18.00	1.037E-04	1.166E-05	1.871E-07	6.478E-07
60	2614	545.2	20.48	9.846E-05	1.189E-05	1.806E-07	5.806E-07
65	2948	536.0	23.26	9.347E-05	1.213E-05	1.744E-07	5.215E-07
70	3312	526.3	26.39	8.879E-05	1.238E-05	1.687E-07	4.691E-07
75	3709	516.2	29.90	8.440E-05	1.264E-05	1.635E-07	4.227E-07
80	4141	505.7	33.87	8.030E-05	1.292E-05	1.588E-07	3.815E-07
85	4609	494.5	38.36	7.646E-05	1.322E-05	1.546E-07	3.446E-07
90	5116	482.8	43.48	7.284E-05	1.354E-05	1.509E-07	3.114E-07
95	5665	470.2	49.35	6.946E-05	1.389E-05	1.477E-07	2.815E-07
100	6257	456.6	56.15	6.628E-05	1.429E-05	1.452E-07	2.545E-07

English unit

Temp. T, °F	Saturation Pressure P_{sat}, psia	Density ρ, lbm/ft³		Dynamic Viscosity μ, lbm/ft · s		Kinematic Viscosity υ, ft²/s	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
-40	10.4	43.08	0.0402	1.966E-04	5.342E-06	4.564E-06	1.329E-04
-30	13.9	42.66	0.0527	1.853E-04	5.472E-06	4.344E-06	1.038E-04
-20	18.3	42.33	0.0681	1.746E-04	5.600E-06	4.125E-06	8.223E-05
-10	23.7	41.79	0.0869	1.645E-04	5.731E-06	3.936E-06	6.595E-05
0	30.4	41.34	0.1097	1.549E-04	5.861E-06	3.747E-06	5.343E-05
10	38.5	40.89	0.1370	1.458E-04	5.994E-06	3.566E-06	4.375E-05
20	48.2	40.43	0.1694	1.371E-04	6.125E-06	3.391E-06	3.616E-05
30	59.8	39.96	0.2075	1.290E-04	6.256E-06	3.228E-06	3.015E-05
40	73.4	39.48	0.2521	1.213E-04	6.389E-06	3.072E-06	2.534E-05
50	89.2	38.99	0.3040	1.140E-04	6.522E-06	2.924E-06	2.145E-05
60	107.7	38.50	0.3641	1.072E-04	6.656E-06	2.784E-06	1.828E-05
70	128.9	37.99	0.4332	1.008E-04	6.786E-06	2.653E-06	1.566E-05
80	153.2	37.47	0.5124	9.486E-05	6.922E-06	2.532E-06	1.351E-05
90	180.8	36.94	0.6029	8.922E-05	7.056E-06	2.415E-06	1.170E-05
100	212.0	36.40	0.7060	8.397E-05	7.189E-06	2.307E-06	1.018E-05
110	247.2	35.83	0.8233	7.903E-05	7.325E-06	2.206E-06	8.897E-06
120	286.5	35.26	0.9564	7.444E-05	7.458E-06	2.111E-06	7.798E-06
130	330.4	34.66	1.1074	7.017E-05	7.594E-06	2.025E-06	6.858E-06
140	379.4	34.04	1.2786	6.617E-05	7.731E-06	1.944E-06	6.046E-06
150	433.2	33.39	1.4730	6.244E-05	7.867E-06	1.870E-06	5.341E-06
160	492.7	32.72	1.6940	5.900E-05	8.006E-06	1.803E-06	4.726E-06
170	558.2	32.01	1.9460	5.578E-05	8.142E-06	1.743E-06	4.184E-06
180	630.1	31.26	2.2346	5.278E-05	8.281E-06	1.688E-06	3.706E-06
190	708.5	30.47	2.5670	5.000E-05	8.419E-06	1.641E-06	3.280E-06
200	794.4	29.62	2.9527	4.742E-05	8.561E-06	1.601E-06	2.899E-06
210	887.9	28.70	3.4053	4.500E-05	8.703E-06	1.568E-06	2.556E-06
220	989.5	27.69	3.9440	4.275E-05	8.844E-06	1.544E-06	2.242E-06
230	1099.0	25.57	4.5987	4.064E-05	8.989E-06	1.589E-06	1.955E-06
240	1219.4	25.28	5.4197	3.864E-05	9.136E-06	1.528E-06	1.686E-06

Figure 3.10: Data of ammonia fluid properties for SI units and English units

English unit

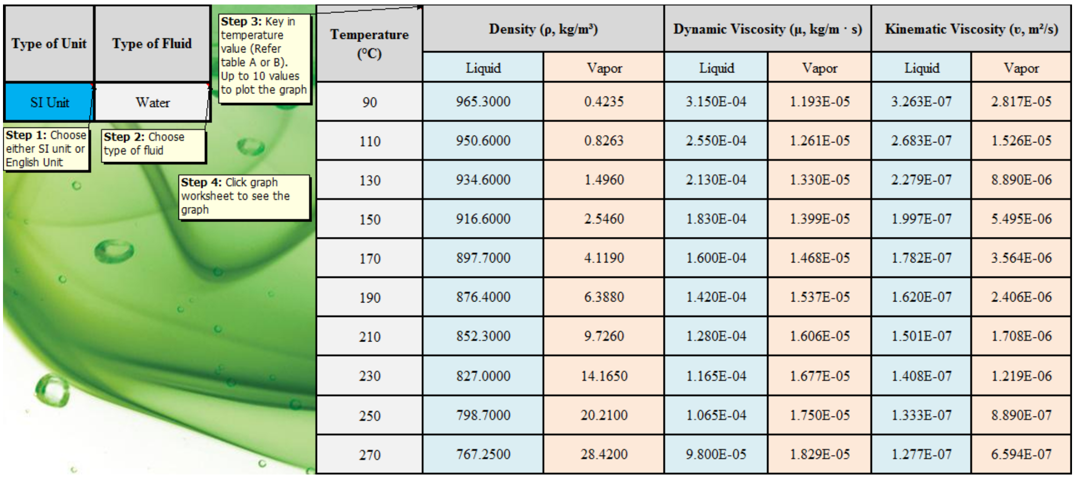
Temp. T, °F	Saturation Pressure P_{sat}, psia	Density ρ, lbm/ft³		Dynamic Viscosity μ, lbm/ft · s		Kinematic Viscosity υ, ft²/s	
		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
-40	10.4	43.08	0.0402	1.966E-04	5.342E-06	4.564E-06	1.329E-04
-30	13.9	42.66	0.0527	1.853E-04	5.472E-06	4.344E-06	1.038E-04
-20	18.3	42.33	0.0681	1.746E-04	5.600E-06	4.125E-06	8.223E-05
-10	23.7	41.79	0.0869	1.645E-04	5.731E-06	3.936E-06	6.595E-05
0	30.4	41.34	0.1097	1.549E-04	5.861E-06	3.747E-06	5.343E-05
10	38.5	40.89	0.1370	1.458E-04	5.994E-06	3.566E-06	4.375E-05
20	48.2	40.43	0.1694	1.371E-04	6.125E-06	3.391E-06	3.616E-05
30	59.8	39.96	0.2075	1.290E-04	6.256E-06	3.228E-06	3.015E-05
40	73.4	39.48	0.2521	1.213E-04	6.389E-06	3.072E-06	2.534E-05
50	89.2	38.99	0.3040	1.140E-04	6.522E-06	2.924E-06	2.145E-05
60	107.7	38.50	0.3641	1.072E-04	6.656E-06	2.784E-06	1.828E-05
70	128.9	37.99	0.4332	1.008E-04	6.786E-06	2.653E-06	1.566E-05
80	153.2	37.47	0.5124	9.486E-05	6.922E-06	2.532E-06	1.351E-05
90	180.8	36.94	0.6029	8.922E-05	7.056E-06	2.415E-06	1.170E-05
100	212.0	36.40	0.7060	8.397E-05	7.189E-06	2.307E-06	1.018E-05
110	247.2	35.83	0.8233	7.903E-05	7.325E-06	2.206E-06	8.897E-06
120	286.5	35.26	0.9564	7.444E-05	7.458E-06	2.111E-06	7.798E-06
130	330.4	34.66	1.1074	7.017E-05	7.594E-06	2.025E-06	6.858E-06
140	379.4	34.04	1.2786	6.617E-05	7.731E-06	1.944E-06	6.046E-06
150	433.2	33.39	1.4730	6.244E-05	7.867E-06	1.870E-06	5.341E-06
160	492.7	32.72	1.6940	5.900E-05	8.006E-06	1.803E-06	4.726E-06
170	558.2	32.01	1.9460	5.578E-05	8.142E-06	1.743E-06	4.184E-06
180	630.1	31.26	2.2346	5.278E-05	8.281E-06	1.688E-06	3.706E-06
190	708.5	30.47	2.5670	5.000E-05	8.419E-06	1.641E-06	3.280E-06
200	794.4	29.62	2.9527	4.742E-05	8.561E-06	1.601E-06	2.899E-06
210	887.9	28.70	3.4053	4.500E-05	8.703E-06	1.568E-06	2.556E-06
220	989.5	27.69	3.9440	4.275E-05	8.844E-06	1.544E-06	2.242E-06
230	1099.0	25.57	4.5987	4.064E-05	8.989E-06	1.589E-06	1.955E-06
240	1219.4	25.28	5.4197	3.864E-05	9.136E-06	1.528E-06	1.686E-06

Figure 3.11: Data of ammonia fluid properties for English units

3.4.4 Graph for Fluid Properties Result

The formula fluid properties results to plot the graph were constructed based on formula for fluid properties. Some change are conducted which is replaced word "Out of Range" to new NA function. This function to prevent the graph plots the blank cell or result out of range where in the range of selected data of graph. In this section, user is free to choose the number of fluid properties results until ten maximum results. For example, the formula for liquid density is:

```
=IF($B$17="SI unit",IF(F18="NO",NA(),INDEX(INDIRECT($C$17&"!B9:I51"),MATCH(F17,INDIRECT($C$17&"!B9:B51"),1),3)+(F17-INDEX(INDIRECT($C$17&"!B9:I51"),MATCH(F17,INDIRECT($C$17&"!B9:B51"),1),1))*(INDEX(INDIRECT($C$17&"!B9:I51"),MATCH(F17,INDIRECT($C$17&"!B9:B51"),1)+1,3)-INDEX(INDIRECT($C$17&"!B9:I51"),MATCH(F17,INDIRECT($C$17&"!B9:B51"),1),3))/(INDEX(INDIRECT($C$17&"!B9:I51"),MATCH(F17,INDIRECT($C$17&"!B9:B51"),1)+1,1)-INDEX(INDIRECT($C$17&"!B9:I51"),MATCH(F17,INDIRECT($C$17&"!B9:B51"),1),1))),IF(F19="NO",NA(),INDEX(INDIRECT($C$17&"!L9:S51"),MATCH(F17,INDIRECT($C$17&"!L9:L51"),1),3)+(F17-INDEX(INDIRECT($C$17&"!L9:S51"),MATCH(F17,INDIRECT($C$17&"!L9:L51"),1),1))*(INDEX(INDIRECT($C$17&"!L9:S51"),MATCH(F17,INDIRECT($C$17&"!L9:L51"),1)+1,3)-INDEX(INDIRECT($C$17&"!L9:S51"),MATCH(F17,INDIRECT($C$17&"!L9:L51"),1),3))/(INDEX(INDIRECT($C$17&"!L9:S51"),MATCH(F17,INDIRECT($C$17&"!L9:L51"),1)+1,1)-INDEX(INDIRECT($C$17&"!L9:S51"),MATCH(F17,INDIRECT($C$17&"!L9:L51"),1),1))))
```



Temperature (°C)	Density (ρ, kg/m³)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (υ, m²/s)	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
90	965.3000	0.4235	3.150E-04	1.193E-05	3.263E-07	2.817E-05
110	950.6000	0.8263	2.550E-04	1.261E-05	2.683E-07	1.526E-05
130	934.6000	1.4960	2.130E-04	1.330E-05	2.279E-07	8.890E-06
150	916.6000	2.5460	1.830E-04	1.399E-05	1.997E-07	5.495E-06
170	897.7000	4.1190	1.600E-04	1.468E-05	1.782E-07	3.564E-06
190	876.4000	6.3880	1.420E-04	1.537E-05	1.620E-07	2.406E-06
210	852.3000	9.7260	1.280E-04	1.606E-05	1.501E-07	1.708E-06
230	827.0000	14.1650	1.165E-04	1.677E-05	1.408E-07	1.219E-06
250	798.7000	20.2100	1.065E-04	1.750E-05	1.333E-07	8.890E-07
270	767.2500	28.4200	9.800E-05	1.829E-05	1.277E-07	6.594E-07

Figure 3.12: Result for fluid properties

For figure 3.12, it shows the result for temperature equal to 90°C, 110°C, 130°C, 150°C, 170°C, 190°C, 210°C, 230°C, 250°C, 270°C and type of fluid water for SI units. Based on these results, the graph was plotted by using of x y scatter with straight line and marks type. There are three graphs which are density versus temperature, dynamic viscosity versus temperature and kinematic viscosity versus temperature. For example, figure 3.13 shows the graphs density versus temperature.

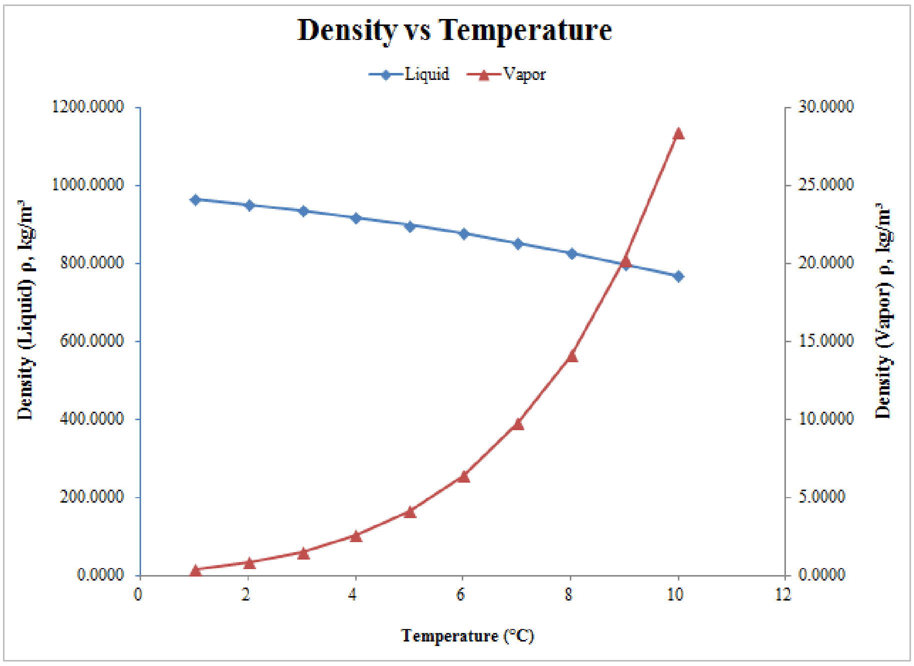


Figure 3.13: Graph density versus temperature

3.4.5 Formula to Obtain Darcy Friction Factor

This part obtain Darcy friction factor based on Colebrook equation where bisection method was used as the method to solve this equation. There are two methods where method 1 by key in roughness, diameter and Reynolds number value while method 2 by key in temperature, roughness, diameter and velocity value.

Based on the Moody Chart, Darcy friction factor is between 0.008 until 0.1 where this value used in bisection method as lower and higher value. One worksheet in Microsoft Excel was used to calculate Darcy friction factor by using bisection method shown in figure 3.14.

BISECTION METHOD TO FIND DARCY FRICTION FACTOR

Iteration	xl	xr	xu	f(xl)	f(xr)	f(xu)	f(xl).f(xr)	Sign	ε_a	Answer
1	0.0080000000	0.0540000000	0.1000000000	-6.87276	0.59240	1.88555	-4.07144	-	-	-
2	0.0080000000	0.0310000000	0.0540000000	-6.87276	-0.93774	0.59240	6.44485	+	74.1935483871	NO
3	0.0310000000	0.0425000000	0.0540000000	-0.93774	-0.01948	0.59240	0.01827	+	27.0588235294	NO
4	0.0425000000	0.0482500000	0.0540000000	-0.01948	0.31325	0.59240	-0.00610	-	11.9170984456	NO
5	0.0425000000	0.0453750000	0.0482500000	-0.01948	0.15462	0.31325	-0.00301	-	6.3360881543	NO
6	0.0425000000	0.0439375000	0.0453750000	-0.01948	0.06966	0.15462	-0.00136	-	3.2716927454	NO
7	0.0425000000	0.0432187500	0.0439375000	-0.01948	0.02564	0.06966	-0.00050	-	1.6630513377	NO
8	0.0425000000	0.0428593750	0.0432187500	-0.01948	0.00322	0.02564	-0.00006	-	0.8384979949	NO
9	0.0425000000	0.0426796875	0.0428593750	-0.01948	-0.00810	0.00322	0.00016	+	0.4210140948	NO
10	0.0426796875	0.0427695313	0.0428593750	-0.00810	-0.00243	0.00322	0.00002	+	0.2100648461	NO
11	0.0427695313	0.0428144531	0.0428593750	-0.00243	0.00039	0.00322	0.00000	-	0.1049222207	NO
12	0.0427695313	0.0427919922	0.0428144531	-0.00243	-0.00102	0.00039	0.00000	+	0.0524886465	NO
13	0.0427919922	0.0428032227	0.0428144531	-0.00102	-0.00031	0.00039	0.00000	+	0.0262374374	NO
14	0.0428032227	0.0428088379	0.0428144531	-0.00031	0.00004	0.00039	0.00000	-	0.0131169979	NO
15	0.0428032227	0.0428060303	0.0428088379	-0.00031	-0.00013	0.00004	0.00000	+	0.0065589291	NO
16	0.0428060303	0.0428074341	0.0428088379	-0.00013	-0.00005	0.00004	0.00000	+	0.0032793570	NO
17	0.0428074341	0.0428081360	0.0428088379	-0.00005	0.00000	0.00004	0.00000	+	0.0016396516	NO
18	0.0428081360	0.0428084869	0.0428088379	0.00000	0.00002	0.00004	0.00000	-	0.0008198191	YES
19	0.0428081360	0.0428083115	0.0428084869	0.00000	0.00001	0.00002	0.00000	-	0.0004099112	YES
20	0.0428081360	0.0428082237	0.0428083115	0.00000	0.00000	0.00001	0.00000	-	0.0002049560	YES
21	0.0428081360	0.0428081799	0.0428082237	0.00000	0.00000	0.00000	0.00000	-	0.0001024781	YES
22	0.0428081360	0.0428081579	0.0428081799	0.00000	0.00000	0.00000	0.00000	+	0.0000512391	YES
23	0.0428081579	0.0428081689	0.0428081799	0.00000	0.00000	0.00000	0.00000	+	0.0000256195	YES
24	0.0428081689	0.0428081744	0.0428081799	0.00000	0.00000	0.00000	0.00000	-	0.0000128098	YES
25	0.0428081689	0.0428081716	0.0428081744	0.00000	0.00000	0.00000	0.00000	+	0.0000064049	YES

Figure 3.14: Bisection method to find Darcy friction factor

For figure 3.15, it shows the result for method 1 where roughness equal to 0.00026 m, diameter equal to 0.05 m and Reynolds number equal to 5000. The formula to obtain Darcy friction factor from friction factor worksheet is:

=IF(I30="Not Available","Not Available",INDEX('Friction Factor'!B5:L104,MATCH("YES",'Friction Factor'!L5:L104,0),2))

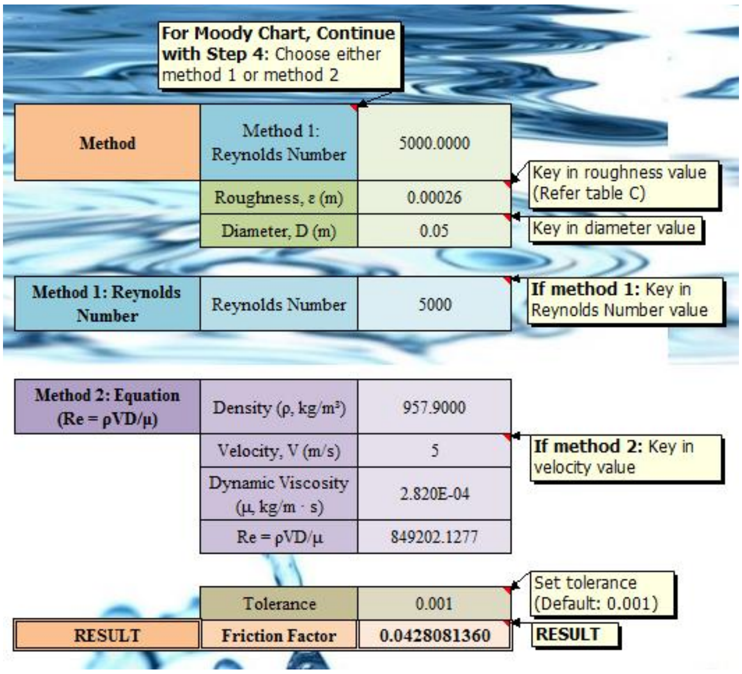


Figure 3.15: Result for Darcy friction factor by using method 1

Table 3.8 shows how the formula works to obtain Darcy friction factor from friction factor worksheet. This table shows steps of formula evaluation which show how Microsoft Excel read the formula.

Table 3.8: Steps of formula evaluation to obtain Darcy friction factor from friction factor worksheet

Evaluate Formula	Description

Evaluation:
IF(I30="Not Available","Not Available",INDEX('Friction Factor'!.
IF(H30=" Method 1: Reynolds Number",I34,I39)
Method 1: Reynolds Number
	Cell H30 = Method 1: Reynolds Number, so the formula refers to method 1. To be select by user

Evaluation: IF(*FALSE*,"Not Available",INDEX('Friction Factor'!B5:L104, MATCH("YES",'Friction Factor'!L5:L104,0),2))	MATCH function find “YES” between L5:L104 in the friction factor worksheet for the answer

Table 3.8: Continued

Evaluate Formula	Description
Evaluation: IF(FALSE,#N/A,INDEX('Friction Factor'!$B$5:$L$104, 18,2))	"YES" find in the row 18, so INDEX function refer to column 2 between B5:L104
Evaluation: IF(FALSE,#N/A,'Friction Factor'!$C$22)	Cell $C$22 in the friction factor worksheet is the answer
Evaluation: 0.0428081360	So, the answer for Darcy friction factor = 0.0428081360

Figure 3.14 shows bisection method calculated by Microsoft Excel to find Darcy friction factor. For f(xl), f(xr) and f(xu), this calculation based on Colebrook Equation. Table 3.9 shows how the formula work to calculate Colebrook Equation for f(xl). This table shows steps of formula evaluation which show how Microsoft Excel read the formula.

Colebrook equation:

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right) \tag{3.4}$$

$$-\frac{1}{\sqrt{f}} - 2\log_{10}\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right) = 0 \tag{3.5}$$

Formula in Microsoft Excel based on Colebrook equation for f(xl):

```
=-(1/(SQRT(E5)))-
(2*LOG((((INTERFACE!$I$31/INTERFACE!$I$32)/3.7)+(2.51/(INTERFACE
!$I$30*SQRT(E5))))))
```

Table 3.9: Steps of formula evaluation to calculate Colebrook equation

Evaluate Formula	Description
Evaluation: -(1/(SQRT(C5)))-(2*LO(*0.0080000000*	Cell C5 = 0.008, this is xl
Evaluation: -11.1803398874989-(2*LOG((((INTERFACE!$I$31/ *0.00026*	I31 in the interface worksheet refer to roughness value equal to 0.00026
Evaluation: -11.1803398874989-(2*LOG((((0.00026/INTERFACE!$I$32)/ *0.05*	I32 in the interface worksheet refer to diameter value equal to 0.05
Evaluation: -11.1803398874989 INTERFACE!$I$30*S	I30 in the interface worksheet refer to Reynolds number value equal to 5000
Evaluation: -11.1803398874989-(2*LOG((0.0014054054054054+(2.51/(5000**0.0894427190999916*))))	Microsoft Excel calculate all this value
Evaluation: *-6.87276*	So, the answer for f(xl) = -6.87276

Table 3.10 shows how the formula works to find answer in the bisection method. This table shows steps of formula evaluation which show how Microsoft Excel read the formula. Formula for Microsoft Excel to find answer in the Bisection Method is:

=IF(K5<INTERFACE!$I$41,"YES","NO")

Table 3.10: Steps of formula evaluation to find answer in the bisection method

Evaluate Formula	Description
Evaluation: IF(K6<INTERFACE!$I$41,"YES","NO")	K6 refer to absolute approximate error, ε_a
Evaluation: IF(*74.1935483870968*<INTERFACE!$I$41,"YES","NO")	K6 = 74.1935483870968. For INTERFACE!$I$41 refer to tolerance where set by user
Evaluation: IF(74.1935483870968<*0.001*,"YES","NO")	From syntax IF, IF(logical_test, value_if_true, [value_if_false]), if 74.1935483870968 less than 0.001, the answer is YES because it is true, while if 74.1935483870968 not less than 0.001, the answer is NO because it is false
Evaluation: *NO*	So, the answer is NO because 74.1935483870968 not less than 0.001

3.5 INTERFACE EXCEL FILE

Interface is interaction between a user and a computer program. It is a display screen on computer when open that program file which the user can click, choose or type in the program. The design of interface will make the program easier and user friendly to use. In this excel file, the user are free to key in value and choose the type of data. This excel file consist of "INTERFACE", "INTERFACE(Graph)", "Graph", "Water", "Refrigerant134a", "Ammonia", "Propane", "Air" and "Friction Factor" worksheets.

3.5.1 Interface of Fluid Properties and Friction Factor

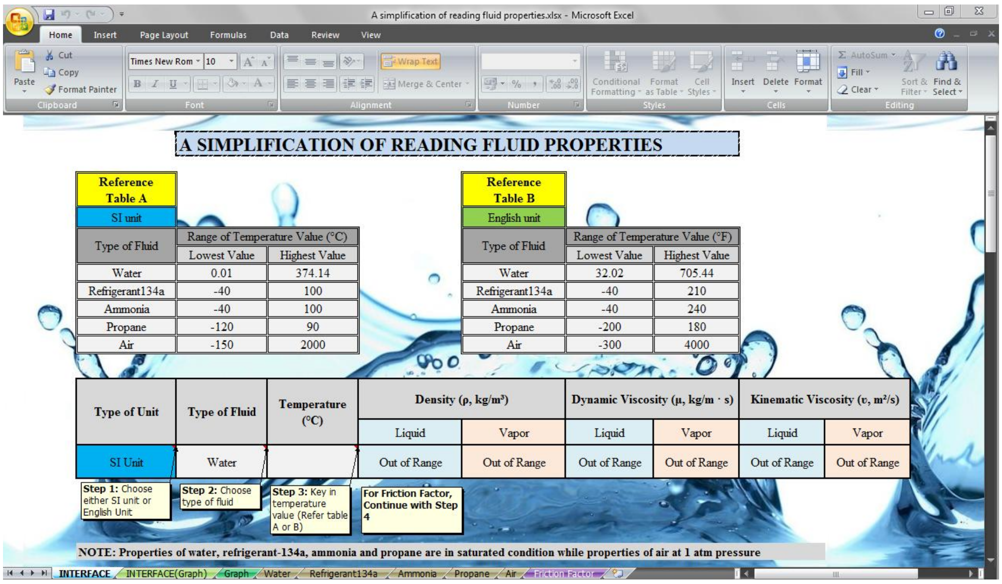


Figure 3.16: Default fluid properties part interface

Figure 3.16 show default fluid properties interface part to obtain density, dynamic viscosity and kinematic viscosity while table 3.11 show the description of interface where the user can key in the value, choose type of data and lastly seen the results. The results are obtain from data sheet in the worksheet "Water", "Refrigerant134a", "Ammonia", "Propane" and "Air" where the example data sheet of water shown in figure 3.17.

Table 3.11: Description of fluid properties part interface

Cell	Description
Type of Unit	Choose type of unit either SI units or English units. Select by user
Type of Fluid	Choose type of fluid either water, refrigerant-134a, ammonia, propane or air. Select by user
Temperature	Key in temperature value. Define by user
Density	Results

Table 3.11: Continued

Cell	Description
Dynamic Viscosity	Results
Kinematic Viscosity	Results

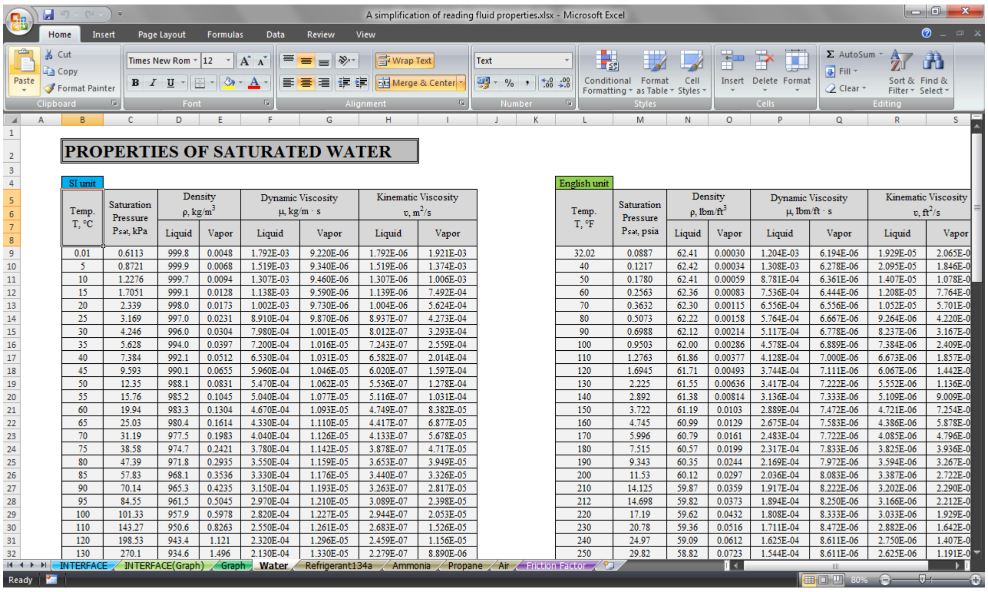


Figure 3.17: Data sheet of water interface

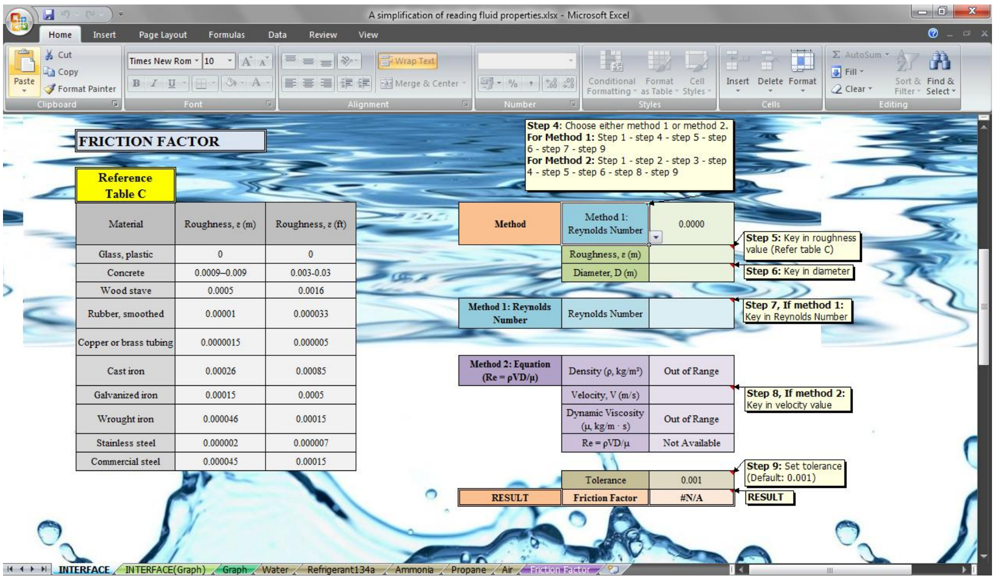


Figure 3.18: Default friction factor part interface

Figure 3.18 show default friction factor interface part to obtain Darcy friction factor where figure 3.16 and 3.18 are in the same "INTERFACE" worksheet. For table 3.12, it shows the description of interface friction factor part. The results are obtained from "Friction Factor" worksheet shown in figure 3.19.

Table 3.12: Description of friction factor part interface

Cell	**Description**
Type of Unit	Choose type of unit either SI units or English units. To be select by user
Method	Choose method 1 or method 2. To be select by user
Roughness	Key in roughness value. User defined
Diameter	Key in diameter value. User defined
Reynolds number	Key in Reynolds number value. User defined
Density	Value obtain from fluid properties interface
Velocity	Key in velocity value. User defined
Dynamic Viscosity	Value obtain from fluid properties interface
$Re = \rho VD/\mu$	Value obtain from Microsoft Excel calculation
Tolerance	Set tolerance. User defined
Friction Factor	Result

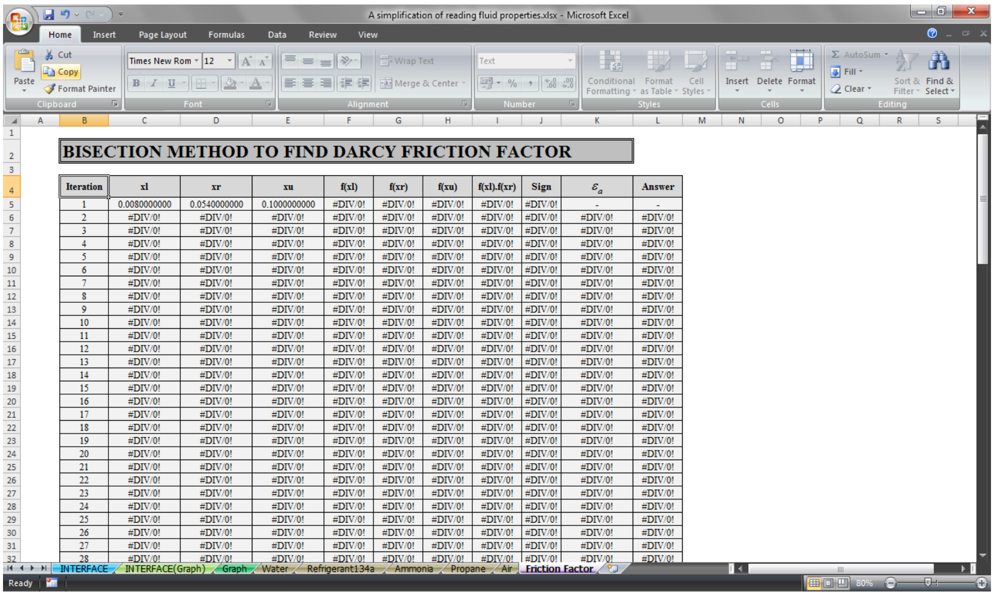


Figure 3.19: Friction factor interface

3.5.2 Interface of Fluid Properties for Graph

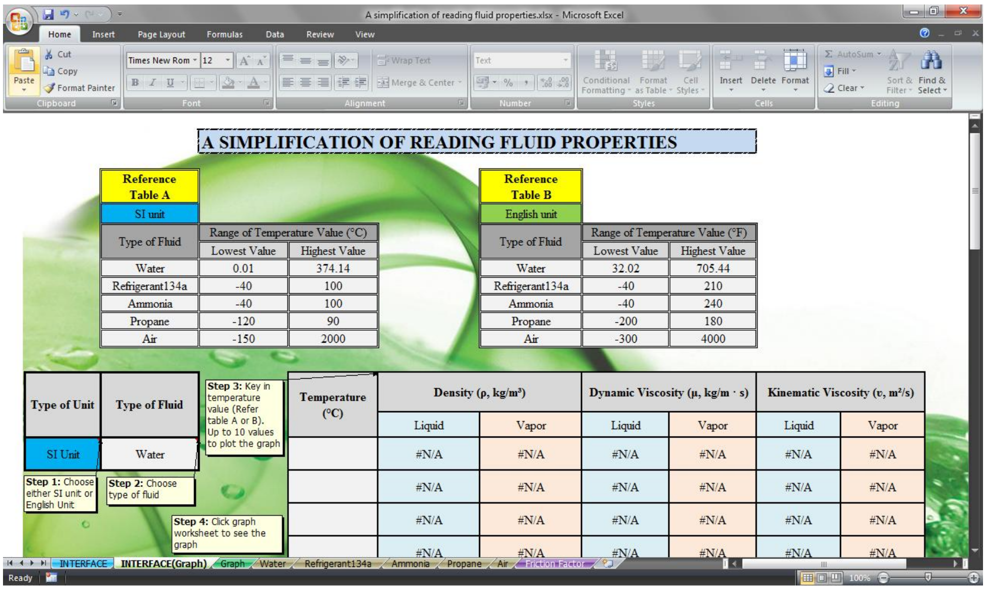


Figure 3.20: Default fluid properties interface for graph

Figure 3.20 shows default fluid properties for graph interface where it has ten cells for key in temperature value. The user is free to key in how much the number of temperature value until ten maximum values where the results used to plot the graph in the “Graph” worksheet. Table 3.13 shows description of fluid properties for graph interface.

Table 3.13: Description of fluid properties for graph interface

Cell	Description
Type of Unit	Choose type of unit either SI units or English units. To be select by user
Type of Fluid	Choose type of fluid either water, refrigerant-134a, ammonia, propane or air. To be select by user
Temperature	Key in temperature value. Define by user (maximum ten temperature value)
Density	Results
Dynamic Viscosity	Results
Kinematic Viscosity	Results

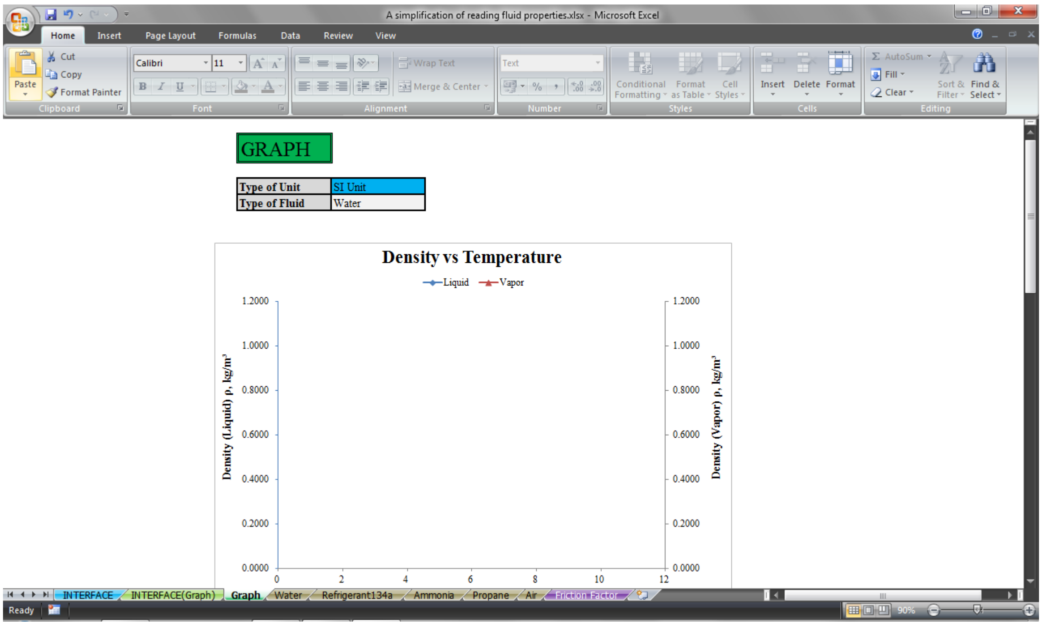


Figure 3.21: Graph interface

Figure 3.21 shows graph interface in the “Graph’ worksheet. On the top interface shows type of unit and type of fluid where this guide can help the user. There are three graphs in this worksheet where the first graph is density versus temperature, second graph is dynamic viscosity versus temperature and third graph is kinematic viscosity versus temperature.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 USER MANUAL

The user manual help the user how to use this excel file. By using this excel file, the user are simply to get value from property tables and obtain friction factor. This is the steps how to use this excel file:

i. Open the excel file and interface appear as shown in figure 4.1. This part to obtain fluid properties of density, dynamic viscosity and kinematic viscosity.

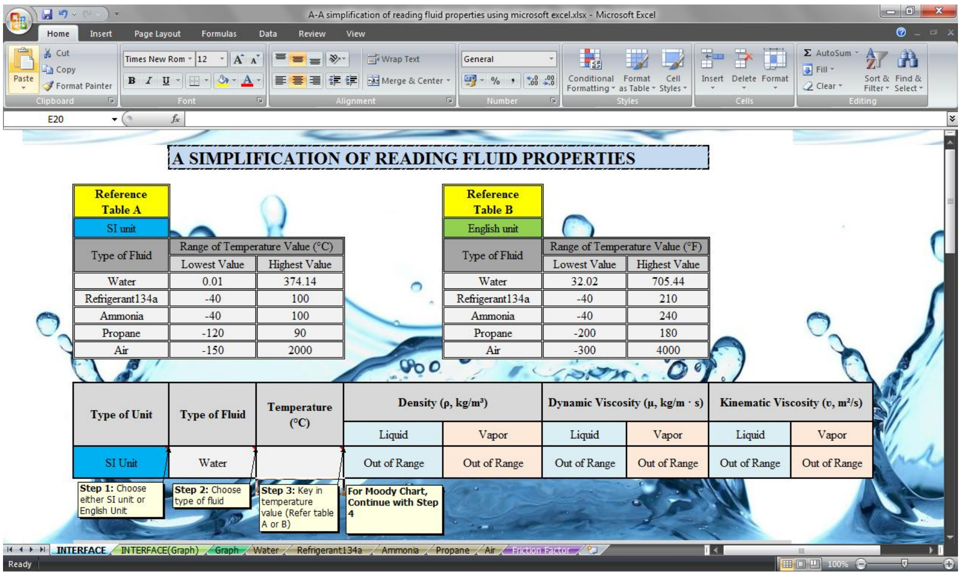


Figure 4.1: Interface for fluid properties

ii. Scroll down the excel file, interface for friction factor shown as figure 4.2.

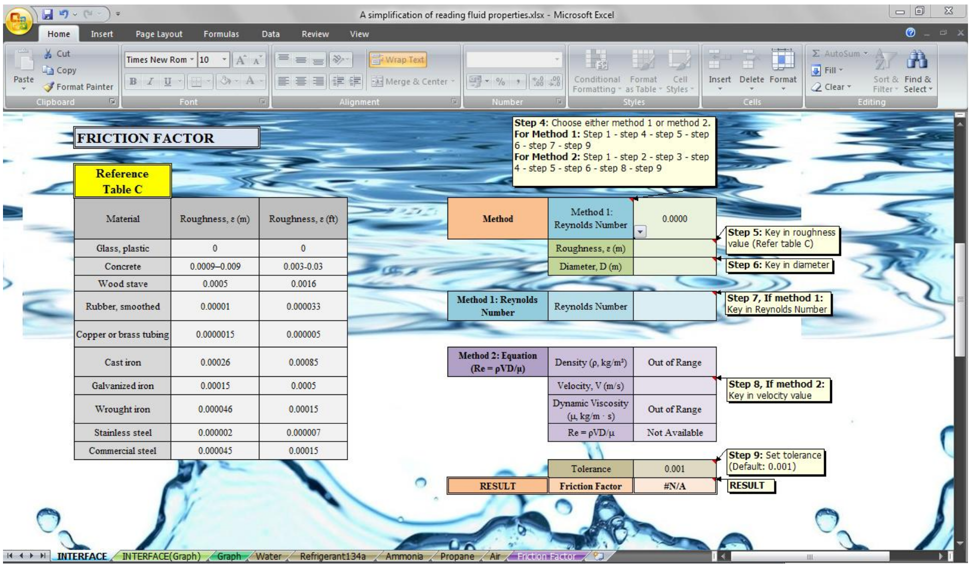


Figure 4.2: Interface for friction factor

iii. Click this cell to choose either SI units or English units.

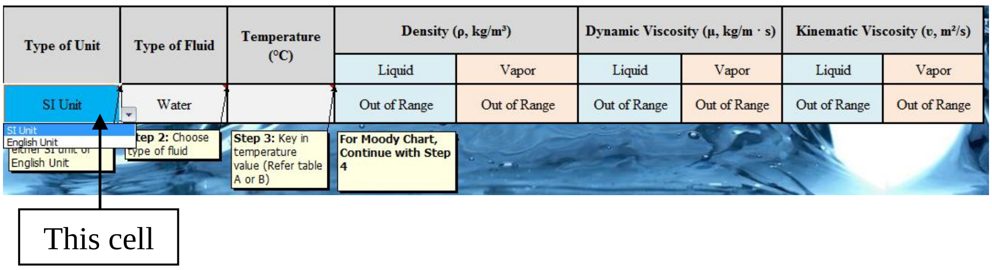


Figure 4.3: Choose type of unit

iv. Click this cell to choose the type of fluid either water, refrigerant-134a, ammonia, propane or air.

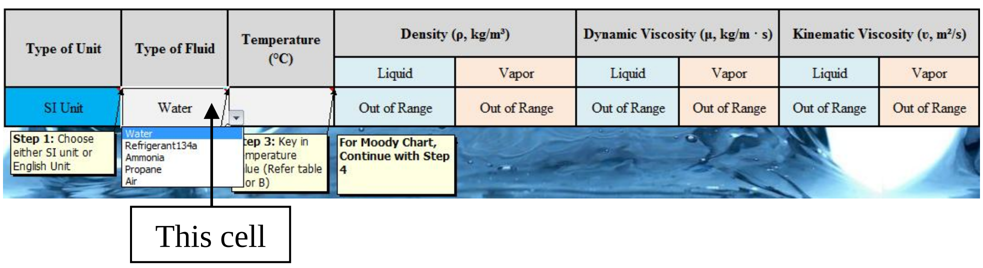


Figure 4.4: Choose type of fluid

v. Key in temperature value in this cell and press enter on keyboard. Refer table A or B for the range of temperature as shown in figure 4.6.

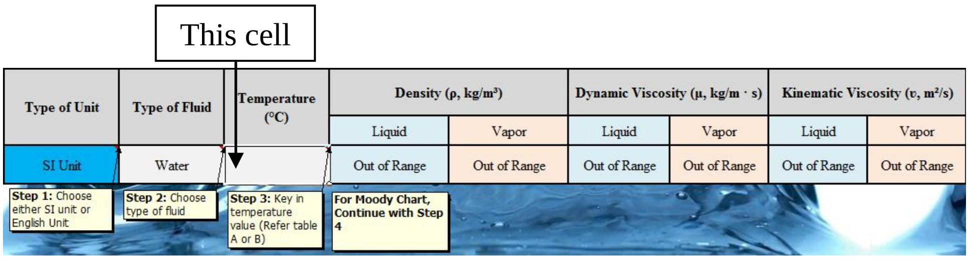
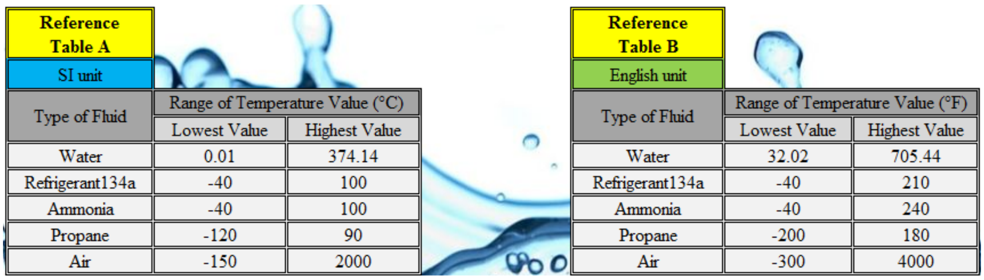


Figure 4.5: Key in temperature value



Reference Table A

SI unit

Type of Fluid	Range of Temperature Value (°C)	
	Lowest Value	Highest Value
Water	0.01	374.14
Refrigerant134a	-40	100
Ammonia	-40	100
Propane	-120	90
Air	-150	2000

Reference Table B

English unit

Type of Fluid	Range of Temperature Value (°F)	
	Lowest Value	Highest Value
Water	32.02	705.44
Refrigerant134a	-40	210
Ammonia	-40	240
Propane	-200	180
Air	-300	4000

Figure 4.6: Reference table A and B

vi. The results for density, dynamic viscosity and kinematic viscosity appear as shown in figure 4.7.

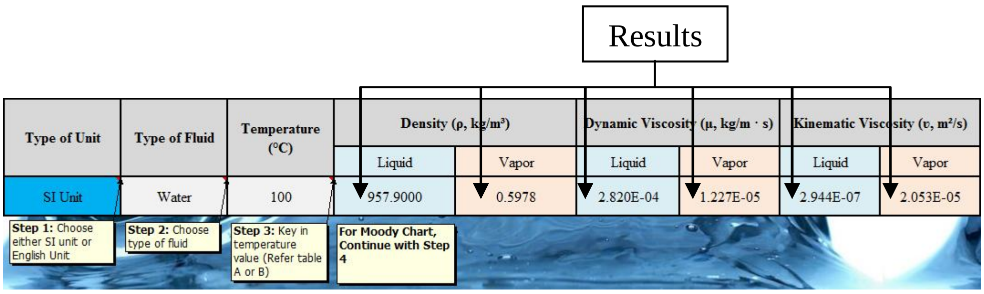


Figure 4.7: The results appear

vii. To obtain friction factor, continue this step. Click this cell to choose either Method 1: Reynolds Number or Method 2: Equation (Re = ρVD/μ). Method I require the user to key in roughness, diameter and Reynolds number value while method 2 require the user to key in temperature, roughness, diameter and velocity value. For method 2, Reynolds number obtains from Microsoft Excel calculation where user must key in temperature and choose type of fluid in fluid properties part.

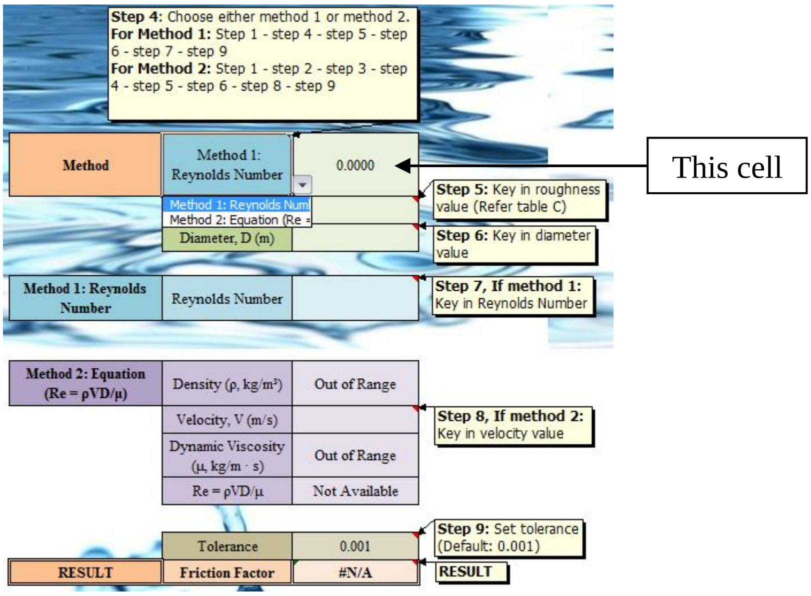


Figure 4.8: Choose method 1 or method 2

viii. Key in roughness and diameter value in these cells. For roughness value, refer table C as shown in figure 4.10.

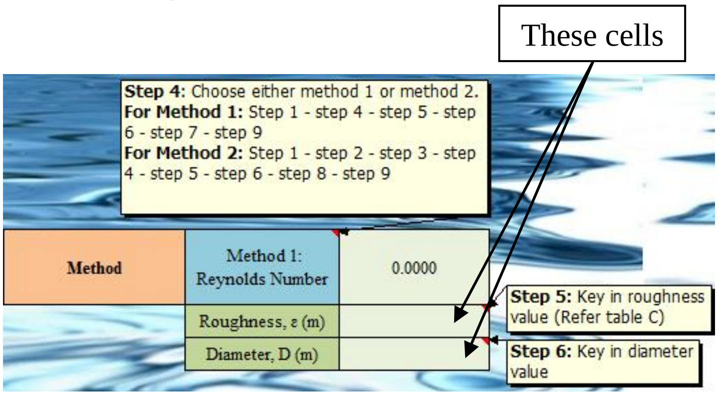


Figure 4.9: Key in roughness and diameter value

Reference Table C		
Material	Roughness, ε (m)	Roughness, ε (ft)
Glass, plastic	0	0
Concrete	0.0009–0.009	0.003-0.03
Wood stave	0.0005	0.0016
Rubber, smoothed	0.00001	0.000033
Copper or brass tubing	0.0000015	0.000005
Cast iron	0.00026	0.00085
Galvanized iron	0.00015	0.0005
Wrought iron	0.000046	0.00015
Stainless steel	0.000002	0.000007
Commercial steel	0.000045	0.00015

Figure 4.10: Table C

ix. If method 1, key in Reynolds number value in this cell. If method 2, skip to step x.

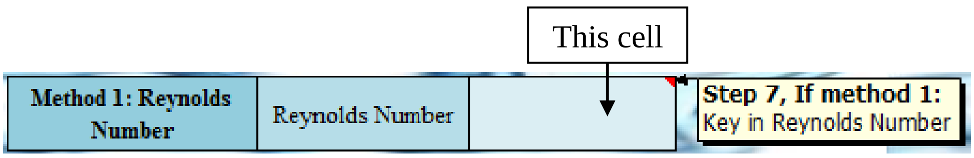


Figure 4.11: Key in Reynolds number

x. If method 2, key in velocity value in this cell.

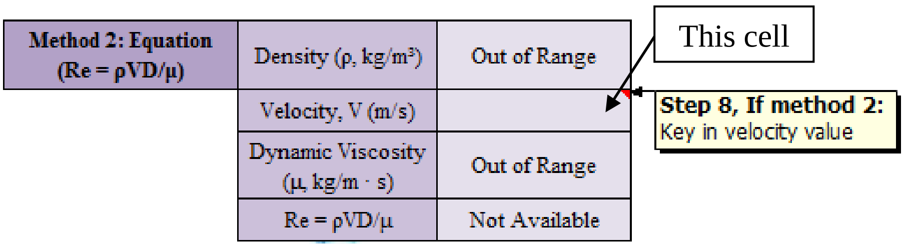


Figure 4.12: Key in velocity value

xi. Key in tolerance in this cell and press enter. The default value is set to 0.001. It is possible to change other value where the small tolerance, the more accurate the result value.

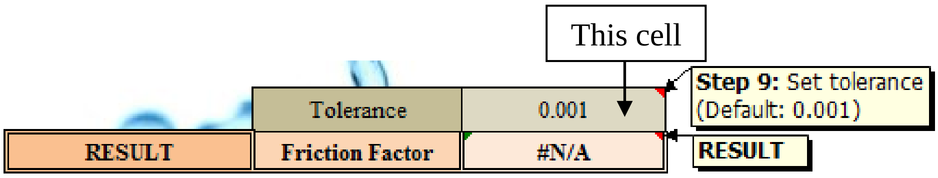


Figure 4.13: Key in tolerance

xii. The result for friction factor appears.

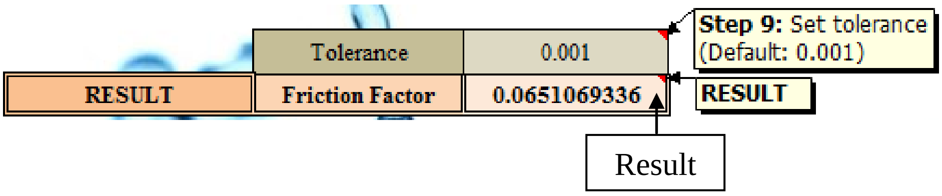


Figure 4.14: Result

vii. To plot graph for fluid properties, click worksheet "INTERFACE(Graph)" as shown in figure 4.15.

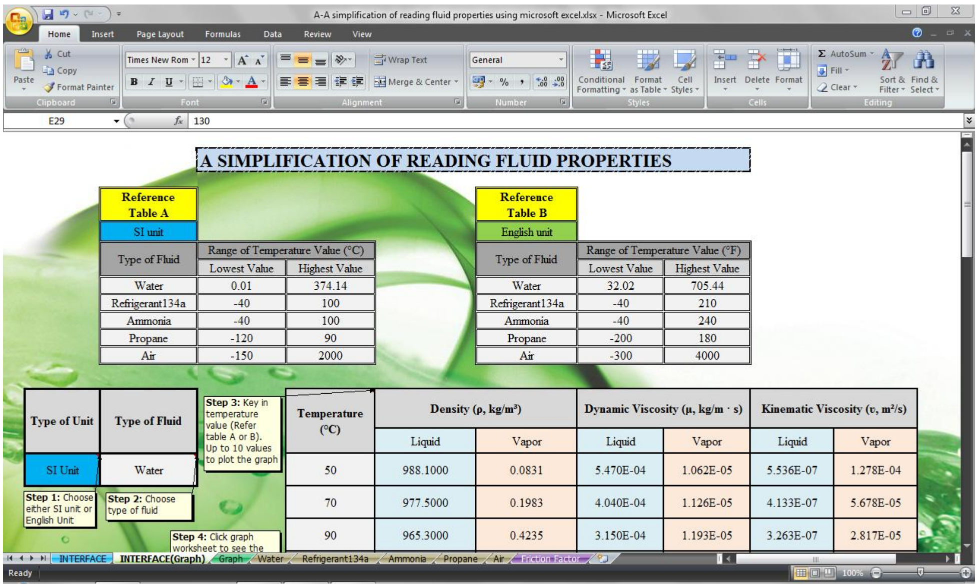


Figure 4.15: Interface for "INTERFACE(Graph)"

viii. Click this cell to choose either SI units or English units.

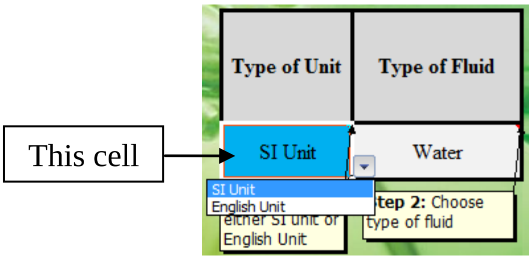


Figure 4.16: Choose type of unit

ix. Click this cell to choose type of fluid either water, refrigerant-134a, ammonia, propane or air.

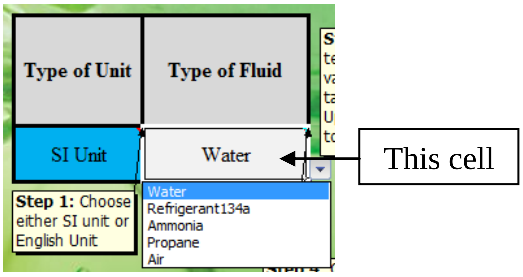
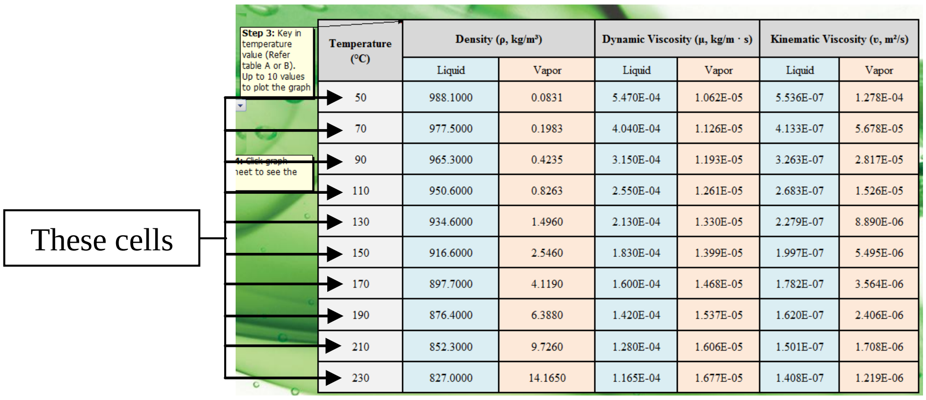


Figure 4.17: Choose type of fluid

x. Key in temperature value in these cells. The user is free to define the number of temperature values until ten maximum.



Temperature (°C)	Density (ρ, kg/m³)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (υ, m²/s)	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
50	988.1000	0.0831	5.470E-04	1.062E-05	5.536E-07	1.278E-04
70	977.5000	0.1983	4.040E-04	1.126E-05	4.133E-07	5.678E-05
90	965.3000	0.4235	3.150E-04	1.193E-05	3.263E-07	2.817E-05
110	950.6000	0.8263	2.550E-04	1.261E-05	2.683E-07	1.526E-05
130	934.6000	1.4960	2.130E-04	1.330E-05	2.279E-07	8.890E-06
150	916.6000	2.5460	1.830E-04	1.399E-05	1.997E-07	5.495E-06
170	897.7000	4.1190	1.600E-04	1.468E-05	1.782E-07	3.564E-06
190	876.4000	6.3880	1.420E-04	1.537E-05	1.620E-07	2.406E-06
210	852.3000	9.7260	1.280E-04	1.606E-05	1.501E-07	1.708E-06
230	827.0000	14.1650	1.165E-04	1.677E-05	1.408E-07	1.219E-06

Figure 4.18: Key in temperature value

xi. After finish key in temperature values, click worksheet "Graph" as shown in figure 4.19. The graphs appear.

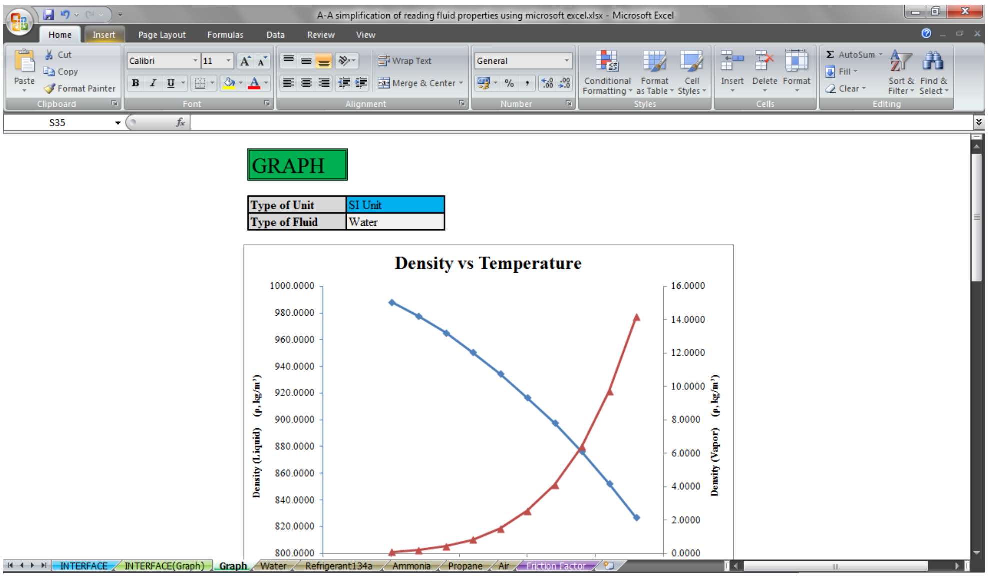


Figure 4.19: Interface for graph

4.2 RESULTS

4.2.1 Result for Listed Value from Property Tables

The result for SI units and English units for listed value from the property tables that obtain from excel file has been taken. Each type of fluid, ten sample results has been taken from the range of temperature. Table 4.1 – 4.5 for SI units while table 4.6 – 4.10 for English units that shows the result for listed value obtains from excel file.

Table 4.1: Result for saturated water

Temperature (°C)	Density (ρ, kg/m³)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (ν, m²/s)	
	Liquid	**Vapor**	**Liquid**	**Vapor**	**Liquid**	**Vapor**
0.01	999.8	0.0048	1.792E-3	9.220E-6	1.792E-6	1.921E-3
25	997.0	0.0231	8.910E-4	9.870E-6	8.937E-7	4.273E-4
50	988.1	0.0831	5.470E-4	1.062E-5	5.536E-7	1.278E-4
100	957.9	0.5978	2.820E-4	1.227E-5	2.944E-7	2.053E-5
150	916.6	2.5460	1.830E-4	1.399E-5	1.997E-7	5.495E-6
200	864.3	7.8520	1.340E-4	1.571E-5	1.550E-7	2.001E-6
240	813.7	16.7300	1.110E-4	1.712E-5	1.364E-7	1.023E-6
300	713.8	46.1500	8.600E-5	1.965E-5	1.205E-7	4.258E-7
360	528.3	144.0000	6.000E-5	2.571E-5	1.136E-7	1.785E-7
374.14	317.0	317.0000	4.300E-5	4.313E-5	1.356E-7	1.361E-7

Table 4.2: Result for saturated refrigerant – 134a

Temperature (°C)	Density (ρ, kg/m³)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (ν, m²/s)	
	Liquid	**Vapor**	**Liquid**	**Vapor**	**Liquid**	**Vapor**
-40	1418.0	2.773	4.878E-4	2.550E-6	3.440E-7	9.196E-7
-30	1389.0	4.429	4.178E-4	3.504E-6	3.008E-7	7.911E-7
-20	1359.0	6.787	3.614E-4	4.651E-6	2.659E-7	6.853E-7
0	1295.0	14.420	2.761E-4	7.471E-6	2.132E-7	5.181E-7
20	1226.0	27.770	2.142E-4	1.075E-5	1.747E-7	3.871E-7
40	1147.0	50.080	1.660E-4	1.408E-5	1.447E-7	2.812E-7
60	1053.0	87.380	1.260E-4	1.704E-5	1.197E-7	1.950E-7
80	928.2	155.300	9.011E-5	1.982E-5	9.708E-8	1.276E-7
90	837.7	217.800	7.203E-5	2.187E-5	8.599E-8	1.004E-7
100	651.7	376.300	4.765E-5	2.833E-5	7.312E-8	7.529E-8

Table 4.3: Result for saturated ammonia

Temperature (°C)	Density (ρ, kg/m³)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (ν, m²/s)	
	Liquid	**Vapor**	**Liquid**	**Vapor**	**Liquid**	**Vapor**
-40	690.2	0.6435	2.926E-4	7.957E-6	4.239E-7	1.237E-5
-30	677.8	1.0370	2.630E-4	8.311E-6	3.880E-7	8.014E-6
-20	665.1	1.6030	2.361E-4	8.669E-6	3.550E-7	5.408E-6
0	638.6	3.4580	1.896E-4	9.405E-6	2.969E-7	2.720E-6
20	610.2	6.7050	1.519E-4	1.017E-5	2.489E-7	1.517E-6
40	579.4	12.0300	1.219E-4	1.099E-5	2.104E-7	9.135E-7
60	545.2	20.4800	9.846E-5	1.189E-5	1.806E-7	5.806E-7
80	505.7	33.8700	8.030E-5	1.292E-5	1.588E-7	3.815E-7
90	482.8	43.4800	7.284E-5	1.354E-5	1.509E-7	3.114E-7
100	456.6	56.1500	6.628E-5	1.429E-5	1.452E-7	2.545E-7

Table 4.4: Result for saturated propane

Temperature (°C)	Density (ρ, kg/m³)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (ν, m²/s)	
	Liquid	**Vapor**	**Liquid**	**Vapor**	**Liquid**	**Vapor**
-120	664.7	0.0141	6.136E-4	4.372E-6	9.231E-7	3.105E-4
-90	633.8	0.1870	3.635E-4	5.143E-6	5.735E-7	2.750E-5
-60	601.5	1.0810	2.430E-4	5.956E-6	4.040E-7	5.510E-6
-40	578.8	2.6290	1.926E-4	6.529E-6	3.328E-7	2.483E-6
-20	554.7	5.5030	1.551E-4	7.136E-6	2.796E-7	1.297E-6
0	528.7	10.3600	1.259E-4	7.794E-6	2.381E-7	7.523E-7
20	500.0	18.1300	1.022E-4	8.534E-6	2.044E-7	4.707E-7
50	448.5	38.7900	7.343E-5	9.950E-6	1.637E-7	2.565E-7
70	403.2	64.0200	5.649E-5	1.138E-5	1.401E-7	1.778E-7
90	329.1	118.6000	3.807E-5	1.448E-5	1.157E-7	1.221E-7

Table 4.5: Result for air at 1 atm pressure

Temperature (°C)	**Density (ρ, kg/m³)**	**Dynamic Viscosity (μ, kg/m · s)**	**Kinematic Viscosity (ν, m²/s)**
-150	2.8660	8.636E-6	3.013E-6
-50	1.5820	1.474E-5	9.319E-6
0	1.2920	1.729E-5	1.338E-5
50	1.0920	1.963E-5	1.798E-5
100	0.9458	2.181E-5	2.306E-5
250	0.6746	2.760E-5	4.091E-5
500	0.4565	3.563E-5	7.806E-5
800	0.3289	4.362E-5	1.326E-4
1000	0.2772	4.826E-5	1.741E-4
2000	0.1553	6.630E-5	4.270E-4

Table 4.6: Result for saturated water

Temperature (°F)	**Density (ρ, lbm/ft³)**		**Dynamic Viscosity (μ, lbm/ft · s)**		**Kinematic Viscosity (ν, ft²/s)**	
	Liquid	**Vapor**	**Liquid**	**Vapor**	**Liquid**	**Vapor**
32.02	62.41	0.0003	1.204E-3	6.194E-6	1.929E-5	2.065E-2
70	62.30	0.0012	6.556E-4	6.556E-6	1.052E-5	5.701E-3
120	61.71	0.0049	3.744E-4	7.111E-6	6.067E-6	1.442E-3
200	60.12	0.0297	2.036E-4	8.083E-6	3.387E-6	2.722E-4
300	57.31	0.1545	1.236E-4	9.389E-6	2.157E-6	6.077E-5
400	53.65	0.5359	8.833E-5	1.066E-5	1.646E-6	1.989E-5
500	48.95	1.4790	6.833E-5	1.200E-5	1.396E-6	8.114E-6
550	45.96	4.2680	6.083E-5	1.280E-5	1.324E-6	2.999E-6
650	37.31	6.1520	4.639E-5	1.542E-5	1.243E-6	2.507E-6
705.44	19.79	19.7900	2.897E-5	2.897E-5	1.464E-6	1.264E-6

Table 4.7: Result for saturated refrigerant – 134a

Temperature (°F)	Density (ρ, lbm/ft^3)		Dynamic Viscosity (μ, lbm/ft · s)		Kinematic Viscosity (ν, ft^2/s)	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
-40	88.51	0.1731	3.278E-4	1.714E-6	3.704E-6	9.902E-6
-20	86.48	0.2905	2.762E-4	2.433E-6	3.194E-6	8.375E-6
0	84.38	0.4635	2.345E-4	3.314E-6	2.779E-6	7.150E-6
30	81.08	0.8660	1.883E-4	4.906E-6	2.322E-6	5.665E-6
60	77.51	1.5090	1.522E-4	6.725E-6	1.964E-6	4.457E-6
100	72.17	2.9350	1.149E-4	9.222E-6	1.592E-6	3.142E-6
140	65.72	5.4550	8.464E-5	1.144E-5	1.288E-6	2.097E-6
170	59.47	8.7620	6.450E-5	1.298E-5	1.085E-6	1.481E-6
190	53.75	12.5300	5.119E-5	1.431E-5	9.524E-7	1.142E-6
210	43.19	21.1800	3.483E-5	1.787E-5	8.064E-7	8.437E-7

Table 4.8: Result for saturated ammonia

Temperature (°F)	Density (ρ, lbm/ft^3)		Dynamic Viscosity (μ, lbm/ft · s)		Kinematic Viscosity (ν, ft^2/s)	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
-40	43.08	0.0402	1.966E-4	5.342E-6	4.564E-6	1.329E-4
-20	42.33	0.0681	1.764E-4	5.600E-6	4.125E-6	8.223E-5
0	41.34	0.1097	1.549E-4	5.861E-6	3.747E-6	5.343E-5
30	39.96	0.2075	1.290E-4	6.256E-6	3.228E-6	3.015E-5
60	38.50	0.3641	1.072E-4	6.656E-6	2.784E-6	1.828E-5
100	36.40	0.7060	8.397E-5	7.189E-6	2.307E-6	1.018E-5
140	34.04	1.2786	6.617E-5	7.731E-6	1.944E-6	6.046E-6
180	31.26	2.2346	5.278E-5	8.281E-6	8.281E-6	3.706E-6
210	28.70	3.4053	4.500E-5	8.703E-6	1.568E-6	2.556E-6
240	25.28	5.4197	3.864E-5	9.136E-6	1.528E-6	1.686E-6

Table 4.9: Result for saturated propane

Temperature (°F)	Density (ρ, lbm/ft³)		Dynamic Viscosity (μ, lbm/ft · s)		Kinematic Viscosity (ν, ft²/s)	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
-200	42.06	0.0003	5.012E-4	2.789E-6	1.192E-5	9.297E-3
-120	39.20	0.0170	2.252E-4	3.556E-6	5.745E-6	2.092E-4
-70	37.32	0.0793	1.569E-4	4.067E-6	4.204E-6	5.129E-5
-30	35.73	0.2041	1.217E-4	4.497E-6	3.406E-6	2.203E-5
0	34.46	0.3703	1.018E-4	4.842E-6	2.954E-6	1.308E-5
30	33.10	0.6259	8.561E-5	5.211E-6	2.586E-6	8.326E-6
70	31.11	1.1659	6.794E-5	5.764E-6	2.184E-6	4.944E-6
120	28.13	2.3562	5.000E-5	6.644E-6	1.777E-6	2.820E-6
160	24.98	4.1145	3.733E-5	7.719E-6	1.494E-6	1.876E-6
180	22.79	5.6265	3.083E-5	8.617E-6	1.353E-6	1.532E-6

Table 4.10: Result for air at 1 atm pressure

Temperature (°F)	Density (ρ, lbm/ft³)	Dynamic Viscosity (μ, lbm/ft · s)	Kinematic Viscosity (ν, ft²/s)
-300	0.2484	4.039E-6	1.625E-5
-50	0.0968	1.006E-5	1.039E-4
0	0.0863	1.102E-5	1.278E-4
100	0.0709	1.281E-5	1.809E-4
200	0.0601	1.446E-5	2.406E-4
500	0.0413	1.878E-5	4.544E-4
1000	0.0272	2.467E-5	9.080E-4
1500	0.0202	2.957E-5	1.460E-3
2000	0.0161	3.379E-5	2.095E-3
4000	0.0089	4.651E-5	5.229E-3

4.2.2 Result for Unlisted Value from Property Tables

The result for SI units and English units for unlisted value from the table that obtain from excel file has been taken. Each type of fluid, ten sample results has been taken from the range of temperature. Table 4.11 – 4.15 for SI units while table 4.16 – 4.20 for English units that shows the result for interpolation value obtains from excel file.

Table 4.11: Result for saturated water

Temperature (°C)	**Density (ρ, kg/m³)**		**Dynamic Viscosity (μ, kg/m · s)**		**Kinematic Viscosity (ν, m²/s)**	
	Liquid	**Vapor**	**Liquid**	**Vapor**	**Liquid**	**Vapor**
1	999.8198	0.0052	1.738E-3	9.244E-6	1.738E-6	1.812E-3
23	997.4000	0.0208	9.354E-4	9.814E-6	9.378E-7	4.813E-4
47	989.3000	0.0725	5.764E-4	1.052E-5	5.826E-7	1.469E-4
99	958.6200	0.5791	2.850E-4	1.224E-5	2.973E-7	2.122E-5
146	918.6400	2.3136	1.886E-4	1.385E-5	2.053E-7	6.076E-6
201	863.1000	8.0394	1.334E-4	1.575E-5	1.545E-7	1.971E-6
254	792.7000	21.6020	1.047E-4	1.765E-5	1.320E-7	8.353E-7
302	709.1300	47.9920	8.520E-5	1.977E-5	1.201E-7	4.155E-7
348	577.6200	113.1720	6.600E-5	2.381E-5	1.142E-7	2.175E-7
374	319.0921	315.2871	4.317E-5	4.296E-5	1.354E-7	1.365E-7

Table 4.12: Result for saturated refrigerant – 134a

Temperature (°C)	Density (ρ, kg/m³)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (ν, m²/s)	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
-39	1415.00	2.9232	4.804E-4	2.641E-6	3.395E-7	9.061E-7
-31	1391.80	4.2480	4.244E-4	3.404E-6	3.049E-7	8.034E-7
-17	1349.40	7.6876	3.468E-4	5.037E-6	2.570E-7	6.574E-7
-2	1301.40	13.4800	2.835E-4	7.166E-6	2.178E-7	5.332E-7
18	1233.20	26.1620	2.198E-4	1.042E-5	1.782E-7	3.993E-7
44	1129.40	56.1440	1.575E-4	1.470E-5	1.395E-7	2.624E-7
57	1068.00	80.6180	1.317E-4	1.662E-5	1.233E-7	2.068E-7
83	903.54	171.5000	8.479E-5	2.035E-5	9.378E-8	1.192E-7
96	748.34	290.7000	5.905E-5	2.463E-5	7.873E-8	8.546E-8
99	675.86	354.9000	5.050E-5	2.740E-5	7.452E-8	7.783E-8

Table 4.13: Result for saturated ammonia

Temperature (°C)	Density (ρ, kg/m³)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (ν, m²/s)	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
-38	687.72	0.7222	2.867E-4	8.028E-6	4.168E-7	1.150E-5
-32	680.28	0.9583	2.689E-4	8.240E-6	3.952E-7	8.885E-6
-19	663.80	1.6756	2.336E-4	8.705E-6	3.519E-7	5.227E-6
1	637.22	3.5896	1.876E-4	9.443E-6	2.943E-7	2.642E-6
17	614.58	6.1194	1.571E-4	1.005E-5	2.556E-7	1.652E-6
43	574.54	13.0920	1.181E-4	1.112E-5	2.055E-7	8.528E-7
64	537.84	22.7040	9.447E-5	1.208E-5	1.756E-7	5.333E-7
86	492.16	39.3840	7.574E-5	1.328E-5	1.539E-7	3.380E-7
92	477.76	45.8280	7.149E-5	1.368E-5	1.496E-7	2.994E-7
98	462.04	53.43	6.755E-5	1.413E-5	1.462E-7	2.653E-7

Table 4.14: Result for saturated propane

Temperature (°C)	Density (ρ, kg/m³)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (ν, m²/s)	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
-117	661.64	0.0212	5.811E-4	4.448E-6	8.778E-7	2.541E-4
-93	636.92	0.1575	3.820E-4	5.064E-6	5.995E-7	3.576E-5
-64	605.90	0.9062	2.568E-4	5.846E-6	4.236E-7	6.834E-6
-39	577.62	2.7525	1.906E-4	6.559E-6	3.299E-7	2.412E-6
-22	557.16	5.1752	1.586E-4	7.074E-6	2.846E-7	1.391E-6
3	524.56	11.3380	1.221E-4	7.900E-6	2.327E-7	6.998E-7
18	503.00	17.2180	1.044E-4	8.456E-6	2.075E-7	4.929E-7
56	435.90	45.3120	6.829E-5	1.033E-5	1.565E-7	2.304E-7
71	400.18	66.0460	5.563E-5	1.149E-5	1.389E-7	1.748E-7
88	337.88	111.7360	4.004E-5	1.408E-5	1.182E-7	1.273E-7

Table 4.15: Result for air at 1 atm pressure

Temperature (°C)	Density (ρ, kg/m³)	Dynamic Viscosity (μ, kg/m · s)	Kinematic Viscosity (ν, m²/s)
-147	2.8163	8.189E-6	3.182E-6
-51	1.5911	1.447E-5	9.249E-6
2	1.2828	1.739E-5	1.356E-5
49	1.0954	1.959E-5	1.788E-5
103	0.9386	2.193E-5	2.338E-5
254	0.6699	2.774E-5	4.145E-5
506	0.4534	3.580E-5	7.909E-5
757	0.3434	4.254E-5	1.243E-4
1245	0.2389	5.312E-5	2.320E-4
1983	0.1568	6.602E-5	4.224E-4

Table 4.16: Result for saturated water

Temperature (°F)	Density (ρ, lbm/ft^3)		Dynamic Viscosity (μ, lbm/ft · s)		Kinematic Viscosity (ν, ft^2/s)	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
33	62.4112	0.0003	1.217E-3	6.204E-6	1.950E-5	2.038E-2
73	62.2760	0.0013	6.318E-4	6.589E-6	1.015E-5	5.256E-3
116	61.7700	0.0045	3.898E-4	7.067E-6	6.310E-6	1.608E-3
211	59.8450	0.0366	1.906E-4	8.236E-6	3.184E-6	2.251E-4
294	57.5020	0.2652	1.268E-4	9.306E-6	2.205E-6	4.068E-5
393	53.9335	0.4980	9.018E-5	1.057E-5	1.672E-6	2.145E-5
489	49.5022	1.3534	7.029E-5	1.185E-5	1.419E-6	9.066E-6
577	43.9944	3.9807	5.708E-5	1.334E-5	1.296E-6	3.374E-6
658	35.7052	7.3181	4.443E-5	1.622E-5	1.245E-6	2.349E-6
705	20.3958	19.2764	2.939E-5	2.828E-5	1.447E-6	1.468E-6

Table 4.17: Result for saturated refrigerant – 134a

Temperature (°F)	Density (ρ, lbm/ft^3)		Dynamic Viscosity (μ, lbm/ft · s)		Kinematic Viscosity (ν, ft^2/s)	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
-38	88.3080	0.1836	3.223E-4	1.782E-6	3.649E-6	9.740E-6
-23	86.7860	0.2711	2.835E-4	2.319E-6	3.266E-6	8.590E-6
-1	84.4860	0.4541	2.365E-4	3.268E-6	2.799E-6	7.209E-6
27	81.4160	0.8190	1.925E-4	4.737E-6	2.364E-6	5.802E-6
64	77.0060	1.6230	1.481E-4	6.977E-6	1.923E-6	4.314E-6
111	70.5340	3.4927	1.060E-4	9.871E-6	1.503E-6	2.830E-6
135	66.6000	5.0670	8.820E-5	1.118E-5	1.324E-6	2.215E-6
182	56.2300	10.8260	5.657E-5	1.379E-5	1.006E-6	1.279E-6
206	45.8140	18.9360	3.849E-5	1.690E-5	8.374E-7	9.029E-7
209	43.8460	20.6150	3.574E-5	1.763E-5	8.142E-7	8.585E-7

Table 4.18: Result for saturated ammonia

Temperature (°F)	Density (ρ, lbm/ft^3)		Dynamic Viscosity (μ, lbm/ft · s)		Kinematic Viscosity (ν, ft^2/s)	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
-37	42.9540	0.0440	1.932E-4	5.381E-6	4.498E-6	1.242E-4
-26	42.5280	0.0589	1.810E-4	5.523E-6	4.256E-6	9.519E-5
-2	41.4300	0.1051	1.568E-4	5.835E-6	3.785E-6	5.593E-5
34	39.7680	0.2253	1.259E-4	6.309E-6	3.166E-6	2.823E-5
63	38.3470	0.3848	1.053E-4	6.695E-6	2.745E-6	1.750E-5
109	35.8870	0.8116	7.952E-5	7.311E-6	2.216E-6	9.026E-6
148	33.5200	1.4341	6.319E-5	7.840E-6	1.885E-6	5.482E-6
187	30.7070	2.4673	5.083E-5	8.378E-6	1.655E-6	3.408E-6
198	29.7900	2.8756	4.794E-5	8.533E-6	1.609E-6	2.975E-6
231	25.5410	4.6808	4.044E-5	9.004E-6	1.583E-6	1.028E-6

Table 4.19: Result for saturated propane

Temperature (°F)	Density (ρ, lbm/ft^3)		Dynamic Viscosity (μ, lbm/ft · s)		Kinematic Viscosity (ν, ft^2/s)	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
-189	41.6750	0.0007	4.423E-4	2.891E-6	1.060E-5	5.671E-3
-135	39.7475	0.0101	2.558E-4	3.408E-6	6.432E-6	3.752E-4
-83	37.8140	0.0559	1.714E-4	3.930E-6	4.533E-6	7.138E-5
-38	36.0500	0.1721	1.279E-4	4.408E-6	3.546E-6	2.579E-5
-7	34.7610	0.3255	1.061E-4	4.760E-6	3.051E-6	1.472E-5
38	32.7160	0.7144	8.177E-5	5.316E-6	2.499E-6	7.468E-6
64	31.4220	1.0691	7.038E-5	5.676E-6	2.239E-6	5.332E-6
132	27.2660	2.8027	4.615E-5	6.924E-6	1.691E-6	2.504E-6
161	24.8705	4.1901	3.701E-5	7.764E-6	1.487E-6	1.859E-6
176	23.2280	5.321	3.213E-5	8.437E-6	1.381E-6	1.600E-6

Table 4.20: Result for air at 1 atm pressure

Temperature (°F)	Density (ρ, lbm/ft³)	Dynamic Viscosity (μ, lbm/ft · s)	Kinematic Viscosity (ν, ft²/s)
-272	0.2216	4.804E-6	2.411E-5
-59	0.0993	9.877E-6	9.995E-5
36	0.0800	1.169E-5	1.461E-4
121	0.0683	1.318E-5	1.929E-4
217	0.0587	1.473E-5	2.515E-4
488	0.0419	1.862E-5	4.450E-4
943	0.0283	2.405E-5	8.514E-4
1395	0.0217	2.854E-5	1.344E-3
2273	0.0146	3.582E-5	2.479E-3
3804	0.0093	4.545E-5	4.893E-3

4.2.3 Result for Darcy Friction Factor

There are two methods as the input to obtain Darcy friction factor. For each method, ten sample results have been taken where results for method 1 considered for SI units while result for method 2 considered for English units. Table 4.21 shows the result for Darcy friction factor using method 1 while table 4.22 shows the result for Darcy friction factor using method 2. For method 2, considered type of fluid is water and temperature equal to 70°F.

Table 4.21: Result for Darcy friction factor using method 1

Type of Material	Roughness, ε (m)	Diameter, D (m)	Reynolds Number, Re	Friction Factor
Glass, plastic	0	0.015	5000	0.0373922424
Concrete	0.0009	0.020	7000	0.0715237427
Wood stave	0.0005	0.025	10000	0.0522747192
Rubber, smoothed	0.00001	0.040	20000	0.0264232330
Copper or brass tubing	0.0000015	0.050	50000	0.0209996185
Cast iron	0.00026	0.080	100000	0.0280039215
Galvanized iron	0.00015	0.100	200000	0.0228028107
Wrought iron	0.000046	0.150	500000	0.0163272171
Stainless steel	0.000002	0.200	1000000	0.0118694229
Commercial steel	0.000045	0.250	30000000	0.0134797668

Table 4.22: Result for Darcy friction factor using method 2

Type of Material	Roughness, ε (ft)	Diameter, D (ft)	Velocity, (ft/s)	Reynolds Number, Re	Friction Factor
Glass, plastic	0	0.083	3.5	27605.4759	0.0239483185
Concrete	0.003	0.167	3.6	57130.5064	0.0474189453
Wood stave	0.0016	0.250	3.8	90276.0830	0.0336535492
Rubber, smoothed	0.000033	0.333	4.0	126576.5711	0.0171970520
Copper or brass tubing	0.000005	0.417	4.4	174356.3758	0.0161561279
Cast iron	0.00085	0.500	4.7	223314.5210	0.0233334503
Galvanized iron	0.0005	0.583	5.1	282545.1342	0.0200527496
Wrought iron	0.00015	0.667	5.5	348608.2215	0.0161831512
Stainless steel	0.000007	0.833	6.5	514526.1592	0.0132140961
Commercial steel	0.00015	1.000	8.5	807733.3740	0.0143276672

4.3 VALIDATION OF EXCEL FILE

Validation result is important part to prevent the result from excel file different with manual reading and manual calculation. A few samples of manual reading or manual calculation results have been taken to compare with excel file results.

4.3.1 Manual Reading from Property Tables

For manual reading from property tables, 6 samples of manual reading have been taken where 3 samples for SI units and 3 sample for English units. This samples result compare with excel file result to investigate the result. Table 4.23 - 4.25 shows the result for SI units while table 4.26 – 4.28 shows the result for English units.

Table 4.23: Result from manual reading and excel file for temperature equal to 100°C and type of fluid is saturated water

Manual Reading

Temp. T, °C	Saturation Pressure P_{sat}, kPa	Density ρ, kg/m³		Enthalpy of Vaporization h_{fg}, kJ/kg	Specific Heat c_p, J/kg · K		Thermal Conductivity k, W/m · k		Dynamic Viscosity μ, kg/m · s		Prandtl Number Pr		Volume Expansion Coefficient β, 1/K
		Liquid	Vapor		Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid
100	101.33	957.9	0.5978	2257	4217	2029	0.679	0.0251	0.282×10^{-3}	1.227×10^{-5}	1.75	1.00	0.750×10^{-3}

Excel File

Type of Unit	Type of Fluid	Temperature (°C)	Density (ρ, kg/m³)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (υ, m²/s)	
			Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
SI Unit	Water	100	957.9000	0.5978	2.820E-04	1.227E-05	2.944E-07	2.053E-05

Table 4.24: Result from manual reading and excel file for temperature equal to 80°C and type of fluid is saturated refrigerant-134a

Manual Reading

Temp. T, °C	Saturation Pressure P, kPa	Density ρ, kg/m³ Liquid	Density ρ, kg/m³ Vapor	Enthalpy of Vaporization h_{fg}, kJ/kg	Specific Heat c_p, J/kg · K Liquid	Specific Heat c_p, J/kg · K Vapor	Thermal Conductivity k, W/m · K Liquid	Thermal Conductivity k, W/m · K Vapor	Dynamic Viscosity μ, kg/m · s Liquid	Dynamic Viscosity μ, kg/m · s Vapor	Prandtl Number Pr Liquid	Prandtl Number Pr Vapor	Volume Expansion Coefficient β, 1/K Liquid	Surface Tension, N/m
80	2635.2	928.2	155.3	106.4	2056	1948	0.0521	0.02133	9.011×10^{-5}	1.982×10^{-5}	3.558	1.810	0.01031	0.00160

Excel File

Type of Unit	Type of Fluid	Temperature (°C)	Density (ρ, kg/m³)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (υ, m²/s)	
			Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
SI Unit	Refrigerant134a	80	928.2000	155.3000	9.011E-05	1.982E-05	9.708E-08	1.276E-07

Table 4.25: Result from manual reading and excel file for temperature equal to 5°C and type of fluid is saturated ammonia

Manual Reading

Temp. T, °C	Saturation Pressure P, kPa	Density ρ, kg/m³ Liquid	Density ρ, kg/m³ Vapor	Enthalpy of Vaporization h_{fg}, kJ/kg	Specific Heat c_p, J/kg · K Liquid	Specific Heat c_p, J/kg · K Vapor	Thermal Conductivity k, W/m · K Liquid	Thermal Conductivity k, W/m · K Vapor	Dynamic Viscosity μ, kg/m · s Liquid	Dynamic Viscosity μ, kg/m · s Vapor	Prandtl Number Pr Liquid	Prandtl Number Pr Vapor	Volume Expansion Coefficient β, 1/K Liquid	Surface Tension, N/m
5	516	631.7	4.116	1244	4645	2749	0.5274	0.02341	1.794×10^{-4}	9.593×10^{-6}	1.580	1.126	0.00223	0.02566

Excel File

Type of Unit	Type of Fluid	Temperature (°C)	Density (ρ, kg/m³)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (υ, m²/s)	
			Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
SI Unit	Ammonia	5	631.7000	4.1160	1.794E-04	9.593E-06	2.840E-07	2.331E-06

Table 4.26: Result from manual reading and excel file for temperature equal to 600°F and type of fluid is saturated water

Manual Reading

Temp. T, °F	Saturation Pressure P_{sat}, psia	Density ρ, lbm/ft³ Liquid	Density ρ, lbm/ft³ Vapor	Enthalpy of Vaporization h_{fg}, Btu/lbm	Specific Heat c_p, Btu/lbm·R Liquid	Specific Heat c_p, Btu/lbm·R Vapor	Thermal Conductivity k, Btu/h·ft·R Liquid	Thermal Conductivity k, Btu/h·ft·R Vapor	Dynamic Viscosity μ, lbm/ft·s Liquid	Dynamic Viscosity μ, lbm/ft·s Vapor	Prandtl Number Pr Liquid	Prandtl Number Pr Vapor	Volume Expansion Coefficient β, 1/R Liquid
600	1541	42.32	3.736	550	1.509	1.759	0.299	0.0461	5.389×10^{-5}	1.380×10^{-5}	0.979	1.90	1.883×10^{-3}

Excel File

Type of Unit	Type of Fluid	Temperature (°F)	Density (ρ, lbm/ft³)		Dynamic Viscosity (μ, lbm/ft · s)		Kinematic Viscosity (υ, ft²/s)	
			Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
English Unit	Water	600	42.3200	3.7360	5.389E-05	1.380E-05	1.273E-06	3.694E-06

Table 4.27: Result from manual reading and excel file for temperature equal to -120°F and type of fluid is saturated propane

Manual Reading

Temp. T, °F	Saturation Pressure P_{sat}, psia	Density ρ, lbm/ft³ Liquid	Density ρ, lbm/ft³ Vapor	Enthalpy of Vaporization h_{fg}, Btu/lbm	Specific Heat c_p, Btu/lbm·R Liquid	Specific Heat c_p, Btu/lbm·R Vapor	Thermal Conductivity k, Btu/h·ft·R Liquid	Thermal Conductivity k, Btu/h·ft·R Vapor	Dynamic Viscosity μ, lbm/ft·s Liquid	Dynamic Viscosity μ, lbm/ft·s Vapor	Prandtl Number Pr Liquid	Prandtl Number Pr Vapor	Volume Expansion Coefficient β, 1/R Liquid	Surface Tension lbf/ft
−120	1.389	39.20	0.0170	200.5	0.4982	0.2971	0.0906	0.00465	2.252×10^{-4}	3.556×10^{-6}	4.457	0.817	0.00094	0.001455

Excel File

Type of Unit	Type of Fluid	Temperature (°F)	Density (ρ, lbm/ft³)		Dynamic Viscosity (μ, lbm/ft · s)		Kinematic Viscosity (υ, ft²/s)	
			Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
English Unit	Propane	-120	39.2000	0.0170	2.252E-04	3.556E-06	5.745E-06	2.092E-04

Table 4.28: Result from manual reading and excel file for temperature equal to 200°F and type of fluid is air at 1 atm pressure

Manual Reading

Temp. T, °F	Density ρ, lbm/ft³	Specific Heat c_p, Btu/lbm·R	Thermal Conductivity k, Btu/h·ft·R	Thermal Diffusivity α, ft²/s	Dynamic Viscosity μ, lbm/ft·s	Kinematic Viscosity ν, ft²/s	Prandtl Number Pr
200	0.06013	0.2409	0.01761	3.377×10^{-4}	1.446×10^{-5}	2.406×10^{-4}	0.7124

Excel File

Type of Unit	Type of Fluid	Temperature (°F)	Density (ρ, lbm/ft³)		Dynamic Viscosity (μ, lbm/ft · s)		Kinematic Viscosity (υ, ft²/s)	
			Gas		Gas		Gas	
English Unit	Air	200	0.0601		1.446E-05		2.406E-04	

From table 4.23 – 4.28, almost all the results for manual reading and excel file shows the same result. Only one result shows the different result but the different only occur for value decimal places. From observations, result from manual tables shows not consistently decimal places for density while for dynamic viscosity show three decimal places. From excel file, result for density only set four decimal places while for dynamic viscosity and kinematic viscosity set three decimal places.

From the results for manual reading and excel file, if the error below 5 %, the result accepted. The equation to calculate error is:

$$Error = \left|\frac{Excel\ file - Manual\ reading}{Manual\ reading}\right| \times 100\ \% \qquad (4.1)$$

Sample calculation:

From table 4.24, the result from manual reading vapor dynamic viscosity equal to 1.982E-5 kg/m³ while the result from excel equal to 1.982E-5 kg/m³.

$$Error = \left|\frac{(1.982E-5) - (1.982E-5)}{(1.982E-5)}\right| \times 100\ \% = 0\ \%$$

Table 4.29: Error for manual reading and excel file result

Table No.	Error (%) Density		Dynamic Viscosity	
	Liquid	Vapor	Liquid	Vapor
4.23	0	0	0	0
4.24	0	0	0	0
4.25	0	0	0	0
4.26	0	0	0	0
4.27	0	0	0	0
4.28	0.05	0	0	0

Table 4.29 show the error results for manual reading and excel file results. From observations, all the error results are below 5 % where almost all the results show the same result. From property tables, there are no data for kinematic viscosity, where the data obtain from equation $\upsilon = \mu / \rho$. However, from excel file the data for kinematic viscosity are already calculated and stated in the data sheet.

4.3.2 Manual Interpolation Calculation

For manual interpolation calculation for unlisted value from property tables, 6 samples of manual interpolation calculation have been taken where 3 samples for SI units and 3 sample for English units. This samples result compare with excel file result to investigate the result. Table 4.30 - 4.32 shows the result for SI units while table 4.33 – 4.35 shows the result for English units.

This sample manual interpolation calculation to find density for liquid value and type of fluid is saturated water. This calculation based on temperature equal to 73°C and for SI units. The step manual interpolation calculation is:

Temp. T, °C	Saturation Pressure P_{sat}, kPa	Density ρ, kg/m³ Liquid	Density ρ, kg/m³ Vapor	Enthalpy of Vaporization h_{fg}, kJ/kg	Specific Heat c_p, J/kg · K Liquid	Specific Heat c_p, J/kg · K Vapor	Thermal Conductivity k, W/m · k Liquid	Thermal Conductivity k, W/m · k Vapor	Dynamic Viscosity μ, kg/m · s Liquid	Dynamic Viscosity μ, kg/m · s Vapor	Prandtl Number Pr Liquid	Prandtl Number Pr Vapor	Volume Expansion Coefficient β, 1/K Liquid
0.01	0.6113	999.8	0.0048	2501	4217	1854	0.561	0.0171	1.792×10^{-3}	0.922×10^{-5}	13.5	1.00	-0.068×10^{-3}
5	0.8721	999.9	0.0068	2490	4205	1857	0.571	0.0173	1.519×10^{-3}	0.934×10^{-5}	11.2	1.00	0.015×10^{-3}
10	1.2276	999.7	0.0094	2478	4194	1862	0.580	0.0176	1.307×10^{-3}	0.946×10^{-5}	9.45	1.00	0.733×10^{-3}
15	1.7051	999.1	0.0128	2466	4185	1863	0.589	0.0179	1.138×10^{-3}	0.959×10^{-5}	8.09	1.00	0.138×10^{-3}
20	2.339	998.0	0.0173	2454	4182	1867	0.598	0.0182	1.002×10^{-3}	0.973×10^{-5}	7.01	1.00	0.195×10^{-3}
25	3.169	997.0	0.0231	2442	4180	1870	0.607	0.0186	0.891×10^{-3}	0.987×10^{-5}	6.14	1.00	0.247×10^{-3}
30	4.246	996.0	0.0304	2431	4178	1875	0.615	0.0189	0.798×10^{-3}	1.001×10^{-5}	5.42	1.00	0.294×10^{-3}
35	5.628	994.0	0.0397	2419	4178	1880	0.623	0.0192	0.720×10^{-3}	1.016×10^{-5}	4.83	1.00	0.337×10^{-3}
40	7.384	992.1	0.0512	2407	4179	1885	0.631	0.0196	0.653×10^{-3}	1.031×10^{-5}	4.32	1.00	0.377×10^{-3}
45	9.593	990.1	0.0655	2395	4180	1892	0.637	0.0200	0.596×10^{-3}	1.046×10^{-5}	3.91	1.00	0.415×10^{-3}
50	12.35	988.1	0.0831	2383	4181	1900	0.644	0.0204	0.547×10^{-3}	1.062×10^{-5}	3.55	1.00	0.451×10^{-3}
55	15.76	985.2	0.1045	2371	4183	1908	0.649	0.0208	0.504×10^{-3}	1.077×10^{-5}	3.25	1.00	0.484×10^{-3}
60	19.94	983.3	0.1304	2359	4185	1916	0.654	0.0212	0.467×10^{-3}	1.093×10^{-5}	2.99	1.00	0.517×10^{-3}
65	25.03	980.4	0.1614	2346	4187	1926	0.659	0.0216	0.433×10^{-3}	1.110×10^{-5}	2.75	1.00	0.548×10^{-3}
70	31.19	977.5	0.1983	2334	4190	1936	0.663	0.0221	0.404×10^{-3}	1.126×10^{-5}	2.55	1.00	0.578×10^{-3}
75	38.58	974.7	0.2421	2321	4193	1948	0.667	0.0225	0.378×10^{-3}	1.142×10^{-5}	2.38	1.00	0.607×10^{-3}
80	47.39	971.8	0.2935	2309	4197	1962	0.670	0.0230	0.355×10^{-3}	1.159×10^{-5}	2.22	1.00	0.653×10^{-3}

Figure 4.20: Properties of saturated water

Source: Cengel and Cimbala (2006)

From figure 4.20, the temperature equal to 73°C is between 70°C and 75°C. The new density for liquid value refer to letter y while new temperature value refer to letter x. x0 and y0 refer the lower value than x and y value while x1 and y1 is the higher value than x and y value. The x, x0, x1, y0 and y1 are the known value. So, the equation to known y value is:

$$\frac{(y-y0)}{(x-x0)} = \frac{(y1-y0)}{(x1-x0)}$$

$$(y - y0) = (x - x0)\left(\frac{y1-y0}{x1-x0}\right)$$

$$y = y0 + (x - x0)\left(\frac{y1-y0}{x1-x0}\right)$$

$$y = 977.5 + (73 - 70)\left(\frac{974.7 - 977.5}{75 - 70}\right)$$

$$y = 975.82 \text{ kg/m}^3$$

Density (liquid), $\rho = 975.82 \text{ kg/m}^3$

Table 4.30: Result from manual interpolation calculation and excel file for temperature equal to 73°C and type of fluid saturated water

Manual Interpolation Calculation

Temperature (°C)	Density (ρ, kg/m³)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (ν, m²/s)	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
73	975.82	0.22458	3.884E-4	1.1356E-5	3.98E-7	5.1014E-5

Excel File

Type of Unit	Type of Fluid	Temperature (°C)	Density (ρ, kg/m³)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (υ, m²/s)	
			Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
SI Unit	Water	73	975.8200	0.2246	3.884E-04	1.136E-05	3.980E-07	5.102E-05

Table 4.31: Result from manual interpolation calculation and excel file for temperature equal to -29°C and type of fluid saturated refrigerant-134a

Manual Interpolation Calculation

Temperature (°C)	Density (ρ, kg/m³)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (ν, m²/s)	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
-29	1386	4.645	4.1188E-4	3.614E-6	2.9714E-7	7.8006E-7

Excel File

Type of Unit	Type of Fluid	Temperature (°C)	Density (ρ, kg/m³)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (υ, m²/s)	
			Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
SI Unit	Refrigerant134a	-29	1386.0000	4.6450	4.119E-04	3.614E-06	2.971E-07	7.801E-07

Table 4.32: Result from manual interpolation calculation and excel file for temperature equal to 52°C and type of fluid saturated ammonia

Manual Interpolation Calculation

Temperature (°C)	Density (ρ, kg/m³)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (ν, m²/s)	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
52	559.42	16.668	1.0712E-4	1.1522E-5	1.9148E-7	6.937E-7

Excel File

Type of Unit	Type of Fluid	Temperature (°C)	Density (ρ, kg/m³)		Dynamic Viscosity (μ, kg/m · s)		Kinematic Viscosity (ν, m²/s)	
			Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
SI Unit	Ammonia	52	559.4200	16.6680	1.071E-04	1.152E-05	1.915E-07	6.937E-07

Table 4.33: Result from manual interpolation calculation and excel file for temperature equal to 297°F and type of fluid saturated water

Manual Interpolation Calculation

Temperature (°F)	Density (ρ, lbm/ft³)		Dynamic Viscosity (μ, lbm/ft · s)		Kinematic Viscosity (ν, ft²/s)	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
297	57.406	0.20985	1.2519E-4	9.3473E-6	2.181E-6	5.0726E-5

Excel File

Type of Unit	Type of Fluid	Temperature (°F)	Density (ρ, lbm/ft³)		Dynamic Viscosity (μ, lbm/ft · s)		Kinematic Viscosity (ν, ft²/s)	
			Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
English Unit	Water	297	57.4060	0.2099	1.252E-04	9.347E-06	2.181E-06	5.072E-05

Table 4.34: Result from manual interpolation calculation and excel file for temperature equal to 4°F and type of fluid saturated propane

Manual Interpolation Calculation						
Temperature (°F)	Density (ρ, lbm/ft³)		Dynamic Viscosity (μ, lbm/ft · s)		Kinematic Viscosity (ν, ft²/s)	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
4	34.284	0.39982	9.9504E-5	4.8896E-6	2.902E-6	1.2316E-5

Excel File

Type of Unit	Type of Fluid	Temperature (°F)	Density (ρ, lbm/ft³)		Dynamic Viscosity (μ, lbm/ft · s)		Kinematic Viscosity (ν, ft²/s)	
			Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
English Unit	Propane	4	34.2840	0.3998	9.950E-05	4.890E-06	2.902E-06	1.231E-05

Table 4.35: Result from manual interpolation calculation and excel file for temperature equal to 488°F and type of fluid saturated air at 1 atm

Manual Interpolation Calculation			
Temperature (°F)	Density (ρ, lbm/ft³)	Dynamic Viscosity (μ, lbm/ft · s)	Kinematic Viscosity (ν, ft²/s)
	Gas	Gas	Gas
488	0.04188	1.86216E-5	4.4508E-4

Excel File

Type of Unit	Type of Fluid	Temperature (°F)	Density (ρ, lbm/ft³)		Dynamic Viscosity (μ, lbm/ft · s)		Kinematic Viscosity (ν, ft²/s)	
			Gas		Gas		Gas	
English Unit	Air	488	0.0419		1.862E-05		4.450E-04	

From table 4.30 – 4.35, the results for manual interpolation calculation and excel file shows the almost same result. The different only occur for value decimal places result. From observations, result from manual interpolation calculation shows not consistently decimal places. From excel file, result for density only set four decimal places while for dynamic viscosity and kinematic viscosity set three decimal places.

From the results for manual interpolation calculation and excel file, if the error below 5 %, the result accepted. The equation to calculate error is:

$$Error = \left|\frac{Excel\ file - Manual\ interpolation\ calculation}{Manual\ interpolation\ calculation}\right| \times 100\ \% \qquad (4.2)$$

Sample calculation:

From table 4.33, the result from manual interpolation calculation liquid dynamic viscosity equal to 1.2519E-4 lbm/ft·s while the result from excel equal to 1.252E-4 lbm/ft·s.

$$Error = \left|\frac{(1.252\text{E} - 4\,) - (1.2519\text{E} - 4)}{(1.2519\text{E} - 4)}\right| \times 100\ \% = 0.008\ \%$$

Table 4.36: Error for manual interpolation calculation and excel file result

Error (%)						
Table No.	Density		Dynamic Viscosity		Kinematic Viscosity	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
4.30	0	0.0089	0	0.0352	0	0.0118
4.31	0	0	0.0049	0	0.0135	0.0051
4.32	0	0	0.0187	0.0174	0.0104	0
4.33	0	0.0238	0.0080	0.0032	0	0.01118
4.34	0	0.0050	0.0040	0.0082	0	0.0487
	Gas		Gas		Gas	
4.35	0.0478		0.0086		0.0180	

Table 4.36 show the error results for manual interpolation calculation and excel file results. From observations, all the error results are below 5 % where the only small errors occur. Although there are no data for kinematic viscosity from property tables, by doing calculation, the results for kinematic viscosity interpolation can be obtain and compare results from excel file.

4.3.3 Manual Reading Darcy Friction Factor from Moody Chart

For manual reading Darcy friction factor from Moody Chart, 6 samples of manual reading have been taken where 3 samples for SI units and 3 sample for English units. This samples result compare with excel file result to investigate the result. Table 4.37 shows the result for SI units while table 4.38 shows the result for English units obtain from manual reading and excel file. Figure 4.21 shows the result for SI units while figure 4.22 shows the result for English units obtains from manual reading. Considered result for SI units using method 1 while for English units using method 2, type of fluid is water and temperature equal to 70°F.

Table 4.37: Result for Darcy friction factor using method 1

Type of Material	**Roughness, ε (m)**	**Diameter, D (m)**	**Relative Roughness, ε /D**	**Reynolds Number, Re**	**Friction Factor**
			Manual Reading		
Glass, plastic	0	0.015	0	5000	0.0365
Cast iron	0.00026	0.080	0.00325	100000	0.0280
Stainless steel	0.000002	0.200	0.00001	1000000	0.0118
			Excel File		
Glass, plastic	0	0.015	0	5000	0.0373922424
Cast iron	0.00026	0.080	0.00325	100000	0.0280039215
Stainless steel	0.000002	0.200	0.00001	1000000	0.0118694229

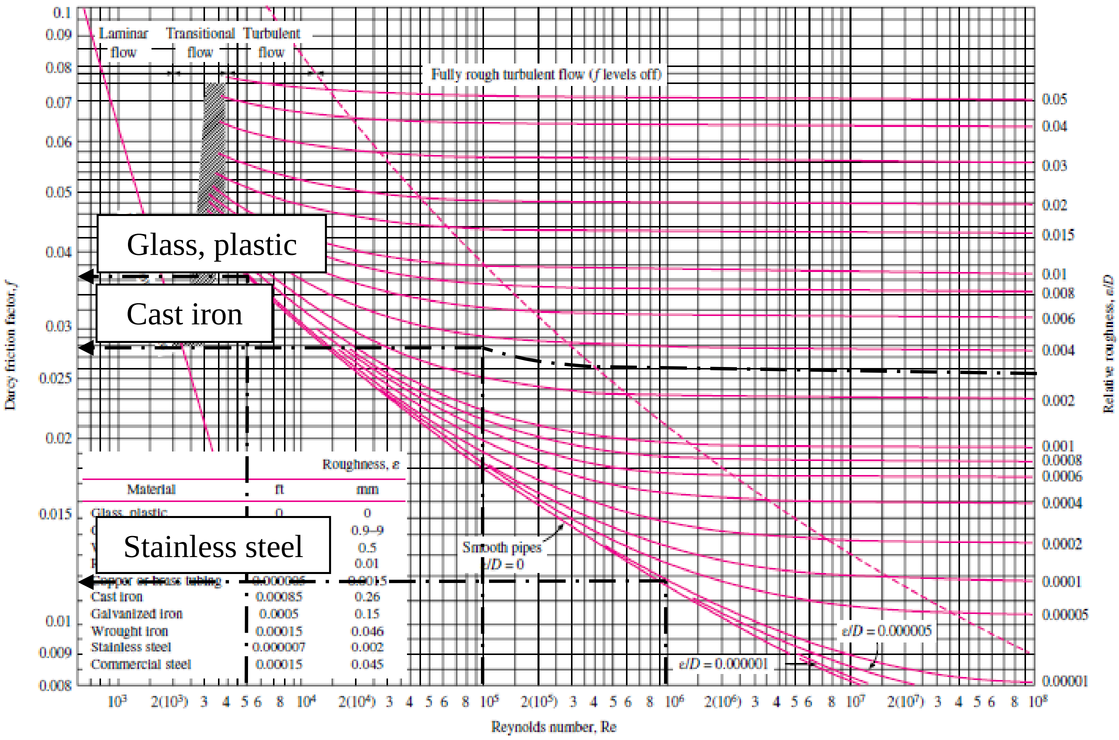


Figure 4.21: Manual reading from Moody Chart

Table 4.38: Result for Darcy friction factor using method 2

Type of Material	Roughness ε (ft)	Diameter D (ft)	Relative Roughness ε/D	Velocity (ft/s)	Reynolds Number Re	Friction Factor
Manual Reading						
Commercial steel	0.00015	0.083	0.0018	3.5	27605.48	0.0271
Copper or brass tubing	0.000005	0.250	0.00002	3.8	90276.08	0.0182
Galvanized iron	0.0005	0.500	0.001	4.7	223314.52	0.0210
Excel File						
Commercial steel	0.00015	0.083	0.0018	3.5	27605.4759	0.0280288391
Copper or brass tubing	0.000005	0.250	0.00002	3.8	90276.08298	0.0184811859
Galvanized iron	0.0005	0.500	0.001	4.7	223314.521	0.0209017029

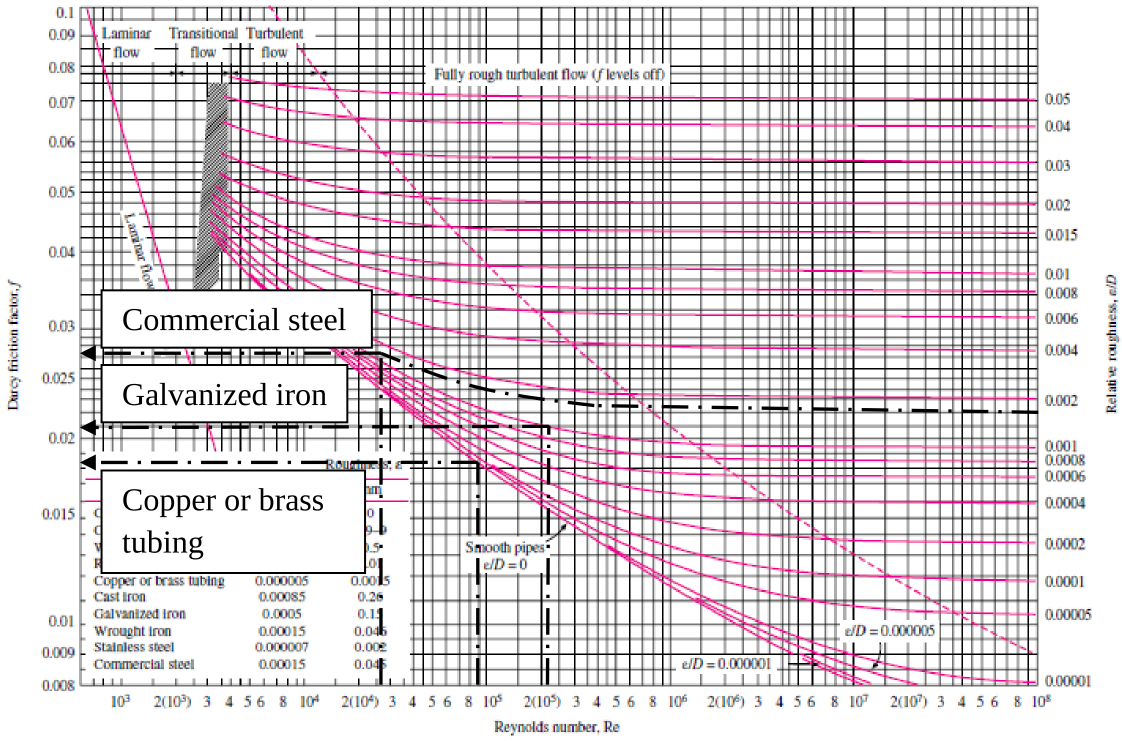


Figure 4.22: Manual reading from Moody Chart

From table 4.37 – 4.38, the results for manual reading and excel file shows the almost same result. From manual reading, it is only possible to read four decimal places result while for excel file is set ten decimal places result.

From the results for manual reading and excel file, if the error below 5 %, the result accepted. The equation to calculate error is:

$$Error = \left|\frac{Excel\ file - Manual\ reading}{Manual\ reading}\right| \times 100\ \% \quad (4.3)$$

Sample calculation:

From table 4.37, the result from manual reading friction factor for cast iron equal to 0.0280 while the result from excel equal to 0.0280039215.

$$Error = \left|\frac{(0.0280039215) - (0.0280)}{(0.0280)}\right| \times 100\ \% = 0.014\ \%$$

Table 4.39: Error for manual reading and excel file result

Error (%)	
Type of Material	Friction Factor
Glass, plastic	2.4445
Cast iron	0.0140
Stainless steel	0.5883
Commercial steel	3.4275
Copper or brass tubing	1.5450
Galvanized iron	0.4681

Table 4.39 show the error results for manual reading from Moody Chart and excel file results. From observations, all the error results are below 5 % where the highest error is 3.4275 % for commercial steel while the lowest is 0.0140 % for cast iron. The highest error occurs for commercial steel because for this data required to construct curve line in Moody Chart that possibility increase the error.

CHAPTER 5

CONCLUSION

5.1 CONCLUSION

This project successfully achieves the objective to develop an excel file to easily obtain fluid properties without manual reading from table. Through excel file, the user can simplify obtain value from property table and obtain friction factor without manual reading or manual calculation. Besides that, this excel file will decrease the time to obtain the properties value and decrease the error from manual reading and manual calculation.

From the beginning until the end of this project, Microsoft Excel has a lot of function where allow manipulating the data and constructing new function by using formula that have in Microsoft Excel. In this project, the functions are modified by adding and deleting the formula to meet the function to obtain the data from property tables.

5.2 RECOMMENDATION

This excel file for future work can upgrade by adding more fluid properties such as specific heat, thermal conductivity, Prandtl number and volume expansion coefficient. Besides that, this excel file can adding more type of fluid like properties of liquids, properties of metals, properties of gases at 1 atm pressure and properties of the atmosphere at high altitude. By upgrade, this excel file will be better and more useful for user.

Advance editing by using Visual Basic for Applications (VBA) will upgrade this excel file to more interesting and functionally. Besides that, the interface will look better than compare by using normal function in Microsoft Excel. Visual Basic for Applications is a program that allows the user to automate the function in Microsoft Excel.

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APPENDIX A

GANTT CHART FOR FINAL YEAR PROJECT 1

Activity	Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Find Literature Review for history property table and Microsoft Excel	Plan															
	Actual															
Find property table for Fluid Mechanics	Plan															
	Actual															
Transfer data from property table into Microsoft Excel	Plan															
	Actual															
Compare existing software	Plan															
	Actual															
Study and construct formula to obtain the data for listed and not listed value	Plan															
	Actual															
Construct interface for user	Plan															
	Actual															
Report writing	Plan															
	Actual															
Report submission and presentation	Plan															
	Actual															

APPENDIX B

GANTT CHART FOR FINAL YEAR PROJECT 2

Activity	Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Construct formula for SI unit and English unit (fluid properties table)	Plan	■													
	Actual	■													
Construct graph for fluid properties	Plan		■	■											
	Actual		■	■											
Compare existing software (Fiction factor)	Plan				■	■									
	Actual				■	■									
Study to solve Colebrook equation using numerical method	Plan				■	■	■	■							
	Actual				■	■	■	■	■						
Study and construct formula to obtain friction factor	Plan						■	■	■	■	■	■	■	■	
	Actual						■	■	■	■	■	■			
Construct interface for user	Plan										■	■	■		
	Actual										■	■	■	■	
Report writing	Plan						■	■	■	■	■	■	■	■	■
	Actual				■	■	■	■	■	■	■	■	■	■	■
Report submission and presentation	Plan														■
	Actual														■