THE APPLICABILITY OF ISO 5151 AND ISO 8187 TEST CONDITION FOR AIR CONDITIONER AND HOUSEHOLD REFRIGERATOR IN MALAYSIA

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ABSTRACT

Malaysia is adopting the minimum energy efficiency standard for room air conditioner and household refrigerator, therefore, the test procedures for rating and testing must be established. Laboratory testing and certification are the important parts of introducing the minimum energy efficiency standard for these appliances. The requirements for the specific country must be clarified before setting the standard. This paper is an analysis of the applicability of ISO 5151 and ISO 8187 air conditioner and refrigerator test condition in Malaysia. The analysis was made based on climatic conditions that prevail in Malaysia. Today, since there is a trend in international harmonization of appliance standard, this paper can be considered as a support of the purpose. A few international test standards were also given.

***Keywords**: Air conditioning, refrigerator, test conditions, test procedure, ratings.*

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1.0 INTRODUCTION

Malaysia, like the other developing countries with hot and humid climates, has been experiencing dramatic growth in the use of air conditioners and household refrigerators. For the last twelve years (1984-1996), Malaysian economy grew more than 7% per annum. At the same time, Gross Domestic Product (GDP) increased from RM79,330 million in 1990 to RM140,600 million in 1997. The income per capita has increased from RM6,230 in 1990 to RM12,050 in 1997 before economic downtrend that was initiated in July 1997 [1]. Economic growth is the main driving factor for higher use of refrigerator and air conditioner which in turn lead to the increasing need for comfort and high style of living that consequently has led to substantial increase in household energy consumption. Refrigeration and air conditioning industry have also expanded extensively to meet the country's demand for these appliances. Due to the lack of government intervention to implement energy efficiency standards, manufacturers are not paying their heed for the improvement of their product. Consequently, inefficient, worn-out equipment and lack of implementing leading edge technology are the major concerns of depleting the country's energy resources rapidly. Escalating energy prices, the increasing expenses of building new power stations, the government utilities and general population awareness on the environment are also the driving factor of this analysis.

Air conditioners and refrigerators are the major energy consuming electric appliances in the household ambience. According to the load survey, around 35% of the total residential electricity consumption are by these appliances [2]. Introducing standards and labeling for room air conditioner and refrigerator can offer great benefits for the consumers, governments as well as the environment. Since, energy efficiency standards and test procedures are interrelated, an energy test procedure for these appliances is utmost needed to mitigate future-demand for energy as well as to mitigate the environmental degradation.

2.0 ENERGY TEST PROCEDURE

An energy test procedure is the base for all energy efficiency standards, labels and other related programs. It represents the technical foundation for all energy efficiency standards and labels. Energy label could not be created without energy test procedure. The function of test standards is to establish a uniform and repeatable procedure or standard method for measuring specific appliances characteristic. Standards are set of procedures and regulations that prescribe the energy performance of manufactured products. Sometimes it prohibits the manufacturing of product less energy efficient than the minimum standard. The standard method recommends levels of performance intended to provide a means by which different brands and models of appliances could be compared and evaluated with respect to the characteristic in design and use of the products. A good test procedure should fulfill the following criterion [3]:

- accurately reflects the relative performance of different design options for a given appliance;
- reflect actual usage condition, yield repeatable, accurate results;
- cover a wide range of models within that category of appliance;
- be inexpensive to perform;
- be easy to modify to accommodate new technologies or features; and
- produce results that can be easily compared with those from other test procedures.

Unfortunately, these goals are contradictory. For example, a test procedure for refrigerator that attempts to closely mimic the actual kitchen/environment conditions and human behaviour is very complicated. It is also expensive. Meier et al, [4] discussed that an independent testing laboratory charges about US$ 2000 to perform DOE test on a single refrigerator. A simple test procedure may be inexpensive but is liable to ignore features that affect the actual energy use, thus causing an inaccurate and unfair ranking of the models. Therefore, every test procedure is a compromise.

Many countries and regions utilize different test protocols to measure energy consumption of different products. This prevents comparison of energy efficiency for such products across the borders where the test protocols differ. For products whose efficiency is dependent upon climate like refrigerator and air conditioner, local climatic condition is another factor affecting energy efficiency. There is a number of meetings and workshops that try to harmonize regional test protocol but it is impossible to harmonize world test protocol. This is because each country has its own climate, characteristic and usage differences for some products, electricity or fuel prices, cultural attitudes with respect to voluntary or mandatory specifications, and the state-of-the-art manufacturing companies in a region. However, there are still ways for the purpose. For example, under the auspicious of the International Standardization Organization (ISO), air conditioner and refrigerator test protocols have been harmonized to some extent among many nations. Nevertheless, there are still some differences between the US and Canada test protocols and the ISO protocols [5].

3.0 ISO 5151 AIR CONDITIONER TEST CONDITIONS

The performance of room air conditioner is described in terms of the energy efficiency ratio (EER). The EER is determined by dividing the cooling capacity of the unit (measured in Btu or Watts) by its input power (measured in Watts). Both the cooling capacity and input power are measured at specific temperature during the steady state operation. Temperature for the ISO 5151 of air conditioner ratings specifies the test condition for three different climates; cool, moderate, and hot. For testing purpose, the manufacturer may choose one, two or all the three climates [6]. The indoor and outdoor test conditions associated with each climate rating are listed in Table 1.

Table 1 ISO 5151 cooling capacity test conditions

Standard Test Condition for Each Climate	**Cool**	**Moderate**	**Hot**
Temperature of air entering indoor side (°C)			
° Dry bulb	21	27	29
° Wet bulb	15	19	19
Temperature of air entering outdoor side (°C)			
° Dry bulb	27	35	46
° Wet bulb	19	24	24

Test procedures to evaluate the performance of air conditioners have already been established in Europe, Japan, North America, Australia, and Philippine. The Philippines has directly adopted the ISO 5151 test standard by Philippine National Standard to become Philippine National Standard 240:1998- Non-ducted air conditioners and heat pumps testing and rating for performance with just a few modifications. The modifications are about test condition to determine the cooling capacity and maximum cooling test condition [7]. In the U.S. presently, several differences exist between the Department of Energy (DOE) test procedure and the ISO standards, such as in test voltages, test-operating tolerances and test procedure for frosting [8]. However, there is only a slight difference in the temperature condition. The British Standards Institution (BSI) (BS 2852: Part1) is based on three conditions such as A, B and C. The A, B and C of BSI are equivalently related to ISO as moderate, hot and cool respectively. It was found that the temperature conditions for both standards were identical. The ISO 5151 test procedure is presumably utilized by China, Japan, Philippine, and South Korea. The resulting differences between the above country's test procedure and ISO 5151 can be negligible. All of the test standards measure the appliances at steady-state condition, but the number of additional measurements and calculation required is slightly different.

4.0 REFRIGERATOR TEST CONDITIONS

Refrigerator is placed in a control chamber (chamber where specific test requirements are set) for a specific period for the performance measurement. Three most important laboratory energy test procedures are the DOE, ISO and Japanese Industrial Standards (JIS). Each of the standards was developed to suit the peculiar conditions found in that region. For example, Japanese home traditionally lacked central heating facility. Hence, JIS test includes two ambient temperatures (i.e. 15°C and 30°C, to reflect the winter and summer kitchen temperatures respectively) and requires a complex schedule of door openings during the first ten hours of commencement of the test. Japan recently abandoned its test procedure in favour of the ISO test procedure. The principal reasons behind that are the high cost of performing the JIS test and the need to retest if the unit is designed for export. The trial and error process needed to achieve the required temperature without extrapolation is also seen as tedious. In addition, the JIS test is open to considerable subjective interpretation. For example, the test calls for door openings but does not specify which doors. Modern Japanese refrigerators often contain six doors [4]. Thailand started their energy-labeling program since 1995 for household refrigerators. In their test procedures, they have incorporated ISO test standard for testing and rating of household refrigerators. There are no door openings schedule in ISO and DOE. Table 2 shows the brief requirements of selected international refrigerator/ freezers test standards.

Table 2 Requirements of international test standards

Parameters	ISO	DOE	JIS
Ambient temperature (°C)	25±0.5, tropical 32	32.2±0.6	15±1 and 30±1
Door openings	No	No	Yes
Food loading	Yes	No	No
Fresh food temperature (°C)	5	3.3	3±0.5
Freezer temperature (°C)	-18	-15	-18
Relative humidity (%)	45%-75%	Not specified	75±5%

4.1 International Standards ISO 8187

The ISO is a worldwide federation of national standards bodies. The ISO 8187 is the relevant standard for testing the energy consumption of household refrigerators [9]. ISO specifies the following four climatic zones:

(i) Extended temperature zone: 25±.5 °C

(ii) Temperate zone: 25±.5 °C

(iii) Subtropical zone: 25±.5 °C

(iv) Tropical zone: 32±.5 °C

Test Period: The test period shall be at least 24 hours long.

Door openings: No door openings were specified in ISO

4.2 Factors That Contribute to Refrigerators Energy Consumption

The following factors must be considered in order to develop refrigerator test standards:

(i) Kitchen temperature

(ii) Door opening

(iii) Relative humidity

(iv) Food loading

(v) Compartment temperature

(vi) Control/thermostat settings.

The effect of the above factor on energy consumption

Most of the thermal load on a refrigerator is by means of conduction through the walls. ASHRAE shows that about 70% of the total refrigerator load come through the cabinet wall. For this reason, temperature of air around a refrigerator is a significant determinant of energy consumption [10]. Since compressor efficiency also declines as the ambient temperature rises, a refrigerator's electricity consumption is very sensitive to the ambient temperature. Meier showed that refrigerator energy consumption varies from 1.25 to 12.6 kWh/day even though the temperature increase is only 11°C (from 17 to 28°C) [4]. A few studies show that the ambient temperature had the greatest effect, door openings are next followed by, food loadings and finally the room humidity had the minimal effects [11-13]. It was also found that the significant increase in energy consumption was due to the control setting from warmer to cooler. Again Meier et al. showed that energy consumption rose to 26% from the warmest acceptable to the coldest possible settings. One study reported that heat removed from food loadings accounts for the majority of the refrigeration load [14]. This load is the function of the product type, mass and temperature difference before and after cooling.

5.0 AN OVERVIEW OF MALAYSIAN CLIMATIC CONDITIONS

To develop test standards for air conditioner and refrigerator, climatic condition for a particular country or region is an important factor. In case of air conditioner, temperature of air entering the outdoor side of the air conditioner is an important factor. Several studies show that ambient temperature is the major contributor of refrigerator energy consumption. On the other hand, relative humidity also has little effect on refrigerator energy consumption. Keeping this in view, Malaysia is a hot and humid country. A large variation of temperature is rare throughout the country.

Table 3 shows the data collected around the country from the Meteorological Department of Malaysia. From the data, the highest maximum temperature was recorded as 37.0°C in Ipoh [15].

Table 3 Records of Temperature and Relative Humidity

City	24hrM	Mdx	Mdn	Hm	Lm	RH
Kota Kinabalu	27.0	31.2	23.5	36.0	18.6	81.5
Senai	25.9	31.7	22.4	36.0	18.2	86.9
Subang	26.7	32.3	23.0	36.8	18.1	82.7
Ipoh	26.9	33.0	23.1	37.0	17.8	81.4
Bayan Lepas	27.2	31.3	23.8	36.3	18.7	82.2
Kota Bharu	26.8	31.2	23.5	36.5	18.3	82.2
Kuantan	26.1	31.6	22.7	36.9	16.8	85.4
Kuching	26.2	31.6	23.0	36.5	18.9	85.4
Average	26.6	31.74	23.12	36.5	18.17	83.5

Note: 24hrM = 24 hour mean temperature, Mdx = Mean daily maximum temperature, Mdn = Mean daily minimum temperature, Hm = Highest maximum temperature, Lm = Lowest minimum temperature, RH = relative humidity.

The average hourly temperature and relative humidity are given in Table 4. The data represent the average humidity and temperature for 10 years from 1986 to 1995. The following steps were taken:

(i) The average temperature and relative humidity for a particular year was summed.

(ii) The total obtained in step (i) is divided by 10.

(iii) Step (i) and (ii) were repeated for each of 24 hours in a day.

Table 4 Records of 10 year average temperature and relative humidity

Hour	Temperature (°C)	Relative Humidity (%)
1	24.54	93.9
2	24.34	94.5
3	24.13	94.7
4	23.97	95.1
5	23.83	95.2
6	23.7	95.3
7	24.04	95.4
8	25.63	92.2
9	27.52	82.0
10	29:21	74.6
11	30.39	70.1
12	31.01	67.5

Table 4 Records of 10 year average temperature and relative humidity (*continued*)

Hour	Temperature (°C)	Relative Humidity (%)
13	31.23	67.0
14	30.98	68.5
15	30.21	71.8
16	29.2	75.6
17	28.09	79.3
18	26.94	83.2
19	26.14	86.5
20	25.73	88.8
21	25.48	90.4
22	25.24	91.4
23	25.03	92.6
24	24.79	93.4

6.0 COMFORT RANGE

For the purpose of choosing the temperature of air entering indoor side, the comfort range of temperature and the effective temperature for the population in the particular country and region were considered. As a starting point, clarification was made on the effective temperature and comfort range for a hot climate country (population) like Malaysia. In fact, to set an effective temperature for all human being is impossible because an optimum and acceptable comfort level varies among the population. Effective temperature is a relative index; an acceptable comfort range has been found to vary from one country (or population) to another. However, a generally acceptable level of comfort range for acclimatized Asians and Africans was found to be higher compared to the higher population of North America and Europe [16]. ASHRAE illustrated the relationship between a new effective temperature scale, sensation, comfort, physiology and health for humans. These data are for prolonged exposures and relate to the acclimatized human in the United States. Optimum effective temperature lies between 19°C and 24.5°C with optimum band between 20.5°C and 23°C [17].

For Malaysian, it is difficult to define a range of effective temperature with which the majority of individuals from hot countries will be able to work at maximum efficiency. However, the comfort range and effective temperature for hot climate have been discussed in the Asian users' manual for the Asian climatic atlas and the compendium of climatic statistics. The result is shown in Table 5 [17].

Table 5 Comfort range and effective temperature for hot climate

Comfort Range	**Effective Temperature °F (°C)**
Above Acceptable	Above 76 (above 24.5)
Upper Acceptable	73 – 76 (22.8 –24.5)
Optimum	69 - 73 (20.6 – 22.8)
Lower Acceptable	66 – 69 (18.9 – 20.6)
Below Acceptable	Below 66 (below 18.9)

7.0 DISCUSSION AND CONCLUSION

It is recommended that Malaysia should introduce the ISO 5151 as the test procedure for room air conditioner. The temperatures that were shown in the ISO 5151 could be accepted in Malaysia. Table 5 shows that the optimum comfort range is similar to the temperature of air entering indoor side in the cool climate. In comparing the data of Table 3, temperature of the air entering outdoor side could also be accepted except for hot climate. However, the study for the hot climate condition could be conducted for the purpose of export. The ISO 5151 should also be implemented in Malaysia because most of the countries in the world have either adopted or directly referred the test condition and test procedure developed by the ISO for the rating of non-ducted air conditioner performance. At the moment, six Asia Pacific Economic Cooperation (APEC) countries have agreed on the testing standards. The countries are able to move appliances freely between some members of the APEC region as a result of an agreement on testing signed in Tokyo in late November 1997. Under the mutual recognition agreement, technical accreditation bodies from six APEC economies; Australia, Hong Kong (China), New Zealand, Singapore, Chinese Taipei, and the USA will accept test report endorsed by the other parties. Malaysia as an exporter country for household appliances, should consider this as one of the consideration because this will reduce the need for retest the product if the unit is designed for export. It will save time and money for exporter.

Table 3 and Table 4 indicate that the daily average temperature ranges from 25°C to 31°C throughout Malaysia and the relative humidity remains from 65% to 95%. However, the actual kitchen temperature and relative humidity are lower than the daily average temperature and the relative humidity to some extent. To compensate for the predictable (load due to conduction through the cabinet walls) and unpredictable loads (load due to usage pattern) that is imposed to household refrigerator daily, a higher temperature test condition can be considered. Apparently, a test procedure that tries to reflect the actual kitchen temperature and usage of human behavior is very complicated. As every test procedure is a compromise, the ISO 8187-refrigerator/freezer test standard can be considered for testing and rating the Malaysian refrigerator/freezer. On the other hand, JIS is not applicable to Malaysian climatic condition because JIS includes two temperatures (15°C and 30°C) for testing and rating of refrigerator/freezer. The 15°C test condition is an obsolete test with respect to the Malaysian climatic conditions. In DOE test standards, freezers test temperature is higher than the ISO freezer test temperature (-15°C for DOE and –18°C for ISO) and there is no specification for the relative humidity in DOE with respect to ISO. Therefore, with the above discussion, it is evident that the ISO 8187 refrigerator/freezer test standard (tropical zone test condition) is the best method for testing and rating the Malaysian refrigerator/ freezer as of our preliminary recommendation. Nevertheless, extensive discussion with professionals, experts, refrigerator/air conditioner manufacturers, utility companies, and international collaborator must take place before the final selection.

To develop the satisfactory standard test procedures is time consuming. For example in the Philippines, it took a long time to achieve an appropriate standard. The first concept was developed in 1983, but the process was put on hold during the 1986 revolution and the testing continued from 1986 to 1991. Finally in 1994, standards and labeling were developed with the collaboration of the manufacturers and government [18]. In the U.S., the test procedure was first developed in the late 1970's. It became effective in January 1980. After the test procedure has been introduced, it has been revised from time to time; the last was in 1997 [8]. In Malaysia, it should not take a long time to establish the test procedures because gaining experiences from other countries can save time. However, this paper is just a starting point towards the introduction of standards and labeling for room air conditioner and refrigerator in Malaysia. Intensive research that involves experts in related areas is needed for this purpose.

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REFERENCES

1. Department of Electricity and Gas supply Malaysia Statistics of electricity supply industry in Malaysia, 1999.
2. Ramani, K.V., Islam, M.N. and Reddy, A.K.N. (1993), *Rural energy systems in the Asia-Pacific*; Survey of their status, planning and management. APDC, Kuala Lumpur, Malaysia.

3. Meier, A.K., Hill, J.E.(1997), *Energy test procedures for appliances,* Energy and Building, 26 (1), 23-33.
4. Meier, A.K., (1995), *Refrigerator energy use in the laboratory and in the field,* Energy and Building, 22 (1): 233-243.
5. Turiel, I. (1997), *Present status of residential appliance energy efficiency standards-an international overview*, Energy and Building, 26: 5-15.
6. ISO 5151. (1994), *Non-ducted air conditioners and heat pumps-Testing and rating for performance*, first edition, Geneva, Switzerland.
7. Personal communication received from Iryzhar Divinagracia, (1999), Fuels and Appliance Laboratory Philippines Department of Energy.
8. Dougherty B.P. (1997), Department of energy air-conditioner/heat pump test procedure update, 3rd International Conference on Heat Pump in Cold Climate, Aug 11-12, 493 – 508.
9. ISO 8187. (1988), *Household refrigerator-freezers-characteristics and test methods*, Geneva, Switzerland.
10. ASHRAE, Equipment handbook (1988), '*Household refrigerators and freezers*. 2nd edition, McGraw-Hill.
11. Kao, J.E. and Kelly, G.E., (1996), *Factors affecting the energy consumption of two refrigerator/freezers*. ASHRAE transaction, 102 (2).
12. Alissi, M.S., (1988), *Effects of ambient temperature, ambient humidity, and door openings on energy consumption of a household refrigerator-freezer.* ASHRAE transaction, 94 (2): 1713-1736.
13. Gage, C.L., (1995), *Field usage and its impacts on energy consumption of refrigerator/freezers*. ASHRAE transaction, 101 (2): 1201-1247.
14. Yunus, A.C. and Michael, A.B. (1987), *Thermodynamics; An engineering approach*, Third edition, McGraw-Hill.
15. Malaysian Meteorological Service. Annual summary of meteorological observation 1972-1998, (1998). Malaysian Meteorological Service, Kuala Lumpur.

16. Van-Straaten, J. F., (1967), *Thermal performance of buildings*. Elsevier, Amsterdam.
17. Asian secretariat, (1990), *The Asian users' manual for the Asian climatic atlas and compendium of climatic statistics*. ASEAN sub committee on meteorology and geophysics Asean committee on science and technology, Jakarta.
18. Duffy, J., (1996), *Energy labeling, standards and building codes: A global survey and assessment for selected developing countries*. GEEI/Publications, Washington, D.C.