The Energy Consumption of Refrigerator Using CFC 12 and HFC 134a

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ABSTRACT

A market survey found ± 7 companies registered to assemble refrigerators, with annual production capacity 600,000 units (1995) using CFC 12 as a refrigerant. The Association of Indonesia Electric Appliance Manufacturers and Suppliers has decided to convert refrigerant from CFC 12 to HFC 134a by January 1998. The influence of ODS and non ODS substances in refrigerators on energy consumption has been performed. The energy consumption of a manually defrost, single door, 150 litre typical capacity refrigerators were measured at the Refrigerator Testing Laboratory University of Indonesia based on the protocol of ISO 7371 (E) 1995 under the ambient temperature of 30 °C with relative humidity between 60 % to 75 %.

The averaged energy consumption of 7 units CFC-refrigerator were between 1.11 and 1.38 kWh/24h, and for the HFC 134a-refrigerators between 1.03 and 1.22 kWh/24h. The energy consumption differences were approximately between 2 to 16 %.

Keywords : Energy consumption, refrigerator

INTRODUCTION

Based on survey data [1],[2] the value of refrigerator production of seven companies during the period 1992 - 1995 is 600,000 units annually, and domestic sales exceed 300,000 units annually. Most of these companies supply small and medium-size units, and larger units are usually imported. More than seventy percent of local production used in households are of the smaller size range 100 – 150 liter capacity, single door, single evaporator with the evaporator acting as the freezer box, manual defrost type and CFC 12 is used as the refrigerant.

Before the economic crisis in 1997 the growth production of refrigerators has been steady. During the period of 1992-1995 the average annual increase in production value was 40 percent [2]. Although the companies have decided to change the production line form CFC to HFC in 1998, there are no current Indonesian national standards for testing the performance of the refrigerators and also there are no information to show how much electrical energy consumed by refrigerators. The required energy consumption of refrigerators is also important to support customers in selecting the most energy efficient of the product. The information about electrical energy consumption stimulates consumer awareness and encourages manufacturers to compete based on an energy efficiency product.

This paper describes the method and results of the measurement of energy consumption of seven local assembled refrigerators.

REFRIGERATOR TEST FACILITY

Structure - The refrigerator testing chamber was constructed with insulated panels and located in University of Indonesia. The 50 mm insulated panels are of aluminum alloy coated steel sheets, laminated to an insulation core of polystyrene. The size of the chamber is 3.23 meters deep, 3.23 meters wide and 2.72 meters tall.

Equipment – To achieve the required test condition, air-cooled chiller with nominal capacity of 7 kW installed outside the chamber. The equipment is provided with chilled water cooling coil to control the dry bulb temperature inside the chamber. The supply air to he chamber distributed by duct system and two diffusers. The indoor air temperature is maintained by room thermostat located inside the chamber.

Instrumentation and control – The temperatures inside and outside refrigerator are measured by calibrated CA thermocouple probes of 1.0 mm in diameter, which are inserted in the center of tinned copper cylinder having diameter = height = 15.2 mm. The temperatures are recorded using automated data acquisition. The relative humidity inside the chamber are measured by calibrated psychrometer. The electrical energy consumption is obtain using calibrated digital power meter with 1% accuracy. The synchronous clock is used to measuring the running time of the compressor (on/off cycles).
Linear dimensions is measured to the nearest millimeter using calibrated ruler.

TEST PROCEDURE

The general test conditions were done in accordance with ISO 7371 (E) 1995 [3], but with the following deviations.
The ambient temperature for all climate classes is 30 °C.
The electric power supply is 220 ± 1 % at 50 Hz ± 1 %.
There is no load in the freezer compartment during the test.

Installation of refrigerators - The refrigerator is placed in the testing chamber as shown in Fig. 1. The refrigerator is placed on a wooden solid-top platform, black painted, open for free air circulation under the platform. The top of the platform is 0.30 m above the test chamber floor and can be extend at least 0.30 m beyond all sides of the refrigerator, except at the rear where it extend to vertical position. Circulation of air around the refrigerator is restricted by surrounding the refrigerator by three vertical partitions. One of the partitions is placed parallel to the rear of the refrigerator, and two other partitions are parallel to the side of refrigerator, fixed on the platform with the distance 30cm from the sides of the refrigerator.

Volume of refrigerators – Gross volume is the total volume within the inside walls of appliance, without internal fittings, doors or lids being closed. Storage volume is the part of the gross volume of any compartment which remain after deduction of the volume of components and spaces recognized as unusable for the storage of food. Total storage volume is the sum of the storage volumes of the fresh food storage compartment, chiller compartment, ice making compartment and frozen food storage compartment.

Determination of gross volume - The gross volume of refrigerator is calculated by dividing the total volume into convenient units of volume of geometric shape which can be easily measured.

Measurement of the temperature of the fresh food storage compartment – The temperature t_1, t_2 and t_3 are located at sensing point T_1, T_2 and T_3 as shown in Fig. 2, half way between the rear internal wall of the refrigerator and the internal wall of the closed door. The fresh food storage temperature is t_m, where t_m is the average of the mean temperature t_1, t_2 and t_3.

Measurement of the temperature of the frozen food storage compartment – The temperature of the frozen food compartment is t_f, and located inside the compartment as shown in Fig.2.

Measurement of the ambient temperature – The temperature in the space surrounding the refrigerator is the arithmetical mean of the mean value of the temperatures t_{a1} and t_{a2}, measured at two points as shown on Fig.3.

Determination of the energy consumption – The energy consumption will be that corresponding to one of the temperature conditions given under a. to d. in Table 1.

Table 1. Different possible storage temperature conditions for determining energy consumption

Value in degree Celcius

Temperatures	Storage temperature conditions			
	a	b	c	d
t^{***}	- 18	≤ - 18	≤ - 18	≤ - 16
t^{**}	≤ - 12	- 12	< - 12	< - 12
t_m	≤ + 5	< + 5	< + 5	< + 5
t_{cm}	≤ + 12	< + 12	< + 12	+ 12
Note – If there are any "two star" sections or "one star" compartments, the temperature conditions for these sections or compartments shall be – 12 °C or below, or – 6 °C or below, as appropriate.				

The energy consumption can be determined either at one of the characteristic temperatures or by interpolation from the results of two tests, one giving a temperature warmer than and one colder than the characteristics temperature of t^{***} = - 18 for condition a., t^{**} = -12 for condition b., t_m = +5 for condition c., t_{cm} = +12 for condition d. in Table 1.

In the case of two tests, the results will be interpolated to meet the requirements of one of the conditions a. to d. (See Ref [3] Fig.6 for further detail).

TEST RESULT

The energy consumption test of the refrigerators were performed at the Refrigerator Testing Laboratory University of Indonesia Jakarta. Tests were done in the test chamber under the mean ambient temperature of 30 °C ± 1 °C at 65 % ± 5 % relative humidity. The refrigerators being tested has the following specification : household single door refrigerator, manual defrost and has the range of capacity between 145 litres to 155 litres. The energy consumption of refrigerators were calculated using standard ISO 7371 [3]. There were seven model of unmodified refrigerators using CFC 12 and seven model of HFC 134a from seven different manufactures being tested. The average values of the energy consumed of each model are shown in Table 2.

Table 2. Energy consumption (kWh/24h) of refrigerators
Typical capacity 150 litre, manual defrost, single door

Refrigerant	CFC-12	HFC134a
Brand A	1.0521	1.1913
Brand B	1.224	1.3874
Brand C	1.0873	1.1151
Brand D	1.0854	1.1532
Brand E	1.0877	1.1894
Brand F	1.0342	1.1353
Brand G	1.1132	1.1813

The test results for energy consumption of CFC 12 and HFC 134a refrigerators of each manufacturer are graphically represented in Figure 4. From the results it can be seen that the energy consumption of the HFC 134a are higher than refrigerator using CFC 12, except the refrigerator assembled by brand B is lower. The differences in capacity , power of compressors and foam insulation of each refrigerator may have contributed to the different results of energy consumption. The energy consumption differences were between 2 to 16 %.

CONCLUSION

The HFC-134a refrigerator consumed more energy than of CFC-12 under the test conditions from ISO. It is clear that HFC-134a was developed by chemical industry to replace CFC-12 in various application. The main advantage of HFC 134a in comparison with CFC-12 is no ozon depleting characteristics. However, HFC-134a has more technical disadvantages in compare to CFC-12.. It is therefore recommended to reconsider the conversion of HFC-134a to CFC-12 as alternative refrigerant in refrigeration technology.

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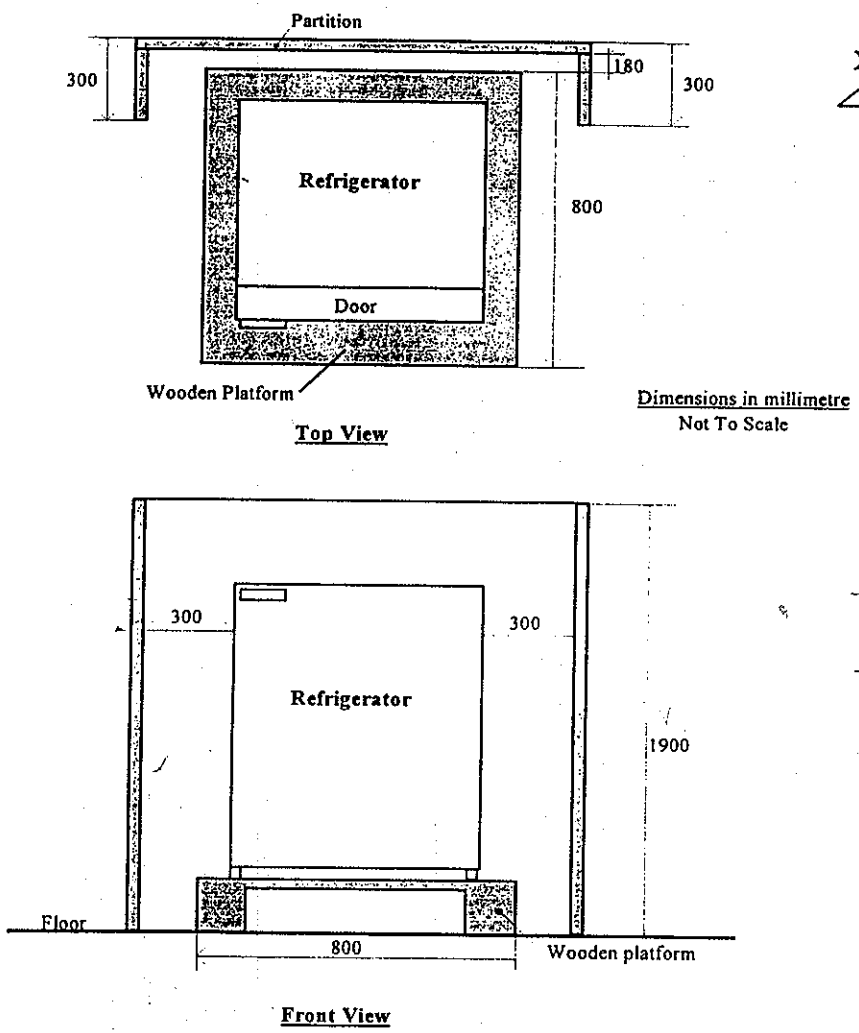

Figure 1. Installation of refrigerator

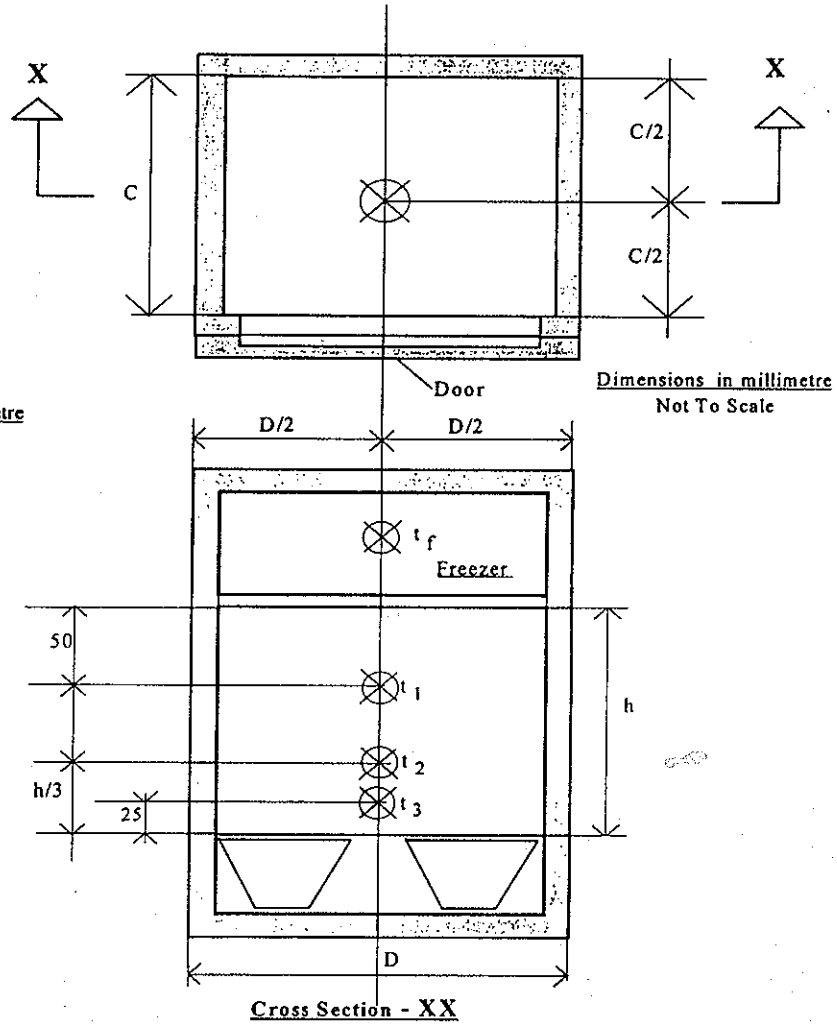

Figure 2. Temperature measurement points inside refrigerator

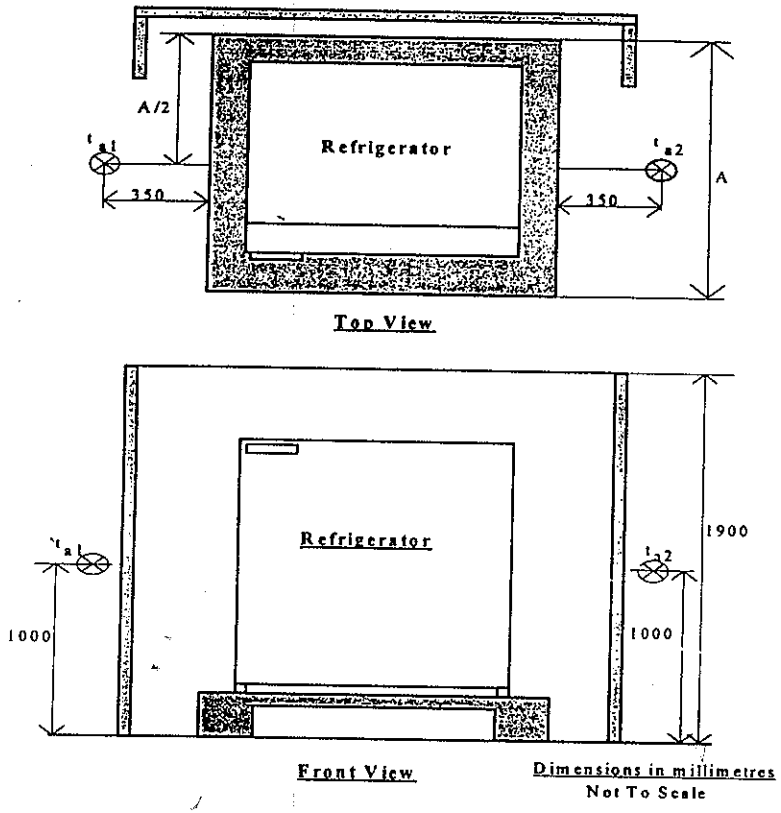

Figure 3. Temperature measurement points surrounding refrigerator

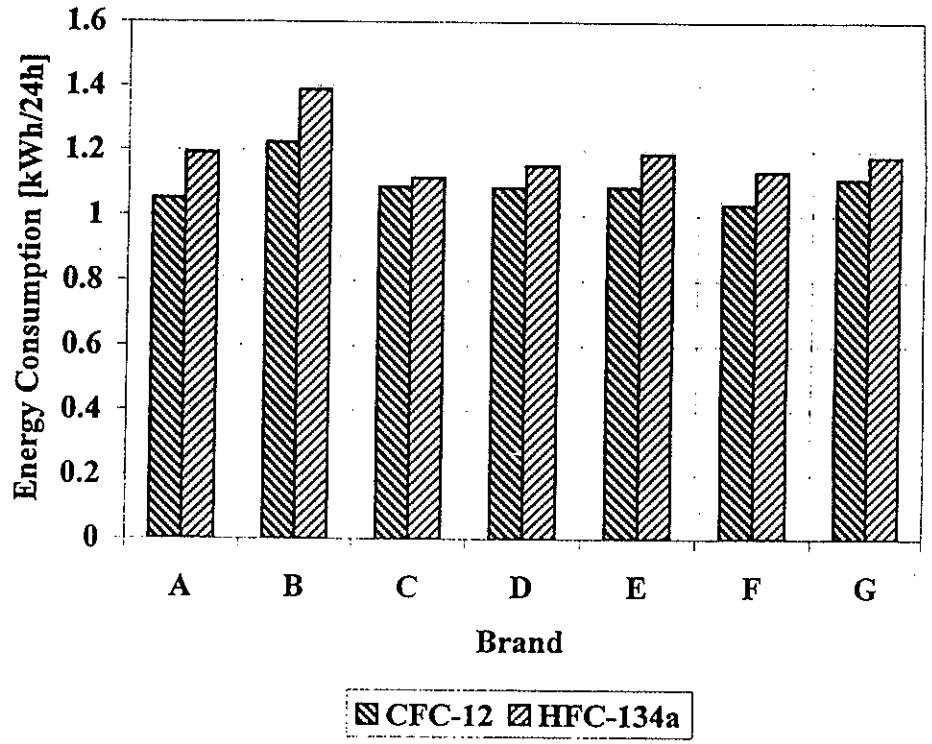

Figure 4. Comparison of energy consumption