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RELIABILITY IMPROVEMENT IN DOMESTIC USE REFRIGERATION: THE NIGERIAN STOCK

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ABSTRACT
Most domestic refrigeration used in Nigeria contains significant quantities of ozone layer depleting CFCs such as RI1 and R12. This has led to the increasing evaporation temperature and low refrigeration cycle coefficient of performance. This paper takes a look on how performance of house use refrigerators can be enhanced using new compound of $C_2HF_2CL_2$ and $C_2H_2F_4$.
Keywords: *Compressor, Evaporator, Refrigerant, Refrigerator, Temperature*

INTRODUCTION
Refrigeration systems typically account for about 25 % of domestic appliance electricity usage [l]. Domestic refrigeration are used for the preservation and storage of food, either at chilled temperature (3°C to 5°C) or frozen temperature (-15°C to -20°C). There are four basic types of refrigeration appliance [2].

- Refrigerators store chilled food and have a small frozen food ice box within the cabinet.
- Larder refrigerators only store chilled food.
- Freezer is used for freezing and storing frozen food.
- Fridge-freezers have approximately equal space for chilled and frozen food in a 2 door unit.

Refrigeration can also be used for air — conditioning applications. However, in the Nigerian climate such usage is negligible and air-conditioning is not addressed in this paper. Almost all domestic refrigerators are electric. The once popular gas fired absorption system is now only used in special situations such as boats or caravans. Construction of domestic refrigeration appliances shows little variation. In all cases manufacturers use hermetic compressors, a steel outer shell, polyurethane (PUR) foam, which is currently blown using CFC R11, a plastic inner shell and magnetic door sealing strips [2]. The insulated cabinet thus created is cooled using either absorption or a vapour compression refrigeration cycle. This paper discusses only the vapour compression refrigeration. The main electricity using component is the compressor which ranges in power between 50W for a small refrigerator and 150W for a large freezer. The electricity is all used to keep the refrigerated space at the correct temperature. Over 80% of the load comes through the walls and door insulation. The remaining load is equally split between warm air infiltration (during door opening) and cooling of products placed inside the fridge Clearly the key to domestic refrigeration efficiency are to minimize the heat loss through the walls and maximize the efficiency of the refrigerant circuit. It is important to note that when a domestic refrigerator is used in a commercial environment such as a restaurant, the heat load created by air infiltration becomes much more signifiean1 because of frequent door opening [2].

Vapour Compression Refrigeration Cycle

The vapour compression system makes use of the fact that a liquid's boiling point increases with pressure [2]. The vapour compression refrigeration cycle, shown in figure 1 has a pressure and hence low temperature (- 18°C to -30°C) liquid refrigerant (usually CFC R12) passed through the refrigerator evaporator which is located within the insulated cabinet. As the refrigerant temperature is much less than the cabinet temperature, heat is transferred from air within the insulated cabinet to the refrigerant. At the low pressure within the evaporator this heat transfer causes the refrigerant to boil. Gaseous refrigerant then passes to the compressor where its pressure is increased. The compression process also increases the temperature of the refrigerant to well above cabinet temperature. The high temperature and pressure refrigerant enters a second heat exchange (the condenser) which is often mounted on the rear external surface of the refrigerator. Heat is then transferred from hot refrigerant gas to the cooler surrounding air; this cools thee refrigerant which condense. The condensing temperature is much higher than the boiling point of low pressure liquid which enters the evaporator. The work required to compress the refrigerant gas from low to high pressure depends on the pressure difference. In order to minimize the power requirement of the compression process the evaporating pressure (and temperature) should be as high as possible, and the condensing pressure (and temperature) should be minimized.

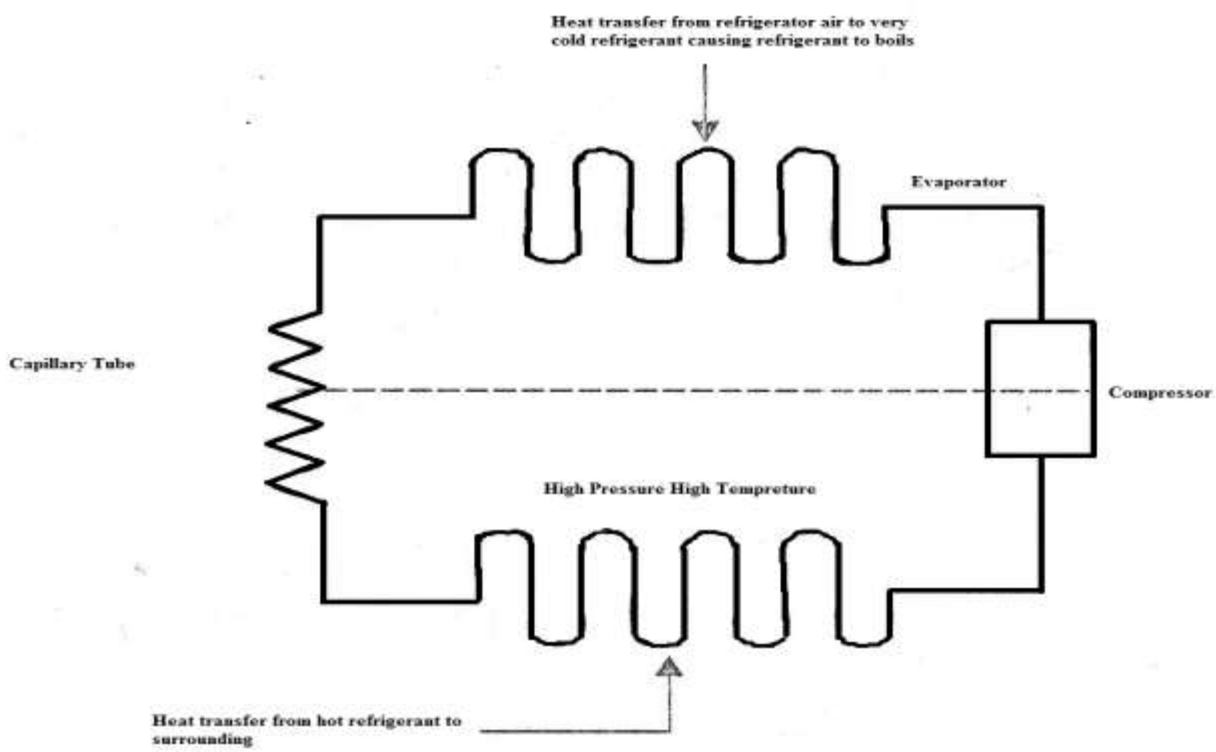

Figure 1.1 Vapour Compression Refrigeration Cycle

Technical Development

The function of a refrigeration appliance is to maintain a storage space at a lower temperature than its surrounding. It then follows that to improve the appliance efficiency we should take actions to reduce the heat gain of the cool space to increase the efficiency with which that space is cooled.

Current and Potential Refrigerants Used in Domestic Refrigeration Appliance

The names, and formulae of refrigerant referred to in this paper are listed in table 2.1.

Table 2.1 Refrigerant in Domestic Refrigeration Appliances

Reference	Name	Formula
R11	Trichlorfluoromethane	$CFCL_3$
R12	Dichlorodifluoromethane	CF_2CL_2
R123	Dichlorotrifluoroethan	$C_2HF_2CL_2$
R134a	Tetrafluoroethane	$C_2H_2F_4$

Source: [3]

At the time of writing, most refrigeration appliances offered for sale in the Nigeria market contain significant quantities of ozone-layer depleting CFC's of two types [3]. CFC R11 is used as a blowing agent in the expansion of polyurethane (PUR) insulation foam between inner and outer cabinet during manufacture.CFC R12 is employed as the refrigerant in the domestic appliance vapour co Impression refrigeration cycle. The environmental requirement to eliminate the use of these CFC' s in order to reduce future damage to the ozone layer will lead to the substitution of Ru and R12 in refrigerator manufacture by other compounds such as R123 in place of Ru and R134a in place of R12.

However, the use of these new compound will each reduce efficiency by 6-8%; the combined penalty of about 15%. These estimates assume a basic substitution of chemicals and do not account for optimization of appliance design which would follow such a change. Such optimization could reduce or eliminate this penalty [3].

Insulation

The graph Figure 2.1 shows how the static heat gain of a 200 litre larder refrigerator depends upon the insulation thickness. From the graph, it is clear that increasing insulation thickness is a well-known route to a low energy consumption product.

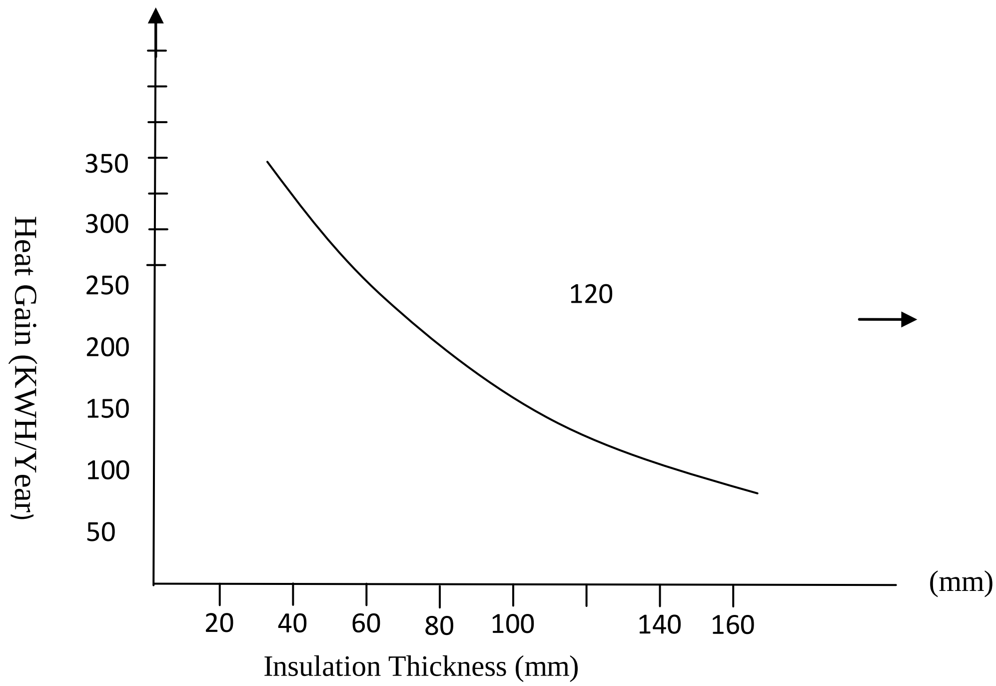

Figure 2.1. Heat Gain of 200 liter Larger Refrigerator

Evaporators

The relationship between coefficient of performance (COP) and evaporatingtemperature is shown in figure 2.2. increasing the evaporating temperature from 40°C to 5°Cwill increase compressor COP from 0.4 to 1.64 well over three times. Figure 2.2 shows apicture of this phenomenon using a Danfoss TL4A compressor

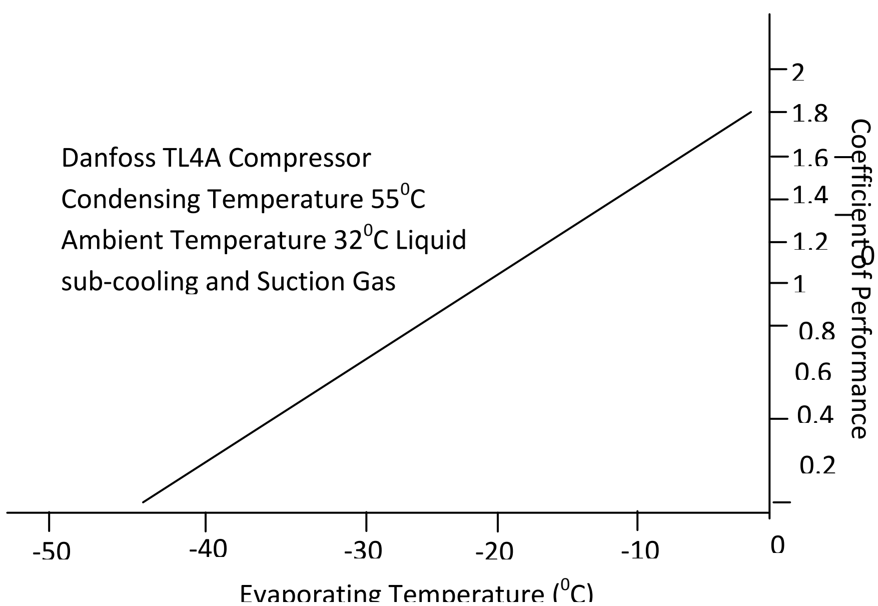

Figure 2.2. Evaporating Temperature on Coefficient of Performance

Table 2.2. Development of Energy Efficient Refrigeration Using a 140 Litre Refrigerator that Consumes 25OKWh of Electricity Annually

Measure	**Per Annum Energy Saving**		**Comments**
	%	**KWh**	
Increase insulation thickness from 30mm to 42.5mm and reduce R11 content of insulation by 50%	17	60	Already done as a preliminary step towards CFC elimination
Double evaporation	29	100	Most refrigerator evaporators are very small leading to very low evaporating temperature
Increase insulation thickness to 70mm	49	171	Greater wall thickness imply loss or amenity: either machine is 55mm larger on each external dimension
Substituting existing compressor by a high efficiency model.	25	88	-

D1SCUSIONS

The future use of refrigerant R12 has been taken into great consideration by refrigeration's manufacturers. The CEC member states have stated their intention to cease production of ozone damaging CFC's by the year 2000. At present it is expected that R134a will be used as an alternative refrigerant. Although this refrigerant change will lead to a theoretical efficiency penalty of 6 — 8%, early indications are that the compressor design changes made to use the new refrigerant will overcome this penalty. Efficiency improvement will be taken in the form of ozone friendliness rather than electricity saving The condition under which the compressor is required to operate will have a major significance upon the refrigeration cycle COP. If the refrigeration cycle COP is to be maximize L then the temperature increase of refrigerant between evaporating and condensing temperature should be closely to ambient. Hot gas bypass through the capillary and large pressure losses in heat exchangers should be avoided. Cycle efficiency will also be enhanced if condensed liquid is sub-cooled before expansion.

The Danfoss performance data shows that sub-cooling of condensed refrigerant from 55°C will result in a 20% increase in COP. Also large condensers with good heat exchange and which permits liquid sub-cooling are preferred. It is possible to use condenser fans to increase heat transfer rates, although they may lead to problems of dust and grease fouling of the condenser surface, and may themselves need maintenance. Where they are used (large freezers) cooling capacity can be increased by 20% and the compressor size can be reduced by around 25%; when fan power is taken into account a net efficiency improvement of 15% is achieved. Table 2.2. Shows how adoption of some of the measures discussed could improve the performance of the typical refrigerator in the Nigerian climate. In the table the saving figures quoted for each measure consider the effect of that measure in isolation.

CONCLUSION

It has been shown that over 80% of the heat load, of the refrigeration appliance is through the insulation. Optimization of insulation can be achieved by the use of materials with higher insulation thickness. For example, the use of an insulation thickness of 70mm will be very much preferable for a low energy refrigerator than a 30mm or 40mm insulation thickness. Efficiency improvement can further be achieved by the use of R134a refrigerant in place of R12 and R123 refrigerant in place of R11. The use of these novel refrigerants will help to minimize the ozone damaging CFC's.

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