POWER CONSUMPTION IN ROOM (SPLIT) AIRCONDITIONING USING ALTERNATIVE REFRIGERANT R-600a

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Abstract

In this age of rapid economic development India is in need of huge of amount of energy including electricity. The prohibitive cost of setting up of new facilities for production of electricity led to the introduction of various means for saving electricity at every front. Airconditioners are huge consumers of electricity. So, reduction in use of electricity in airconditioner could be very much beneficial to the cause of the nation. At the same time all measures are being taken to save the environment from the hazards of global warming producing chemicals and burning of fossil fuels. All these purposes could be met by introduction of hydrocarbon refrigerants like Isobutane (R-600a). As such in the present work tests have been conducted to measure the saving in electrical energy when the existing-22 gas (refrigerant) is replaced by R-600a as refrigerant in the same system. It is found that substantial saving could be achieved in the consumption of electricity by this replacement without compromising the basic cooling effect. However, the flammability factor of R-600a is to be properly taken care of.

Keywords: *refrigerant, alternative, electricity, consumption, isobutane, Montreal protocol, ozone depletion, global warming, flammability*

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1. INTRODUCTION

Airconditioners are huge consumer of electricity. Hence many research works are going on to explore the possibility of reducing the energy consumption to some extent.

Annual air conditioner sales in the EU are expected to grow from 4.9 million units in 2005 to almost 10 million by 2020. At the same time the stock will increase from around 40 million units to 110 million installed air conditioners [Riviere et al,2009]

Power generation in India began more than a century ago in 1898 when the first hydro power unit was set up at Darjeeling. When India achieved freedom in 1947, the country had an installed capacity of 1,360 MW. But as of September 2012, The electricity sector in India has an installed capacity of 207.85 Terawatt (TW), the world's fifth largest [Central Electricity Authority, GOI, 2012].

Though the achievement is sizeable, but considering the rapid development that are taking place in India, it will have to achieve within next 10 years more than what it achieved in last seven decades.

Energy is the indispensible part of development. The limited energy access is reflected,(as shown in Figure 1.1 below), in the relatively low Human Development Index of India.[MoEF, GOI]

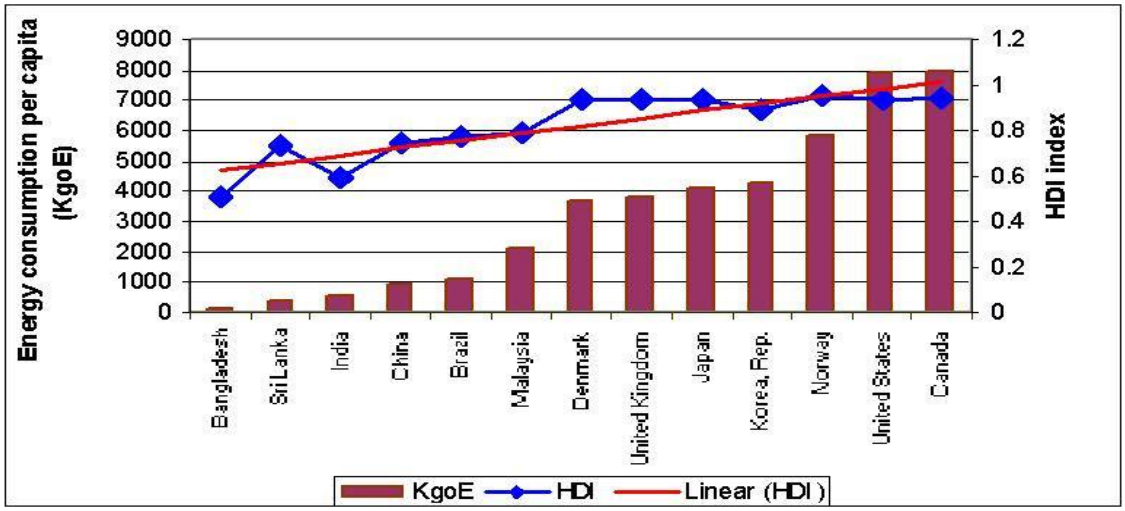

Fig. 1.1 Energy consumption is a prime driver of the Human Development Index. [source: MoEF,GOI]

2. LITERATURE SURVEY

Literature survey was done to find the previous research in this field.

Farzad et al,1993 experimented the effect of expansion device on airconditioners system performance characteristics.

Rodriguez,1995 mentioned different tests of effects of ambient temperature, evaporator airflow rate etc and also conducted two tests on effect of refrigerant charge by changing the amount of charge on 3 ton and 3.5 ton airconditioners

Chris Neme et al 1999. discussed the possibility of saving energy in residential airconditioners by solving problems of installation of these units, where they specially focused on four factors viz. equipment sizing, refrigerant charging, ensuring adequate airflow and sealing ducts properly. They concluded that proper installation, servicing and maintenance can improve 17% energy efficiency.

Shen et al, 2006 described the impact of non uniform refrigerant mass flow in evaporator of airconditioner using R-410A and R-407C as refrigerants.

Kopecka et al, 2013, tested the performance and efficiency of airconditioners using alternative refrigerants.[85a]

3. R-600a AS ALTERNATIVE REFRIGERANT

Use of freons as refrigerant is to be stopped mainly due to their adverse effect of depletion of ozone gas in the atmosphere. CFC gas in refrigerators has already been stopped before 1st January,2010. However the HCFC gas is allowed as refrigerant of airconditioners till 2030 due to its comparatively less harmful affect on ozone [table 1.1].

Albert Einstein actually came up with the idea of an eco-friendly refrigerator and patented one in 1930s with his colleague Leo Szillard. The design was partly used in the first domestic refrigerators, but the technology was abandoned when more efficient compressors became popular in the 1950s. The refrigerator patented by Einstein and Szilard's did not use freons.

The refrigerant which is being used in room airconditioners extensively since 1950s is hydro-chloro-flouro-carbon (HCFC) or commonly called as R-22. However, one MoU among almost all the countries in the world signed on 16th September,1987 at Montreal, Canada and known as Montreal Protocol decided to permanently stop use of R-22. This is done to save the ozone layer of the Earth, which is the protective layer around the earth lying at 10 to 50 km above earth surface and protecting the earth from the harmful UV-B rays of the sunlight.

As a result of Montreal Protocol (1987) and subsequent Meeting of Parties (2007), all HCFC refrigerants including the most common refrigerant R-22 are going to be replaced by alternatives and R-22 will be completely stopped by 2030. The phase of reduction of production of HCFC refrigerant is shown in Fig1.2 Project HPMP (HCFC Phase-out Management Plan) under Ministry of Environment and Forestry, govt. of India and being implemented all over the country with support from GTZ, Germany (Gesellschaft fur Internationale Zusammenerbeit)

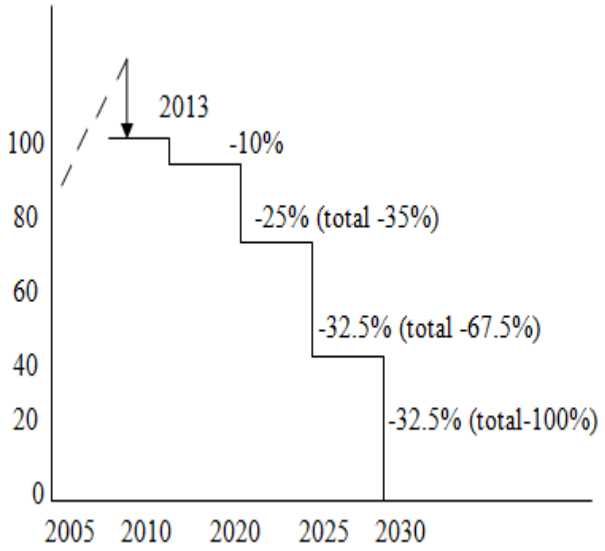

Fig. 1.2 Reduction of production of HCFC by year (base year 2009-10)

As the production of R-22 began to reduce as per Montreal Protocol, from 2013 and likely to be completely stopped by 2030 as shown in Fig. 8.1, there is hectic search for a good alternative to R-22.

Many alternatives are being experimented around the world. The main alternatives are in the group HFC (hydro-fluoro-carbon) and HC (hydro carbon). Though some other alternatives like CO2, air etc are also in the list but due some technical reasons, the alternative refrigerants in the HFC and HC groups are experimented more seriously and some are already being used by many manufacturers.In the HFC group the widely experimented and used refrigerants are R-410A, R-407C, R-404A etc. In the HC category the refrigerants, which are under consideration are R-600a, R-290 etc.

While selecting an alternative refrigerant, apart from the performance of the refrigerant in the system, their Ozone Depleting Potential and Global Warming Potential are also taken into consideration. However, under Montreal Protocol, the first priority is to remove all chemicals (read refrigerants) having ODP. The list of different alternative refrigerant with their ODP and GWP are shown in table 1.1.

Table 1.1 Ozone depletion Potential (ODP) and Global Warming Potential (GWP) of different Refrigerants (source: HPMP slides)

Refrigerant		Atmospheric Lifetime (Years)	ODP	GWP (100 Year)
CFC	CFC-11 (Baseline ODP)	50	1	4000
	CFC-12	102	1	8500
CFC Blend	R-502		0.33	5260
HCFCs	HCFC-22	13.3	0.055	1700
	HCFC-123	1.4	0.02	93
	HCFC-141b	9.4	0.11	630
HFCs	HFC-134a	14.6	0	1300
	HFC-152a	1.4	0	120
	HFC-245fa	7.3	0	820
Natural Fluids	HC-290 (Propane)	-	0	3
	HC-600a (Isobutane)	-	0	3
	HC blend	-	0	3
	R-744 Carbon Dioxide	-	0	1
HFC Blends	R-404A	-	0	3260
	R-407A	-	0	1770
	R-407C	-	0	1530
	R-410A	-	0	1730

From table 1.1 , it is obvious that hydrocarbon refrigerants like R-290 (propane), R-600a (isobutene) etc. , which are classified as natural refrigerants have ODP zero and very little GWP. Hence from environmental point of view these are very good refrigerants. As such it is decided to test the power consumption pattern of a hydrocarbon refrigerant R-600a in a split room airconditioner.

Another reason of selecting HC refrigerant for testing is that the typical charge quantity used in units using hydrocarbon like propane, is approximately 0.10 kg kW^{-1} compared to 0.25kg kW^{-1} for R-22 [ACRIB,2001]. The reduced amount of refrigerant leads to reduction in energy consumption and at the same time it is environment-friendly.

4. THE TESTS AND RESULTS

The tests and their results are given in section 4.1 and 4.2

In this research work a few tests were performed to measure the energy consumption pattern in the same airconditioner in which all tests were done, by changing the refrigerants in different amount.

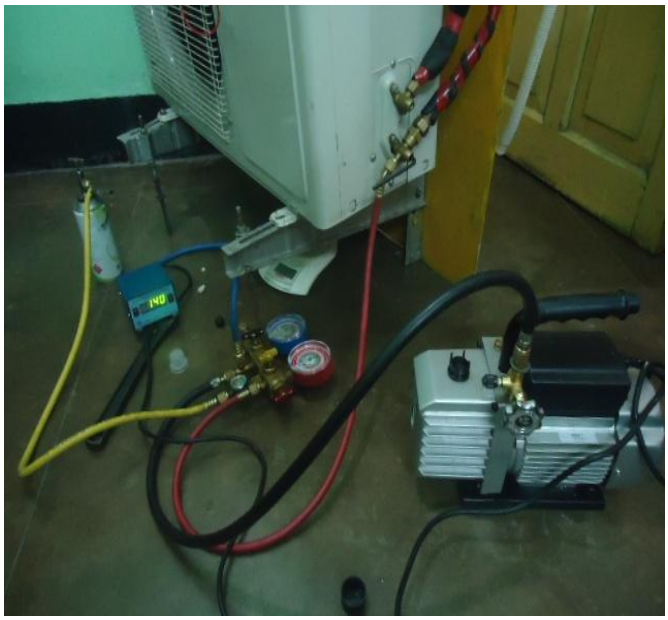

Fig 1.3 Setup for evacuation of the airconditioner and charging R-600a

4.1 Tests for Energy Consumption at Different Charges

At first the refrigerant is changed from R-22 to R-600a, which is a hydrocarbon refrigerant and as such miscible with the mineral oil used with R-22. The amount of hydrocarbon gas is only 40% of the amount of R-22 [HPMP] and as such 236 gm (40% of 590gm) of R-600a is charged in the system.

Before charging the refrigerant R-600a following steps were conducted as per norms.

(i) recovered the existing R-22 refrigerant using recovery machine.
(ii) system is evacuated to 200 micron using two stage rotary vacuum pump with blank-off pressure of 10 micron.

After charging the system with R-600a refrigerant, leak test was done by nitrogen gas of 99.9995% purity.

Thereafter the connections are made through the wattmeter to the power supply. Thermostat is set at 16^0C. Ambient temperatures are taken as 27^0 C, 32^0C and 33.1^0C to verify its stability.

Though ambient temperatures were maintained with the help of room heaters, but humidity was not controlled as the present work was aimed to study the behaviour of the system at field condition where there will be no humidity control. The ambient temperature variation was kept within $\pm 0.5^0$C.

The results of one set of such test is given in graphical form in Fig.1.4 using R-600a and R-22 as refrigerants

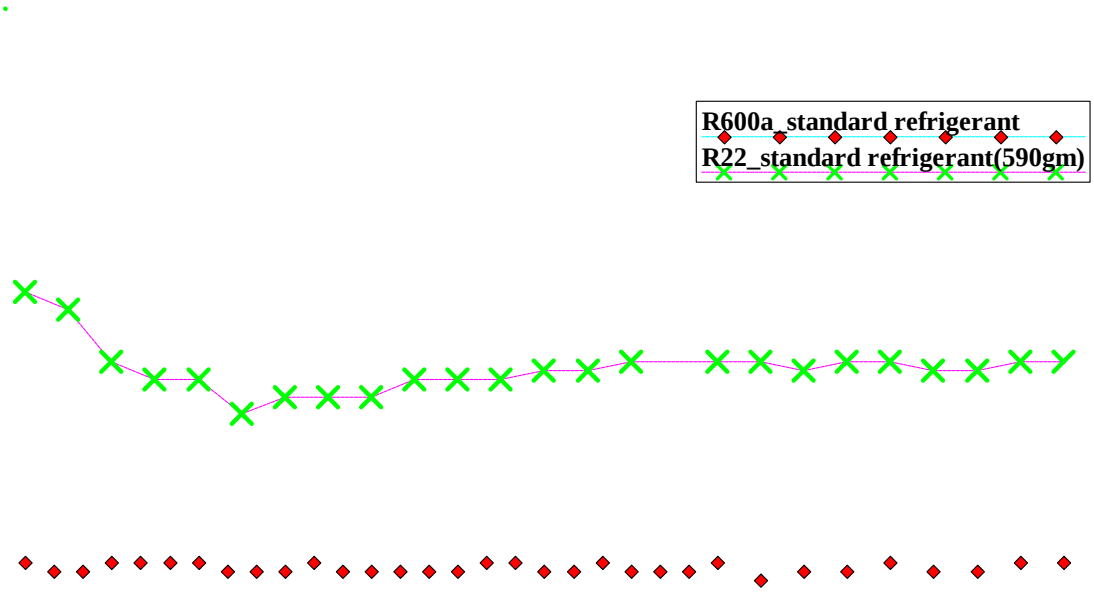

Fig. 1.4 Graph showing the power consumption by split airconditioner with different refrigerant

4.2 Energy Consumption with R-22 and R-600a as Refrigerant in the Same Airconditioner.

From the graph 1.4 for 8 months (240 days) running @ 8hrs per day,

The power consumption with R22 refrigerant standard (590 gm)

= 241350 Watt.minutes
= 241350 X 8/6 X 240 /60000
= 1287 kWHr

The power consumption with R600a = 159604 watt.minutes (for 6 hours)

= 159604 X 8/6 hrs X 240 days /60000
= 851 kWHr per annum

It is observed that power consumption is sufficiently low when R-600a is used as refrigerant. It is safe from environmental point of view as well. However its problem is that being a hydrocarbon it is flammable and so extra care is required while using it as a refrigerant.

4.3 Cost of Power Consumption in Room ACs

An estimated 358 million air-cooled air conditioners (cooling and heating) are installed worldwide, [Butrymowicz et al 2005] which is consuming a huge amount of electricity.

Calculating the annual cost of power for an air conditioner:
Air conditioner sizes are often given as "tons" of cooling where 1 ton of cooling is being equivalent to 12,000 BTU/h (3.517 kW). This is approximately the power required to melt one ton of ice in 24 hours. The annual cost of electric power consumed by an airconditioning unit may be calculated as follows

Actual consumption per hour X No of hrs per day X 240 days per year
X cost of electrical energy per kWHr (1.1)

From equation 1.1and graph 1.4, the cost of electricity and subsequent saving in the use of R-600a can be calculated

Considering 8 hours a day use for 8months or 240 days a year and the existing tariff of electricity in Guwahati, the cost of consumption are shown below

Using R-22 as Refrigerant

Energy consumed in 6 hours = 241350 watt.minutes
241350 watt minute/60000 X 8/6 X 240 X Rs. 5.74/kWHr = Rs.7387 per year

Using R-600a as Refrigerant

Energy consumed in 6 hours = 159604 Watt.minutes
i.e. 159604 /60,000 X 8/6 X 240 days X Rs.5.74 = Rs. 4886 per year

Table 1.2 Difference of consumption and cost in R-22 and R-600a

Refrigerant	Consumption per year (kWHr)	Cost of consumption (Rs.)
R-22	1287	7387
R-600a	851	4885

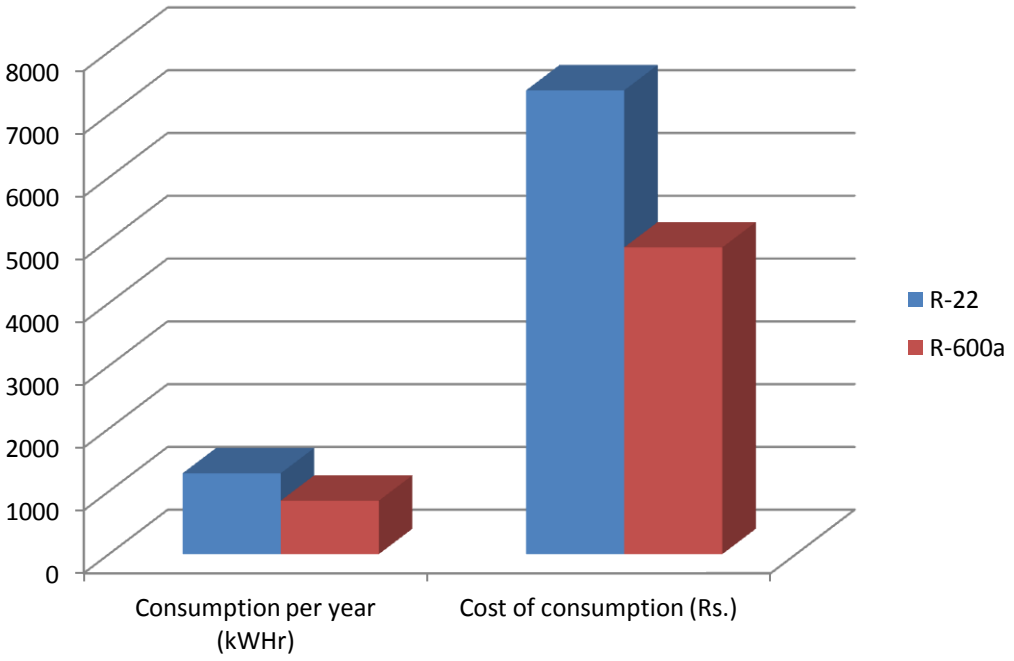

Fig 1.5 Comparative bar diagram showing saving in consumption of electricity and cost

5. CONCLUSION

From the above tests it is observed that a substantial amount of energy (and cost) is saved by using R-600a as refrigerant in place of R-22. At the same time it is an environment-friendly refrigerant, which can be released into the atmosphere without causing any harm to the environment. The performance of cooling is almost same as that with R-22. However, the problem is that R-600a, being a hydrocarbon gas is flammable. As such it is not allowed to be used in refrigerators and airconditioners, especially in mobile airconditioners in many European countries.

But now-a-days many safety features are available to contain this effect.

Since R-600a is compatible with mineral oil, which is used with R-22 as well, so R-600a could be considered seriously as a drop-in substitute for R-22.

Table 1.3 The safety designation (flammability) and GWP (environmental effect)

Refrigerant	Safety Designation	GWP(100 years horizon)
R600a	A3	3
R22	A1	1700

As shown in Table 1.3 the refrigerant R-22 is safe from the point of view of flammability hazard but have high Global warming potential threatening the environment. On the other hand refrigerant R-600a is comparatively safe for the environment (GWP 3 only), but is considered as highly flammable (A3). Hence, the safety features against possibility of fire must be properly taken while using R-600a as refrigerant.

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