*International Journal of Application or Innovation in Engineering & Management (IJAIEM)*
**Web Site: www.ijaiem.org Email: editor@ijaiem.org**
**Volume 11, Issue 6, June 2022** **ISSN 2319 – 4847**

# Evaluation and Safety of HC Refrigerants Used in VCR System

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**Abstract**

There is no ozone depletion or global warming with HC (Hydro Carbon) refrigerants, although they are extremely combustible. New freezers in Oman employ R600a, and many warm-temperature pumps and air conditioners now use R290, which consumes 5 to 25 percent more electricity than R-12, R-134a, or R-22 (CFC) (HCFC). A/C systems that use the refrigerants R-12 and R-134a have been successfully adjusted using HC combinations (AC). R-12, a chlorofluorocarbon refrigerant, is needed to combat ozone depletion and global warming. There is no ozone depletion or global warming with R-134a hydrofluorocarbon since it is nonflammable and difficult to distribute.

Using R-12 and then HC, we measured the total AC performance of five different samples in our lab. 60 percent of propane and 40 percent of butane come from the general market. This provided an average of 15% more cooling capacity than R-12, despite the higher superheat and, on average, 10% better condenser pressure.

For a domestic refrigerator, the increase in insurance risk due to HC flammability is zero. Due to the high rate of R-12 and R-134a maintenance, the increase in car air conditioning is abysmal. When it comes to large constructions, the air flow of plant rooms as well as special measures for hazardous materials (HC) might increase or worsen the risk of insurance.

R-600a has half the leakage, stress loss, and condenser pressure of R-12 and R-134a, but quadruple the transmission of warm temperatures. This explains why R-600a freezers save money on energy use. It may be necessary to rethink heat pumps and car air conditioners to accommodate R-600a.

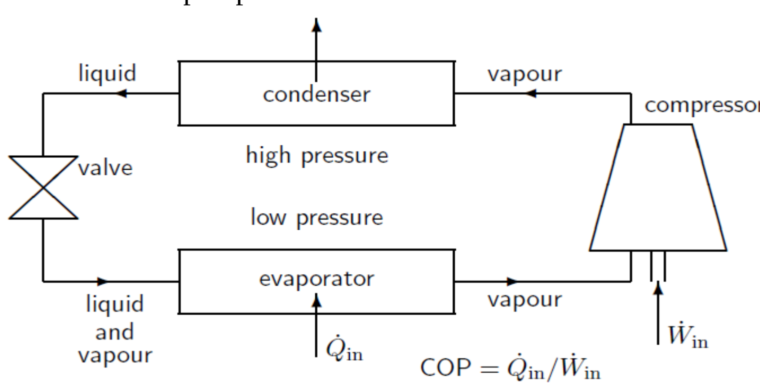


**Figure 1:** layout of vapor compression refrigeration (VCR) cycle.

**History of Refrigerant**

Evaporator efficiency (COP) is the ratio of heat absorbed by the evaporator to the amount of power being delivered to the compressor by the compressor. Excessive COP reduces pollution by reducing the amount of power needed to perform a task. Figure 1 roughly depicts the four components of a vapor compression cycle. Condenser heat is used to cool and liquefy vapor as it passes through a compressor, which is powered by a motor. This combination of liquid and gas is heated in an evaporator and then returned to the compressor via the valve or limit.

However, centrifugal compressors (Austin 2012) necessitate refrigerants of excessive molecular mass, despite being inexpensive, shockingly green, and simple to stress with sealed automobiles. Air conditioner centrifugal chillers offered CFCs a first market that could find the money for their excessive upgrading costs. As a refrigerant, Thomas Jr. suggested using chlorofluorocarbons (CFCs). He had already gained a reputation as a research engineer for General Motors, where he was responsible for offering the addition of bring about gasoline. CFCs are excellent refrigerants because of their high molecular weight and lack of flammability.

Hermetic motors have been installed in all small and large compressors, reducing the risk of refrigerant leaks. Many of the first refrigerants were dangerous to handle since they were either poisonous or combustible, or both. Early refrigerators quickly spilled refrigerant, especially through the seals on the compressor stress shaft, producing a hearth place and health risk. Early refrigerators. When a hermetic motor is used, there is no shaft seal that can leak refrigerant (Bilal 2005) Everything was changed to say that flammable refrigerants or propellants caused terrible flames and explosions, which everyone agreed with. The use of ammonia, HC, and precise refrigerants in residential constructions was eliminated. The rapid expansion of CFC revenue in applications where more advanced alternatives already existed was made possible by enthusiastic promotion of their lack of flammability.

**Impacts of Environment**

CFC-induced stratospheric chlorine is considered to be at least in part responsible for the stratospheric ozone depletion observed at the poles. CFCs are no longer being produced or imported at high-ranking sites across the world. Akas (2003) said that " CFCs have been accountable if these modest consequences fade after fifty years, but if they worsen or continue, they are no longer the only culprits. Chlorine emitted into the stratosphere catalyzes the degradation of ozone into oxygen, and UV light reaches lower altitudes as it travels through the stratosphere. Three percent worldwide ozone depletion for typical CFC emissions of 800000 tons / year is required for credible estimates of this effect's value to emerge. a century has passed.

A unique time's ODP is the ratio of ozone destroyed by 1 kg of material discharged promptly into the ecosystem to that destroyed by 1 kg of dichlorodifluoromethane (a potent greenhouse gas) (R-12). To put it another way, the global warming potential (GWP) for a certain time period is the ratio of 1 kilogram of material discharged to the surroundings to 1 kg of carbon dioxide. ODPs and GWPs are incorporated into international control agreements, and GWPs may be applied to future taxes as well. Values are shown in Table 1. Carbon dioxide interest within the environment has been developing grade by grade for at least the last century. The rise in Earth's temperature has been attributed to carbon dioxide radiation houses since the turn of the century. In comparison to carbon dioxide, CFCs have radiation effects that are hundreds of times worse (Table 1). Cities and nations all around the world are being submerged as a result of rising global temperatures. CFCs became an extraordinary reason for the eradication of CFCs because of their role in global warming. However, while the magnitudes of ozone loss and global warming have been referenced most frequently, the relative effects of other chemicals exposed to the environment have been more accurately described.

**Table 1:** Environmental impacts of refrigerants (one century year basis).

| Refrigerant | R-12 | R-22 | R-134a | R-600a | RC-270 |
|---|---|---|---|---|---|
| Class | CFC | HCFC | HFC | HC | HC |
| Atm. Life yrs. | 1.25 | 14 | 17 | <1 | <1 |
| ODP | 1 | 0.08 | 0 | 0 | 0 |
| GWP | 7500 | 1600 | 1300 | 7 | 7 |

**Table 2:** HC refrigerants used for domestic and light commercial applications.

| Code - Chemical Name | Triple (◦C) | Boil (◦C) | Critical(◦C) |
|---|---|---|---|
| R290 Propane | -190 | -40.08 | 95.70 |
| R600A Butane (Iso) | -150 | -10.76 | 135.70 |
| R600 Butane (Normal) | -140 | -0.55 | 150.01 |
| Propane & Butane | Values vary mixtures of the above | | |

**Requirements of Refrigerant**

Car air conditioners have a charge of about 1 liter. The seals on the pulley-driven compressors can let out as much as 0.5 liters each year. Re-gassing, a common practice in the industry, was to release the remaining refrigerant into the atmosphere before calculating a totally luminous price. A one-liter-per-year leakage fee is equivalent to re gassing. In 1992, 3204 tons of CFC refrigerant were expected to be consumed, with 1530 tons of that amount going into automobile air conditioners and the rest ending up in the environment. Car air-conditioner refrigerant ODP and GWP cannot be ignored. Table 1 shows that the most common HC and HC refrigerants may be used safely. Refrigeration and air conditioning systems of various sizes use R22, and 2252 tons of it were sold in 1991/92. (Park 2007). Table 1 shows that this HCFC's ODP and GWP are significantly worse than those of R134a. Chemically resilient, noncorrosive, low boiling points, and a temperature above ambient are all requirements for acceptable overall performance and longevity of refrigerants for household and light-duty commercial use. Table 2 lists the hydrocarbons and mixtures that meet these specifications in real life. HC refrigerants are what we call them over here.

**Performance of HC refrigerants**

Man-hoe (2008) conducted a laboratory test using RWE's R-22 modified by means of method of employing R-290 on RWE's 20 kW water to water and 15 kW brine to water pumps. Table 4 demonstrates that while R-290's heating efficiency declined, its coefficient of performance (COP) was extended, resulting in lower power usage. Temperature difference between condenser liquid and compressor vapor did not benefit R-22 in the test conditions, but R-290 significantly on the other hand. It is assumed from the transport and thermodynamic records (Arora 2008) that R290 models with the same capabilities as R-22 will still have a COP advantage

All Foron models, including those from Bosch Siemens, AEG, and Liebherr, now utilize HC refrigerant. Table 3 compares the results of EA Technology, UK, on UK R12 and German R600a refrigerators (Wang 2012). Refrigerators using R600a refrigerant do not have all of their impressive advantages due to the refrigerant itself. An excellent 25 g is the standard HC charge in a German refrigerator (G Yan 2015). For many years, German refrigeration mechanics have secretly updated R22 in heat pumps with industrial propane.

**Table 3:** Energy consumption of domestic refrigerators with internal temperature 5◦C and ambient 25◦C.

| Make- Model | Refrigerant | Capacity(L) | Consumption (kWh/24 hr.) |
|---|---|---|---|
| UK-A | R-12 | 130 | 0.72 |
| UK-B | R-12 | 165 | 0.7 |
| Liebherr- KT1580 | R-600a | 160 | 0.35 |
| Siemens-KT15RSO | R-600a | 145 | 0.5 |

**Table 4:** Capacity and coefficient of performance increase on substituting R290 for R22 in typical German heat pumps (Goetzler 2014).

| Type | R22 Performance | | R290 % Increment | |
|---|---|---|---|---|
| | Heat kW | COP | Heating | COP |
| WI 24 10◦C to 35◦C | 23.5 | 4.1 | -10.5 | +9.5 |
| WI 24 10◦C to 55◦C | 21.5 | 3.2 | -16.1 | +3.5 |
| SI 17 0◦C to 35◦C | 16.5 | 3.5 | -9.2 | +5.2 |
| SI 17 0◦C to 55◦C | 14.5 | 2.5 | -15.5 | +1.2 |

| | | | | |
|---|---|---|---|---|
| SI 17 0◦C to 35◦C | 15.5 | 3.5 | -5.5 | +16.5 |
| SI 17 0◦C to 55◦C | 13.5 | 2.5 | -10.4 | +11.8 |

Refrigerant rate, suction superheat, condenser stress, and relative cooling capacity potential were measured by Claudio (2014) on automotive air conditioners. R-12 was once compared to commercial propane and butane mixtures. The motors had been set to idle when the measurements were taken. The relative cooling capacity of the HC mixture to R-12 has been determined using the passenger compartment air conditions and the compressor speed, pressures and temperatures in the refrigerant circuit. The measurements of the HC/R-12 cap potential ratio differed by as much as 20% on a regular basis. It has been shown that a blend of 60 percent propane and 40 percent butane can increase cooling capacity by around 10 percent above R-12. The data suggested decreased compressor operation, however this can no longer be determined with accuracy. The recorded superheats were astonishing, with condenser pressure rising by an average of 8%.

**Comparison of refrigerants**

Heat pumps (Table 4, Jchen 2008) and vehicle air conditioners (Verma 2013) have shown performance gains consistent with the trans port and thermodynamic advantages of HC refrigerants (ASHRAE 2015). In addition to refrigerators, R-600a (Table 3) is commonly used in homes to increase the COP of small refrigerators. If you're suspicious that this is due to R-600a's superior engineering and production capabilities, we explain why in the section that follows. Table 5 compares refrigerant homes (Muthuraman 2018) and factors that influence the COP of household refrigerators.

In addition to calculating COP with 20 K suction superheat, it is thought that saturated vapor at -15°C enters a super compressor, while saturated liquid at 30°C enters a boom valve. Arora (2008), Table 7 on the internet page sixteen of Arora (2008). 7, in addition, relies on the foregoing hypotheses. There are three refrigerants in Table 5 that are now used in tightly manufactured household refrigerators, as well as RC270, which is no longer in Table 7 of ASHRAE (2015).

**Table 5:** An hypothetical reversed Rankine cycle with saturation temperatures ranging from -15°C to 30°C was used to compare the measured energy consumption of residential refrigerators. Comments are indicated by the use of leading numerals.

| Refrigerant-Chemical classification | R-12 | R-134a | R-600a | RC-270 |
|---|---|---|---|---|
| $x_1$ Molar mass (g/mol) | 120.9 | 102 | 58.1 | 42.1 |
| $x_2$ Refrigerating effect (J/g) | 116.9 | 150.7 | 262.3 | 359.1 |
| $x_3$ 30◦C sat. liquid volume (L/kg) | 0.773 | 0.844 | 1.835 | 1.636 |
| $x_4$ 30◦C sat. vapor volume (L/kg) | 23.59 | 27.11 | 95.26 | 62.41 |
| $x_5$ 30◦C sat. vapor viscosity (μPas) | 12.95 | 12.48 | 7.81 | 9.07 |
| $x_6$ Condenser pressure (kPa) | 743.2 | 770.7 | 403.6 | 827 |
| Evaporator pressure (kPa) | 181.9 | 163.6 | 89.2 | 206 |
| $x_7$ Condenser gauge $x_6$ −101.3 (kPa) | 641.9 | 669.4 | 302.3 | 725.7 |
| COP 0 K suction superheat | 4.67 | 4.67 | 4.71 | 4.71 |
| COP 20 K suction superheat | 4.71 | 4.71 | 4.82 | 4.82 |

| | | | | |
|---|---|---|---|---|
| Compressor discharge temp. (◦C) | 39.3 | 36.6 | 30 | 52.7 |
| Effective displacement (L/kJ) | 0.79 | 0.81 | 1.52 | 0.65 |
| Cond. loss par. $x_2x_4x_5/(x_2x_6)$ (μPas) | 1.45 | 1.31 | 0.64 | 1.00 |
| 15◦C sat. liquid k/μ (kJ/kg K) | 0.28 | 0.29 | 0.49 | 0.79 |
| Liquid molar volume $x_1x_3$ (mL/mol) | 93.5 | 86.1 | 106.7 | 68.8 |
| Leakage speed $x_3x_7/(x_4x_5)$ (1/ns) | 1.62 | 1.67 | 0.75 | 2.1 |

Table 5 shows that R600a has a single unimportant benefit and a slew of large advantages for residential refrigerators. —
Until the introduction of R12, open-pressure compressors were common, and the low ambient evaporator pressure in R600a might lead to air leakage via the shaft seals, reducing the system's overall dependability. Compressors in domestic refrigerators are not open-pressure. Pressures that ordinarily build up in the condenser are the easiest for the evaporator to endure while the fridge is in storage. R600a's condenser gauge pressures are a lot lower than zero, and they're not even close. Five metal thicknesses for other refrigerants may be reduced by 0.5. This decreases capital costs and environmental concerns, and it may increase COP by decreasing the barrier to warm temperature transmission. COP for R600a is 1 percent higher than COP for R134a in a reversed Rankine cycle with no liquid subcooling and no suction vapor superheat, as well as good heat transmission and compression. The reversible COP of all the refrigerants is close to five. There is an expansion valve located near the compressor suction line in domestic refrigerators, where a capillary tube is in close thermal proximity. Some refrigerants' COP increases with the liquid-suction warmth trade, whereas others' COP falls. R600a has an idealized COP of 2% better than R134a when the superheat temperature is 20 K. The ten percent to twenty percent differentiation must include only exclusive outcomes.
It is possible to use a less expensive and more environmentally friendly electric motor because of the low compressor discharge temperature for R600a. A bigger compressor is implied by R600a's enormous forceful displacement; nevertheless, the condenser pressure gauge pressures, which are half that of the compressor wall thick ness, may be 0.5. Compressor mass and capital price might be slashed with a common reduction. However, the compressor is going to be a lot smaller than if it were powered by an electric motor. R600a and R134a pistons and valves may have the same ground give up. Greater green is possible since the relative roughness of an R600a compressor may be less.
A serpentine condenser with laminar flow is used in small freezers. The condenser loss parameter includes all refrigerant homes that contribute to COP loss due to pressure drop in condensers of the same period and tube mass but varying diameter and wall thickness. The pressure decrease of the other refrigerants causes R600a to lose nearly half of its COP. Conduction through the thin liquid layer on the wall is particularly important in the transmission of heat by forced convection within tiny device condenser and evaporator tubes. According to ASHRAE (2015), the most widely accepted correlations for this warm temperature flip are based on the adequate/ ratio between the liquid's thermal conductivity and its dynamic viscosity. Consequently, R600a's warm temperature switch conductance is higher than R12 and R134a's. " For airtight compressors, diffusion through the sealing materials is the primary source of refrigerant loss, hence an immoderate warm temperature transfer conductance results in a reduced COP loss. Refrigerant hazards and precautions based on molecular size. With a large molecule, a reduced loss price and a longer time of operation with an abnormally high COO are possible. Because R600a has a large molecule, its diffusion loss is expected to be reduced.
Pinholes or fractures are the most common means by which significant refrigerant losses ascend to the surface in a laminar isothermal flow. The rate at which a given refrigerant leaks out is directly related to

the time it takes for the full amount to seep out. Massive leaks in R600a structures result in higher COP masses for a longer period of time. In situations where device mass and leakage are critical, as well as when evaporator or condenser temperatures are extremely high, R600a is an excellent choice. If the device has to be changed to reduce GWP, R600a is a better alternative to R12 and R134a than RC270. In comparison to other ammonia forms, Ammonia R717 has superior warm temperature switching, but it suffers from higher vapor stress, corrosion, and toxicity. Because of its toxicity, this product is not recommended for use in the home.

Lubricants made of high-purity HC refrigerants are genuinely compatible with them. Refrigerant HC can be used with R12 driers since it absorbs the smallest amounts of water. CFCs can be replaced with HC refrigerants with the right vapor pressures using thermostatic growth valves. Other booms may also need to be adjusted or replaced at some point.

**Hazards and precautions for refrigerants**

Any refrigerant whose vapor pressure is higher than the surrounding airs can cause an explosion with a greater flash. When lubricant or refrigerant combustion occurs nearby, the functionality grows more rapidly. Explosion venting is crucial in limiting the upward tension push to the gap's right capacity. Windows can be blown out of buildings with 2 kPa.

Fire When a fire breaks out, flammable lubricant and refrigerant must be properly expelled from the building, especially if the temperature of combustion surpasses 100 MJ. Poisoning or asphyxiation Except for air and oxygen, all refrigerants are asphyxiating. It is Ventilation's goal to avoid critical harm or death in the case of an infamous refrigerant leak. Among refrigerants, the amount of air glide critical varies greatly.

Chemical reaction or corrosion at refrigeration temperatures, HC refrigerants are non-reactive and chemically robust. Burns caused by heat or cold Insulation should be used to avoid skin-to-bloodless metal contact. When liquid refrigerant is accidentally released, it must be carefully drained.

All refrigerants need safety precautions to avoid harming people or damaging property. As a result of these variables, a variety of protective measures can be employed to prevent damage. Using AS 1677–1986's grouping of refrigerants as a means of protecting some refrigerants while ignoring others results in insufficient protection. For HC refrigerant safety, AS 1596–1989 and textile safety information sheets from vendors provide more relevant data.

**Table 6:** Data on fires and explosions using HC and RC270 refrigerants (Perry and Chilton 1973 Table 9-20). The HC refrigerants that replace R12 are represented by P50, which is made up of an equal amount of R290 and R600a.

| Ref. Code | Liquid.25◦ C kg/m$^3$ | Mol.mass g/mol | Flam. Limits Vol. % | Stoch. Mix Vol. % | Ignit ◦C | Flame m/s | T-Flame ◦C | Heat MJ/kg |
|---|---|---|---|---|---|---|---|---|
| **R290** | 493 | 44.1 | 2.1-11.4 | 4.02 | 504 | 0.4 | 2232 | 50.3 |
| **R600** | 573 | 58.1 | 1.7-10.3 | 3.12 | 431 | 0.37 | 2238 | 49.5 |
| **P50** | 523 | 50.1 | 2-10.8 | 3.58 | 490 | 0.38 | 2236 | 49.8 |
| **RC270** | 621 | 42.1 | 2.6-12.3 | 4.44 | 498 | 0.49 | 2310 | 49.7 |

Using the data in Table 6 and the refrigerant tables (Mhaske et al. 2016), you may determine whether or not a discharge line is necessary for the pressure remedy valve when calculating explosion venting. One thousand parts per million (ppm) for HC refrigerants and 400 ppm for RC270 are the long-term publicity limits. One hour following a full release of refrigerant, the air flow in an empty plant room should be sufficient to bring concentrations back down to those levels. During occupied plant rooms, air flow must be restricted to prevent damage at the ground level from the complete refrigerant discharge. There aren't any criteria. As a precaution, ventilation that reduces the HC refrigerant hobby by 25 percent, as well as RC270 by 10 percent, is recommended.

**Explosion chance**

Some (Ibrahim 2014) say that the risk of HC refrigerants exploding in small-scale constructions like refrigerators and automobile air conditioners is catastrophic. We'll do a few trials to get a sense of how likely it is. According to Claudio (2014), the 'bomb in cabinet' twist of destiny was tested on 142-liter freezers utilizing R290. All of the fridges examined had propane prices that were significantly lower than forty g. A spectacular leak released 11 pounds of mass into the surrounding environment, according to the researchers. The rest was left at atmospheric pressure inside the oil or within the pipes. As an added surprise, they decided to offer 19 g on each of the unique manufacturers' versions. An internal ignition mechanism was then developed to generate an excessively strong spark, and a connection was connected to the evaporator to allow refrigerant to enter the cabinet. After allowing the propane to seep into the cage for 15 minutes, tests were carried out with the ignition ignited immediately. With just a little file opening the door and a brief-lived flame in the cabinet being captured by camera, the resultant ignition turned out to be explosive. Even after several testing, the flame's depth was insufficient to sear the plastic liner. Following a longer blending period, the explosion was stronger, but a section of the gasoline line had stratified at the bottom of the closet and was quickly consumed after the fire."

This worst-case scenario couldn't hurt beyond a doubt every individual who was near the refrigerator at the time. There is no longer any way for the explosion and fire to even sear the combustible liner, let alone ignite the ordinary contents of refrigerators. This may be true. A perfectly beautiful fatigue fracture may also be the greatest way for an unexpected leak to occur during normal operation. Refrigerators include enclosed light switches and thermostats that, if destroyed in an unintended manner, might ignite a combination. It's a great twist of destiny that may not cause any damage to the company's assets. To make this twist of fate even more incredible, German manufacturers chose R600a because of its lower vapor pressure. In Australia, car air conditioners need at least one liter of liquid refrigerant. In the passenger compartment, the evaporator and normal expansion valve are located between the dashboard and firewall. Only a complete and instantaneous liquid line rupture directly before the expansion valve is required to release a white cloud of HC refrigerant into the passenger cabin. In a matter of seconds, opening a window can stabilize the situation. The house windows of the car may be blown out in an instant if the occupants failed to detect the cloud and one of them ignited a fit. The expense of replacing the glass might be a little high. People injured in explosions caused by household appliances, such as the OMR1000, may have purple or stinging skin for several days after the explosion. To protect the people within, the glass is sent flying away from them. The cold, easy air that follows is vitally crucial in preventing asphyxiation. Wang (2012) used a propane welding torch linked to a hydrocarbon refrigerant cylinder to seek for ignition properties in order to evaluate the likelihood of this future twist. The car was placed in a covered area outside and left to idle for about 10 minutes until it reached normal operating temperature. She turned on the welding torch and adjusted the settings so that it produced a bright yellow, 70 mm-long flame. She used an air blast to put out the flame and a cigarette lighter to see whether it could be easily re-ignited.

**Table 7:** Airflow and refrigerant charge measurements (Wang 2012) provide information on the maximum period a combustible concentration can persist in the passenger compartment while the fan and vent are running.

| Model Year of Make | Berlina-2000 | Suzuki-2005 | Huyndai-2010 | GMC-2015 | Nissan-2020 |
|---|---|---|---|---|---|
| **HC Refrigerant charge (g)** | 298 | 460 | 425 | 315 | 840 |
| **Ambient Temperature (◦C)** | 19.5 | 17.5 | 18.3 | 21.0 | 16.0 |
| **Atmospheric Pressure (kPa)** | 100.4 | 99.9 | 101.3 | 100.8 | 101.2 |
| **Compartment Volume ($m^3$)** | 5.81 | 3.81 | 4.16 | 3.48 | 4.36 |
| **Measured Air inflow (L/s)** | 2.52 | 85 | 77.4 | 85.1 | 173 |
| **Maximum HC Conc. (vol. %)** | 2.48 | 5.83 | 4.88 | 4.38 | 9.14 |
| **Maximum Flammable Time (s)** | 497 | 48 | 48 | 32 | 38 |
| **Explosion Freq. (10−9/year)** | 29 | 3 | 3 | 2 | 2 |
| **Insurance Risk Incr. (OMR/year** | 0.002 | 0.0002 | 0.0002 | 0.0001 | 0.0001 |

Over the modern engine, electric, ignition and exhaust, the extinguished torch was completed. Afterwards, the door and light switches, fan motor, relays, and cigarette lighter in the passenger compartment had been checked. Over fifteen mints and 50 to 100 g of combustible refrigerant were utilised for each take a look at, depending on the make and kind of automobile. 5 automobiles are listed in Table 7 based on their version and manufacturing time during the course of 365 days. It's not unusual for fuel to leak into a vehicle's cabin. Using open relays, switches, or vehicles that might ignite a fuel line/air combination is probably careless on the part of the manufacturer. In addition, enclosed electric driven components are more reliable, which saves on guarantee claims. As a side effect, a tell or cigarette lighter is the most convenient way to start a refrigerant combination in the passenger cabin. The average number of cigarettes smoked each day by the entire riding population is roughly 10. (Maclaine 1995). Cigarette lighters are used to light around half of the cigarettes that people smoke in their automobiles, but this does not necessarily mean that the cigarettes are igniting. As a result, we now have five ignitions that can be activated by varying levels of pressure throughout the day.

Results from Maclaine (1995) employing carbon dioxide fuel as a tracer are summarized in Table 7 (Maclaine-1995). A covered location was used to take readings while the engines were running. There was no vent in the Kings wood, thus the only way for air to get in was by infiltration.

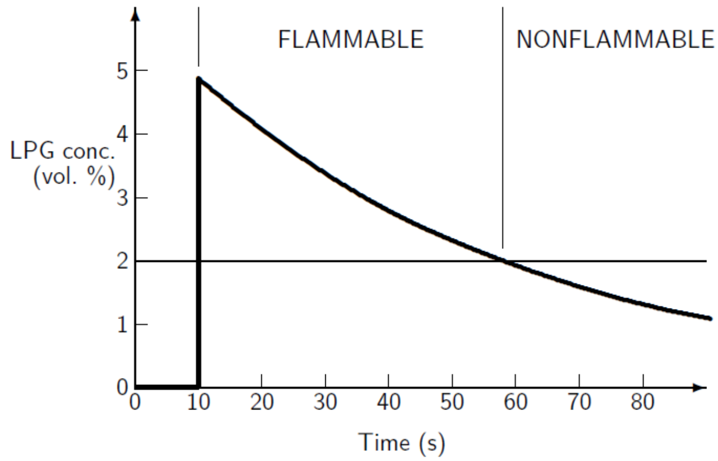


**Figure 2:** HC refrigerant concentration assumed in passenger compartment to calculated maximum flammable time for Pulsar in Table 7.

We've never heard of a fatigue fracture of a pipe that didn't leak before the whole separating of the steel taking place between the firewall and the boom valve. A white cloud forming behind the dashboard at the passenger's side is the obvious indicator. There is a highly combustible combination of hydrocarbons in each of the five vehicles shown in Tables 6 and 7. We will anticipate proper right here that such fractures get up as soon as regular with million running years because of this that numerous get up in Australia every 12 months. The cloud is also assumed to be ignored by a cigarette smoker, who does not close his or her window. As shown in Figure 2, the expected attention profile for within the passenger compartment is used to determine how long the concentration remains over the Pulsar's 0% increase flammability limit. A 48-second maximum flammable time is shown in Table 7. Following MacLaine's (1994) recommendation, the payoff increase is assumed to be OMR 38000 if the car happens to be deskbound at the time of the twist of destiny. Table 7 shows a negligible increase in the insurance risk.

Table 8 shows a rough estimate of the annual increase in insurance risks due to the switch from R12 to HC refrigerants in a vehicle's air conditioner. Due to R12's high rate and the crook's need to improve it, there is an excessive price for crash maintenance on R12 air-conditioners. In comparison to R12, HC refrigerants have a 23 OMR/12 months' lower insurance risk. Early and more exact investigations of HC in automotive air conditioners were conducted by MooYeon and colleagues (2008). They came to the conclusion that the danger of injury from HC refrigerant is 35 x 107 every 365 days in the US. In Table 8, the front/rear frequency is imagined to be fourteen times faster than it actually is, validating the low insurance possibility of HC refrigerants

**Table 8:** Annual insurance risk increment on conversion of R12 car air conditioner to HC refrigerants

| Scenario | Payout | Frequency/yr. | Risk |
|---|---|---|---|
| Engine by fatigue fire | OMR380 | $1 \times 10^{-7}$ | +0.0001 |
| Passenger fatigue fire | OMR38000 | $2 \times 10^{-9}$ | +0.0002 |
| Slow collision fire | OMR380 | $2 \times 10^{-4}$ | +0.20 |
| Fast front/rear fire | OMR38000 | $5 \times 10^{-6}$ | +0.50 |
| Slow collision R12 loss | -OMR20 | $2 \times 10^{-2}$ | −1.00 |

| | | | |
|---|---|---|---|
| Slow collision R12 recovery | -OMR40 | $2 \times 10^{-2}$ | −2.00 |
| Total Risk Increment | | | −2.30 |

Within the engine compartment of many Australian vehicles, the boom valve may be found. This prevents a significant volume of refrigerant from escaping from the vehicle's cabin in a short period of time. If, as in the case of the Berlin of Table 7, the clean air is moving at a high glide rate but the refrigerant rate is barely changing, a flammable combination must be reached relatively near to the leak. Because of this, it is unlikely that a bomb will be found in the passenger cabin in the near future. Technicians may also be alerted to the presence of odorized HC if they detect invisible leaks in handling quantities of more than 1 kg. Odorization is no longer a significant factor in reducing the risk of subsequent explosions because of the white cloud that grows an explosive combination at low costs. Additionally, corroding valves in refrigerators may significantly increase their power usage (Preisendanz 1993).

## Conclusion

There are 5 million liters of liquid risk-free refrigerants in Oman per year, and bulk prices are now over five OMR/L. Customers will choose HC refrigerants because they are effective, do not deplete the ozone layer, and contribute minimally to global warming. First, R290 and HC combinations can replace R12 and R134a with R290. As new tools take use of R600a's lower vapor pressure, the market for this substance will grow. HC refrigerants are often better to conventional refrigerants in terms of their ability to save 10% to 20% on power costs.

## Acknowledgement

Refrigeration and Air Conditioning Laboratory at The University of Technology and Applied sciences, HCT-Muscat used for refrigerant handling, instrumentation design and construction for the measurements for this research review work.

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