

Hydrocarbon Refrigerants in Motor Vehicle Air Conditioning Systems - Reflections and Projections

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Hydrocarbon (HC) refrigerants specifically designed as an alternative for fluorocarbon-based motor vehicle air conditioning systems (MACS) have now been applied commercially for over 11 years. Peer reviewed studies have shown that usage rates are large enough to yield statistically significant 'real world' safety trend data. This data shows no material difference in safety trends between MACS using HC refrigerants and those using existing fluorocarbon refrigerants.

Negative press regarding the use of HC refrigerants (particularly in MACS) principally originates directly or indirectly from fluorocarbon interests and does not reflect reality. Neither is this press a benevolent act by fluorocarbon interests to protect consumers from the dangers of a competing product, but rather a marketing campaign to inhibit the use of hydrocarbons as an alternative in existing and new refrigeration systems. Such publicity has created a false perception of risk which has slowed the acceptance and adoption of this viable alternative refrigerant application.

Marketing efforts against hydrocarbon refrigerants continue with vigor and success, showing no signs of abating. Long-standing relationships combined with effective lobbying and fear campaigns have created high levels of reluctance and perception of risk amongst the 'major' vehicle manufacturers from using HC refrigerants at point of manufacture. Consequently, the rate of growth of hydrocarbon refrigerant use in MACS is unclear. However, awareness of the real world safety record of HCs in MACS is growing, and regulatory trends appear to be moving towards greater acceptance of HCs. Growth in the Australian retrofit market continues, and seems likely to spread into regions abroad. Substantial efficiency gains from R & D using advanced designs in MVACs using HC R600a refrigerant remain a distinct possibility.

1. Introduction

Disclosure: The author receives benefit from the sale of hydrocarbon (HC) refrigerants, through his involvement with HyChill Australia.

HyChill Australia supplies hydrocarbon refrigerants and associated lubricants, flushing agents and other products to Australian and international markets. HyChill Australia is not the only supplier of hydrocarbon refrigerants in Australia, but enjoys the largest hydrocarbon refrigerant market share according to the best information available. HyChill continues to grow substantially, having tripled its sales and support team over the past two years. HyChill Australia fully endorses and supports the application of HC refrigerants as alternatives to fluorocarbons in motor vehicle air conditioning systems (MACS). However, it should be noted that HyChill is also very active in fixed Heating, Ventilation and Air Conditioning (HVAC) sectors, with total sales into this sector now larger than the motor vehicle sector.

As requested, this paper will deal with the use of HC refrigerants in motor vehicle air conditioning systems.

2. The Facts about Hydrocarbons (HC's) in Motor Vehicle Air Conditioning Systems (MACS)

June 2004 saw the publication of a peer-reviewed paper in the highly respected International Journal of Refrigeration, demonstrating clearly that use of hydrocarbon refrigerants in motor vehicles was significant and widespread [1].

This research showed that, at the end of 2002, the number of motor vehicle air conditioning systems using hydrocarbons reached 5 million vehicles across Australia and the United States alone [1]. Table 1 is a compilation of results of this research, and details the total number of cars using HC refrigerant from 1996 until the end of 2002. Interestingly, this data was found to be consistent with independent field surveys conducted in the United States in 2002 [2] by the MACS Society Worldwide, an organisation that certainly cannot be accused of having loyalties to the HC refrigerant industry.

Note also that air conditioners in all these vehicles were previously using R-12 or R-134a and were 'retrofitted' with hydrocarbons without any safety or performance modifications being made to the air conditioning system. The lubricant need not be changed when using HC's in MACS, however HC's are compatible with a wider range of oils than R-134a. Consequently, switching from more toxic and corrosive lubricants (such as PAG oil) to safer and more stable lubricants (such as mineral oil) has many advantages.

Year	1996	1997	1998	1999	2000	2001	2002
Sales (Mg/yr)	136.6	174.2	160.1	258.8	359.0	225.4	272.4
No. vehicles to date (x10 ³)	1147	1703	2134	2925	4062	4464	4999
Car user years (x10 ³)	1411	2587	4337	6532	9523	13643	18165

Table 1: Combined USA/Australian HC MACS use data to end of 2002 calendar year [1]

Note: Australian figures were as at June 30 of the nominated year, therefore these figures are slightly conservative.

The author is not aware of any subsequent publication that seriously challenges these findings. Such findings, however, do not instantly neutralise years of negative campaigning and misinformation.

Table 1 also details the calculated total number of car-user-years of HC refrigerant use. As the table shows, usage exceeded 18 million car-user-years at the end of 2002. This data supports many risk assessments conducted in the past [3] [4] [5] which predicted very low risk levels, but goes further to indicate that these risk assessments are considerably conservative in the light of historical data - by as much as 100 times [1]. The National Highway Traffic Safety Administration in the USA conducted their own examinations in 1993 and concluded there was 'no safety defect trend' [1].

Most importantly, the data shows that studying the rate of incidents involving real world use of HC refrigerants in MACS will yield statistically valid and reliable results, which can be used directly to quantify the difference (if any) in risk between HC and existing refrigerant technologies for this application. The historical incident record shows that there is no material difference in risk level when using HC's in MACS compared to fluorocarbons.

In an effort to demonstrate the legitimacy of the application of HC's to MACS, and in response to the queries of well intentioned industry bodies [6], the HC industry in it's foundational years sought expert risk assessments, only to have vested interests publish conflicting expert opinions as part of an ongoing campaign. The 'real world' evidence presented above supersedes such theoretical risk assessments and confirms the original assessments which concluded in favour of HC's (in fact, showing them in many cases to be quite conservative). This position is further supported by a range of publications on injury risk [3] [4] [5], insurance risk [7] [8] and performance advantages [9] [10].

3. The Fictions

Given that the actual safety data is now verifiable and reliable, there is little more to say on the general topic of safety of HC's in MACS. However, if the facts are so clear, then it begs the question:

“Why, then, is there so much negative press and publicity surrounding the use of hydrocarbon refrigerants in motor vehicles?”

This question is worthy of further inquiry. This document will attempt to clarify how such disparate circumstances can easily develop, and highlight how the industry actually operates, in contrast to how it might operate in an 'ideal world'. It is my hope that it will clarify the broad issues and underlying motivations so that future debate can be based on real evidence, balanced inquiry and a

healthy appreciation for the nature and circumstances of the industry. It is presented in the interests of evoking positive change in an industry which has the potential, if enough are willing, to dramatically reduce its environmental footprint, with additional benefit to the Australian economy.

3.1 Fundamental understanding #1: Identify the source

The overwhelming majority of negative press and denunciation of hydrocarbon refrigerants originates from:

- A. Active campaigning by the fluorocarbon industry directly or by organisations representing that industry, or
- B. Government and non-government organisation responses to campaigning and lobbying by fluorocarbon interests. Specific influences are utilised to affect regulatory restrictions on the application of hydrocarbons, based on flawed lines of inquiry. We are not aware of any regulatory restraint that was the result of an actual safety incident.

With so much negative press originating from competing interests, and a recognition that developing such press takes considerable time, effort and money, one should consider whether or not it is a genuine attempt by a benevolent chemicals industry to protect consumers from personal danger, or whether there is some other purpose behind it.

3.2 Fundamental understanding #2: It's a marketing campaign, not a safety campaign

Thesis: The campaigns against hydrocarbon refrigerant use in motor vehicles are not ultimately concerned with safety.

The evidence supporting this thesis is quite straightforward. In Australia the Trade Practices Act provides mechanisms to protect the consumer from products that are not "fit for purpose". These very mechanisms provide an open opportunity for industry or government to put to the test, in the courts, the matter of whether hydrocarbon refrigerants are "fit for purpose" when applied to motor vehicle air conditioning systems. Had this been undertaken at the beginning, the matter would be settled with finality. It could still be taken up now. Furthermore, cost of seeking a legal settlement should cost far less than a prolonged 12 year marketing campaign.

Occupational health and safety regulations provide a further basis to settle the matter in the courts once and for all. In fact, lobbying and 'stunting' enabled the erection of trade restrictions against HC's in MACS in Queensland and New South Wales, under the guise of occupational health and safety concerns. In these states there is yet more scope for those seriously concerned about HC safety in MACS to have the matter settled with finality in the courts. Instead, occupational health and safety regulations in two states of Australia (New South Wales and Queensland) merely stand as a trade barrier. The fact that hydrocarbon refrigerants are still being fitted to MACS in NSW should be evidence enough. If safety regulations exist but are not being exercised, one can reasonably conclude that the purpose for their existence is something other than protecting health and safety.

The obvious corollary to this thesis is that the campaigns are principally concerned with marketing and anti-competitive behaviour. They are conducted to slow, as much as possible, the transition from fluorocarbon refrigerants to alternatives. Financial benefit to the fluorocarbon industry by

inhibiting transitions to alternative refrigerants is significant indeed.

The reason for such a concerted effort against hydrocarbons is appreciated more fully by recognising that, unlike the other natural refrigerants (Ammonia, CO₂, etc), specifically prepared HC's will work (very efficiently) as a direct replacement for R-12 or R-134a in existing systems. A common argument put forward by the fluorocarbon industry are that such systems were not designed for alternative refrigerants. Such arguments are clearly ignorant of the obvious opportunity to design alternatives *for* existing systems, which is precisely what can be done with HC's.

History shows that the campaign against HC's in MACS bears many similarities to the unsuccessful campaign against HC's in domestic refrigerators in Europe in the early 1990's. Having largely lost that battle throughout most of the world, the campaign has turned towards motor vehicles. The campaign uses three main approaches: fuelling fear in the press regarding the flammability of hydrocarbons (sometimes attended by staged footage of 'explosions'), concerted lobbying of vehicle and component OEMs and associations and using influence with government to have bans or restrictions on the application of HC's put in place, particularly in regions with hotter climates (that is, higher refrigerant consumption).

3.3 Fundamental understanding #3: The realities of business and government

Most people want to believe that government and business operate on a fair, logical and reasonable basis. Whilst this is the ideal aim, those actually involved in business know the reality is often far from this ideal.

Looking across the spectrum of business and government, such problems are often more prevalent in industries or sectors that have been 'closed shops' - this includes monopolies, oligopolies and industries benefiting from government regulatory protection. The fluorocarbon industry has enjoyed status in one or more of those categories in various markets and jurisdictions across the world for a very long time.

'Closed shop' industries often allow for the development of influential relationships with government and other industries, simply through forced interdependence and interconnectedness (financially and otherwise), amongst other reasons. An example of this is the relationship between the (largely US-based) fluorocarbon industry and the USEPA - such influence resulted in the USEPA stepping outside it's role of "Environment Protection" to issue advice and rulings in the interests of public health and safety (regarding the use of hydrocarbon refrigerants in motor vehicles¹). Such action is clearly stretching the intended purpose of punitive powers given to the USEPA in the interests of

¹ More recently, the USEPA claims that use of HC refrigerants is not as widespread as recent published, peer reviewed literature suggests. On what basis do they make such a claim? The USEPA uses two principle assertions to support it's claim. Firstly, they imply that sales figures of HC refrigerant dramatically overstate the actual usage rate. This would only be a credible argument if the industry was new and developing 'stock levels' at stores and warehouses, or if the industry were intentionally stockpiling so as to 'skew' the data. The industry is 11 years old now - more than enough time for stock levels to equalise, and the idea of stockpiling is utterly ridiculous. Furthermore, such sales-based methods are standard practice - The Australian Greenhouse Office uses sales-based methods to estimate fluorocarbon refrigerant consumption in its Burnbank Report of 2002. Secondly, they claim that the "MACS Survey" (which was quoted in recent literature as confirming a sales-based analysis of the widespread HC consumption in MACS) identifies MACS 'contaminated' with HC, not principally charged with HC. This claim is made without justification, and carries little weight in any event, as more than 5% v/v (approx) of HC's mixed with 134a is also a flammable mixture.

environment management, and its rulings in this area contradict real world evidence and the findings of the US National Highway Traffic Safety Administration (NHTSA), the US body originally intended (and equipped with the expertise) to deal with safety issues.

Furthermore, there are few plausible explanations for the protection and encouragement afforded HFC-based domestic refrigerators in the USA, other than as a further example of “influence superseding evidence”. This becomes particularly clear when it's recognised that, in countries other than the USA, more than 120 million domestic refrigerators now use HC refrigerant[11] with an impeccable safety record since introduction 13 years ago. It should come as no surprise that the fluorocarbon industry is largely US-based, and that similar non-tariff trade barriers often exist to protect US industries.

Similar influential relationships often develop between the 'closed shop' industry and the industries with which they trade. This affords these industries the opportunity to procure recommendations for or against products or designs with an ease not afforded to outsiders. By way of example, the fluorocarbon industry has been able to secure the non-endorsement of HC refrigerants in MACS by various vehicle OEM's and associated organisations. These are not product bans, but obviously carry marketing weight in the minds of consumers, industry and media, and are quoted continually.

Once again, if there was material case for a ban then it should have been followed up through the courts long ago. The reality is that more marketing damage is done to the hydrocarbon refrigerant industry by leaving the matter untested at law and the question unanswered.

3.3 The Great Diversion - Fluorocarbon MACS are a flammability risk?

By focussing discussion on the flammability or non-flammability of the refrigerant, a “Great Diversion” has been created. The fact that all refrigerants in MACS are present in combination with a significant quantity of lubricant, which is highly flammable under typical MACS failure scenarios, is inescapable. Such incidents have occurred in practice [12] and the mechanisms are basic science.

Such diversions have even greater deleterious effects on constructive debate when the toxicity of products of heating and combustion of the more toxic lubricants required for use with R-134a (such as PAG oil) is ignored because people are led to believe that ignition 'cannot happen' with R-134a. Rather, incident records show that these issues should be taken very seriously [13]. A positive contribution to decreasing this risk can be achieved by using HC refrigerants in conjunction with less potentially harmful lubricants such as mineral oil.

The fact is that HFC systems are flammable, and HC systems are also. The historical record shows that the probability of ignition of HFC and HC systems is non-zero, but sufficiently low to be deemed safe. Putting that another way, the chance of there being a statistically measurable increased risk but not be reflected in real world incidents by now is so low as to be safely considered impossible.

3.2 “Bait and Switch”

Baiting people's fear and curiosity over flammability allows the discussion on risk to be switched from a 'total risk' assessment to one entirely focussed on flammability. Whilst this action supports

fluorocarbons, it does consumers and the environment a significant disservice.

The overwhelming majority of refrigeration fluids in use present a serious risk to humans. This includes natural refrigerants, fluorocarbons and lubricants. Examination of Material Safety Data Sheets for these substances identifies these risks. A wholistic assessment of the risks of refrigeration fluids reveals a much wider range of significant risks than flammability alone:

- (a) toxicity due to direct contact or inhalation,
- (b) toxicity due to contact or inhalation of byproducts (due to heating/burning/chemical reaction),
- (c) asphyxiation due to displacement of oxygen, and
- (d) flammability.

For statements on risk to be valid, they must include an assessment of the refrigerant AND oil combination in a refrigerant circuit, and they must consider all types of risk. Presenting a complete “total risk” assessment of refrigerant systems is beyond the scope of this report. However, Table 2 presents a brief qualitative assessment of 'total risk' elements of common systems.

Refrigerant	Flammability (of refrigerant)	Flammability (typical refrigerant/oil mix)	Potential chemical risks^a (Asphyxiant, toxic direct inhalation, toxic products of heating and/or combustion)
R-12	Non-flammable	Flammable ^b	Not addressed here (phased out substance)
R-134a	Combustible (but does not itself sustain flame)	Flammable ^{a,b}	R134a: Asphyxiant, direct inhalation risk (TWA: 1000ppm), toxic products of combustion Oil (PAG): Toxic direct inhalation, highly toxic products of heating, highly toxic products of combustion ^c
R-290/R-600a	Flammable	Flammable	Refrigerant: Simple asphyxiant ^d Oil: Depends on type used. Much less toxic lubricants than PAG (such as mineral oils) can be used ^c

Table 2: Key safety characteristics of common refrigerant systems

^a Considered in combination with standard charge of oil (PAG). All current commercial MACS designs require lubricant to be present. Quantities vary with system design, but a typical average quantity is 40%/60% oil/refrigerant ratio by mass. Refrigerant is miscible in standard MAC lubricants, and is therefore present throughout the MAC system.

^b Many typical fault scenarios may cause discharge of an “atomised” oil/refrigerant leak that is flammable, as discovered in New Zealand [12]. Lubricants commonly used in MACS are flammable (ignition temperatures are typically below that of HC's).

^c Refer to Material Safety Data Sheets for oil and refrigerant and comments/references that follow.

^d R290 and R600a are saturated hydrocarbons and generally have fewer material incompatibilities and are less likely to break down into toxic byproducts in the presence of elevated temperatures (refer to MSDS). As with fluorocarbons, the contribution to risk generated by choice of lubricant should be considered.

It should be noted that more recent studies [12] [14] [15] [13] [16] [17] indicate toxicity hazards of fluorocarbons and associated lubricants are more severe than previously thought. These newly discovered issues cover direct toxicity, long-living products of decomposition (such as trifluoroacetic acid), flammability hazard (particularly of typical refrigerant/lubricant mixtures) and non-effectiveness of containment methods.

4. Projections

It is very difficult to make accurate predictions about the future of hydrocarbon refrigerants in motor vehicle air conditioning systems. What is clear is that HyChill's sales continue to grow, as does the organisation itself in order to support its markets. HyChill's total workforce has doubled in the last two years.

The marketing campaign against hydrocarbon refrigerants has, to date, been very successful in keeping hydrocarbons out of vehicle OEM production lines. Whether this situation will continue is hard to predict. Certainly, it seems that the 'major' vehicle OEM's would not be the first to make such a switch, as it is commonly understood such a transition by a major OEM would result in the negative press campaign being redirected at them. OEM's have developed a deep respect for the effectiveness of such campaigns, and that such campaigns are effective irrespective of any factual basis. However, HyChill is aware that major OEM's and compressor manufacturers have tested hydrocarbons and are capable of switching production to HC's very quickly should the opportunity arise. Furthermore, awareness is growing that a well designed HC R600a motor vehicle air conditioning system is an extremely efficient, light and cost-effective alternative. The regulatory trends also seem to be reversing, as more regulations restricting fluorocarbons are being developed, and restrictions against hydrocarbons are being relaxed.

Nevertheless, HyChill's sales continue to grow in MACS and other markets. More recently HyChill is enjoying particular success in previously unexplored HVAC markets. HyChill's policy does not allow me to divulge details about those markets at this time - such is our respect for influence of competing interests. I look forward to advising the industry of this progress once these new markets have matured.

With real world safety data now in hand and on the public record, HyChill is particularly excited to be involved with a real opportunity to contribute positively to the environment and the economy through the application of Australian made hydrocarbon refrigerants to the motor vehicle air conditioning market. However, the HC refrigerant industry is not under any illusions that HC refrigerants in any way dominate the MACS market, or will in the immediate future. The HC industry operates against an unrelenting headwind of aggressive negative marketing and lobbying campaigns at almost every level of industry and government. Nonetheless, HyChill Australia estimates that HC refrigerants have captured in excess of 10% of the automotive MACS market, and is very pleased with this result in the light of these challenges. With continued growth in the fixed HVAC market also, hydrocarbon refrigerant technology is certainly here to stay.

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