Hydrocarbon Conversions of Larger Chillers and Coolers

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1. INTRODUCTION

The Energy Resources Group (ERG) and its partners have converted small and large chillers, from 50 tr to 300 tr, in hospitals, hotels, office blocks, factories, universities and schools. The program started in late 2004 and has progresses steadily. Typically these units are rooftop, water and air cooled chillers. Successful conversions have been carried out on R22, R134a and R400 series systems.

2. BARRIERS TO HYDROCARBONS

ERG and one of their key agents previously identified the potential for natural refrigerants, in particular hydrocarbons. In the beginning, a number of major problems were identified, which are described below:

- *Product distribution.* There were challenges associated with supplying hydrocarbon refrigerant to areas where it was needed, Making the necessary investments to ensure stock and quality, and developing regular supply lines.

- *Availability*. Local availability of hydrocarbon refrigerant was also a problem. Local refrigerant suppliers refused to carry it, based on perceived safety hazards. However, since hydrocarbons have been used extensively in other industrial, commercial, and consumer applications, safety is a lesser hurdle and consists mainly in ensuring proper training for use and servicing operations.

- *Quality.* Another challenge, common to any refrigerant, was guaranteeing quality. There are many refrigerants in the market that are of questionable quality, and hydrocarbon refrigerants are not exempt from this. Quality can be compromised not just by impurities (e.g., sulphur, oxides, moisture, etc.), but also by incorrect blending of the hydrocarbon refrigerant components (e.g., R-290, R-600a). Base stocks of hydrocarbons usually contain high levels of n-butane, iso-butane, propylene, ethane, pentane, and other hydrocarbons that can alter the pressure/temperature relationship, as well as other properties. This makes it difficult for original equipment manufacturers (OEMs) and service personnel to balance the system properly. Therefore, the use of high quality, highly refined base products is critical in the blending process.

- *Training.* While the use of HC refrigerants is very similar to other types of refrigerants, there are several additional items that technicians must be aware of. To some extent, it is not additional training but a reminder of the correct ways of doing things taught in trade schools. Technicians must fully understand the characteristics of hydrocarbons so that they do not cut corners or carry out sub-standard procedures.

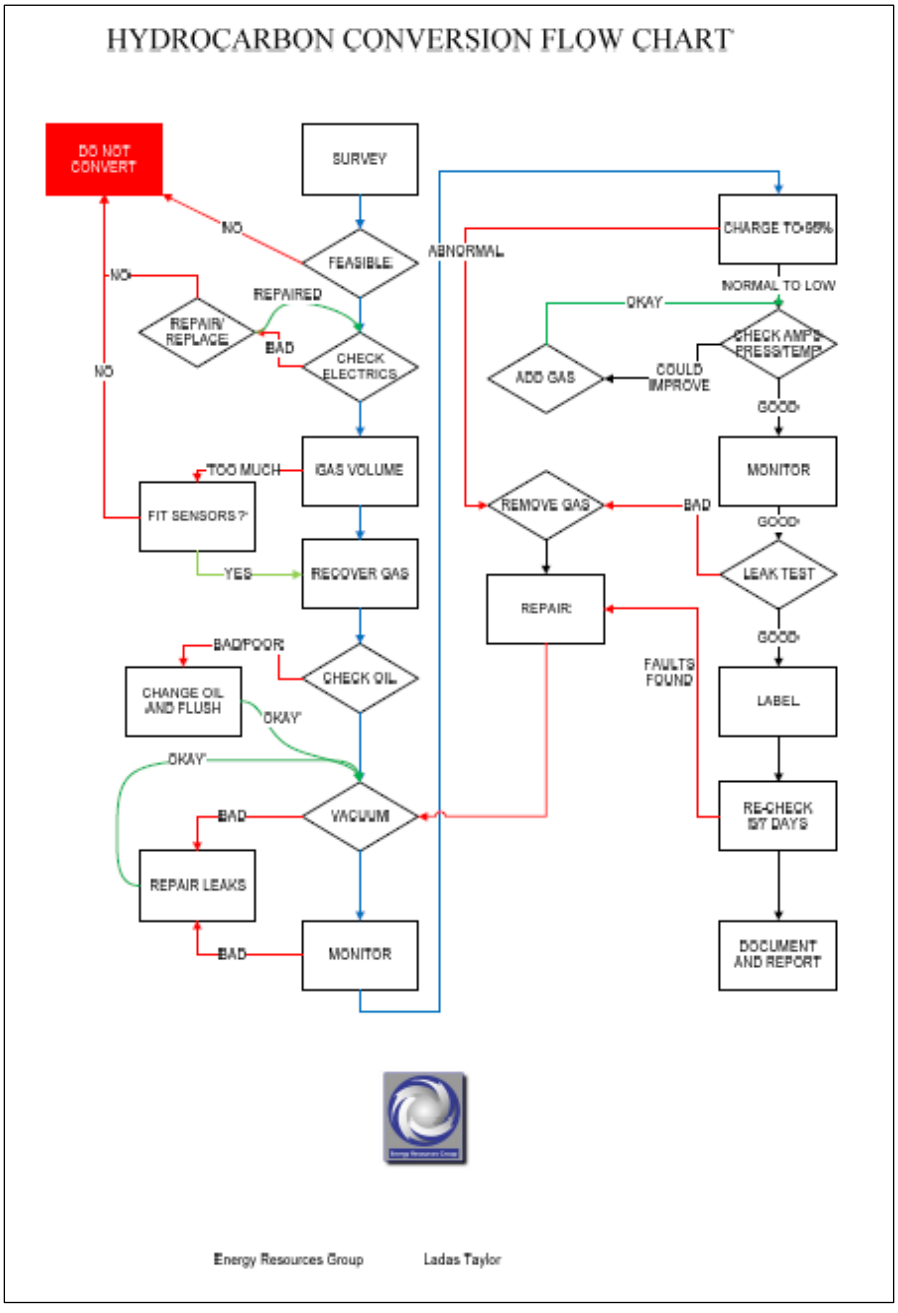
With their partners, ERG successfully addressed nearly all of the above issues

3. CONVERSIONS TO HYDROCARBON REFRIGERANTS

Over the last eight years, the ERG in association with key partners in Asia, especially Nat-Energy Resources of Singapore, has developed a programme to offer companies the opportunity to reduce or eliminate their reliance on ozone depleting or high-global warming potential (GWP) synthetic refrigerants. Such conversions generally involve the following procedures:

- Introduction of concept
- Equipment diagnosis survey and report
- Safety audit
- Pre-retrofit repairs and servicing
- Pre-retrofit system and energy consumption monitoring
- Fitting of safety devices
- System conversion
- Post retrofit system and energy consumption monitoring
- Conversion report
- Regular service and maintenance – unless client opts for in-house personnel to be trained

The sequence of events is detailed within the flow chart in the figure below. To describe the process in more detail, a case study is provided in Section 4.



To date, most projects have been sourced through introductions from previous customers, partners, associates, from energy savings technology providers looking for partnerships, or website enquiries from organisations looking for environmentally-sustainable technologies, such as those that must comply with ISO 14001 certification requirements. A list of the projects completed to date is included in Appendix 1.

There have been, and always will be, some projects, sites, or chiller types that are not suitable for conversion to hydrocarbon refrigerants. This could be due to location, serviceability, and other reasons described (see text box, right). For this reason, a full site survey and safety audit must always be carried out.

Types of Systems that Generally Cannot be Converted to HCs

There are a variety of systems that are not recommended for conversion to HCs, namely:

1. Centrifugal Chillers – ERG is currently working on formulating a HC blend to suit this application, but it is only in the very early stages of development
2. Flooded evaporator systems that utilise a mechanical float system – this is due to the very different density of HCs over HCFCs or HFCs. Flooded systems with an electronic 'float' system can be used.
3. Cooling equipment in close proximity to ignition sources that cannot be economically isolated/ sealed off.
4. Cooling equipment where the necessary ventilation is lacking and/or where it is not economical to modify/install ventilation systems; basement systems with little or no ventilation must be approached carefully.
5. Where the volume of the refrigerant – if it leaked into a conditioned/ occupied space – exceeded the safety levels.

3.1 Costs for Conversions

It is almost impossible to give a cost for conversion– as every system/application is different – and much depends on the original state of the system. Additionally, the costs involved in returning a system to "normal operational standards" after possibly years of neglect cannot be measured. However, when a system is returned to operational level and then converted to HCs, the savings enjoyed normally offer a return of investment well within a 12-month period. Many contractors/agents offer to carry out the HC conversions with zero up-front cost, and share in the savings the customer achieves.

3.2 Servicing HC Equipment

The servicing of a unit charged with HC is no different than those charged with any other refrigerant. However, the technicians/contractors must be trained to carry out servicing "by the book" and not cut corners. For example all refrigeration/air conditioning technicians are trained to never braze/weld on a system using ANY refrigerant because:

- The gases given off when CFC, HCFC, or HFC burns are very toxic;
- Nitrogen should always be used in a system when brazing/welding to stop the formation of oxides;
- When high temperatures are applied to refrigerants (when welding or brazing) it causes the elements of the refrigerants to change– and reduces any refrigerant effect;

4. CASE STUDY OF A CONVERSION OF LARGE CHILLERS IN SINGAPORE

In April 2005, Nat-Energy Resources–Singapore managed a hydrocarbon conversion project for China Classic Pte Ltd (a subsidiary of Far East Organisation), located in the Far East Square in Singapore. The equipment converted included five York air-cooled chillers, model YDAJ98MU7-50PA, with a nominal capacity of 700 kW for each of the five equally sized units. Figures 2 and 3 are photographs of the chillers involved. Each chiller was comprised of four circuits, each containing a charge of approximately 25 kg of *ERG Minus 50*—a refrigerant blend of R290 (propane) and R1270 (propylene).

Figures 2 and 3: Far East Square Shopping Complex, Roof Top, Chiller No 3, York Air-Cooled System Model: YDAJ98MU7-50PA

The following steps were carried out prior to retrofitting the systems, which reflect best practices and compliance with international standards:

- *Conducted equipment survey and prepared report:* A standard inspection on the system was carried out and reports were submitted to the client. In cases of leaks or defects, appropriate actions must be taken. (See Appendix 2.)

- *Performed safety audit:* As these chillers were on the open rooftop, leak detectors were not required. An officer from Singapore Civil Defence Force (SCDF) inspected the site after conversion and gave an official approval, which was submitted to the National Environment Agency's (NEA). A safety survey was carried out to ensure that there was adequate ventilation, no exposed electrical or fire source nearby, no smoking signs, and proper control of access by the public. All electrical components and panels were sealed. (Please refer to Appendix 2.)

- *Performed pre-retrofit repairs and servicing:* Prior to the retrofit, leaks were detected and repaired. Monthly routine checks are now carried out, with only normal servicing required.

- *Monitored the performance and energy consumption of the pre-retrofit system:* kWh and run-hour meter were installed on February 19, 2005 to capture and determine pre- and post-HC conversions data. During the pre-conversion monitoring period (February 19, 2008 and March 8, 2008) the following data were recorded:
  - Baseline kW per hour consumption: 193.82 kW per hour (2 compressors)
  - Cooling performance: LCWT = 7.7 °C, ECWT = 10.1 °C

– *Fitted safety devices:* Gas leak sensors are only required when concentration of air for HC in an enclosed area falls into the flammability window between 1.9% and 10%. In the case of Far East Square, it was not necessary to install leak sensors. However, detection devices can easily be fitted to any system, with sensors connected to the ventilation fans and/or an alarm that will be triggered once a leak is detected. Further interfaces, such as solenoid valves, can also be integrated into an alarm system. In such a case, clear warning labels and signs such as, "Chiller Refrigerant is Flammable" and "No Smoking" should be prominently displayed.

– *Personnel training:* A safety talk was given to engineers and contractors in charge of the chillers. Technicians were educated about the "bad habits" and shortcuts that may have been picked up over the years.

The following technical procedures were followed to convert the systems, performed on March 28, 2005 –March 30, 2005:

– *Recovered existing refrigerant:* Existing refrigerant in the system was recovered and stored in dedicated recovery cylinders. The amount of refrigerant was weighed to ascertain current refrigerant charge.

– *Replaced spare parts where necessary:* Pre-conversion servicing was carried out. In particular, filters, driers and valve cores were replaced where necessary; leaks were repaired; oil quantity and quality were checked and replaced as necessary; and the system was flushed with nitrogen in order to ensure the removal of any residue substance.

– *Performed vacuum/leak test:* The system was vacuumed overnight. After this was completed, a tight vacuum was held for 30 minutes to test for leakages on the system.

– *Charged hydrocarbon refrigerant:* The original gas charge/weight was determined by documents or nameplates provided by the manufacturer or from the quantity of recovered gas. The required HC charge is equal to 90% of the original charge divided by 3. For example, if the original R22 charge was 10 kg, the amount of HC required would be: 10 kg ÷ 3 = 3.3 kg × 0.90 = 2.97 kg. The HC should be charged initially through the high-side/discharge service valve with the unit at OFF condition, then the unit should be run for 30 minutes, the compressors should be allowed to settle, and then the unit should be turned off for 10 minutes.

– *Fine tuned to optimise performance:* The units were then re-started for 10 minutes. The pressure should drop by 1-2 PSI because of refrigerant absorption by oil. Then, very slowly, 5 to 10 g was added each time (not more than 5 PSI at a time), to allow the unit to settle to achieve to get the best cooling result for the lowest amp reading. By doing this slowly, the chances of over-charging the unit are eliminated. The system must then be run for another 15 to 20 minutes to ensure that optimal performance has been reached.

– *Checked for leaks:* The system was tested for leaks using soap and water.

– *Labelled and monitored the system:* The Nat Energy information label was displayed in a prominent position on the unit. The unit was monitored over the next few days.

– *Monitored system performance and energy consumption:* KWh and run-hour meters were installed to monitor the monthly energy consumption. These readings were recorded monthly for billing purposes. Monitoring data from April 1-11, 2006 are as follows:
  - kW per hour consumption: 162.64 kW per hour (2 compressor)
  - Cooling Performance: LCWT = 6.4 deg C, ECWT = 11.2 deg C

A conversion report of the type shown in Appendix 2 is provided to the client upon completion, which illustrates the performance pre- and post-HC conversion. After conversion, the 8 year-old chillers achieved an energy consumption savings of more than 16%, as well as a drop of 12.2% in total current (amps) consumed. Cooling efficiency improved by nearly 17%. Following the completion of the project, no additional costs or special maintenance were required; only standard monthly servicing, maintenance, and annual shutdown. Some photographs of the power meters are provided in Figures 4 and 5.

Figures 4 and 5: Monitoring Device Installed – kW-hr Meter & Run-hr Meter, York Air-Cooled System Model: YDAJ98MU7-50PA

5. PROSPECTS FOR CONVERSIONS IN DEVELOPING COUNTRIES

To date, more than 70 HC conversion projects have been completed by ERG and its associate partners in Asia, including Singapore, Malaysia, Indonesia, and the Philippines. Already, many programs are in place where local technicians and contractors can be trained to correctly use HCs – several thousands have already been trained under various programs from organisations like UNEP, GTZ, SwissContact, foreign government aid programs, and the like—in addition to ERG's own customer base. ERG is currently working on several of these programs throughout developing nations, and through its many partners, offer HC conversions and local technician training. But developing country governments need to be involved and pro-active.

6. FINAL REMARKS

There is nothing new or unique about converting larger chillers/coolers to hydrocarbons. If technicians are trained properly, the correct procedures are followed, and the right safety devices are in place, a HC charged chiller will offer a lifetime of service with reduced power consumption and more efficient cooling. After conversion, the units draw less current, generally cool faster, and operate on lower head pressures.

Finally, as an addition to the provision of hydrocarbon refrigerants for retrofitting systems, the Nat-Energy Resources facilities in Singapore include a state of the art CFC, HCFC, HFC and halon destruction system (Figure 6), so prevention of emissions of ODS and high-GWP gases can be guaranteed following the conversion.

Figure 6: CFC, HCFC, HFC and halon destruction system

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APPENDIX 1
Hydrocarbon Conversion Projects and Associated Energy Savings in Asia

The following projects were completed by ERG and associate partners.

Singapore

1. Far East Square Shopping Mall using York 200TR Water-cooled Recip Chiller recorded 16% savings.
2. Defence Science & Technology Agency using Carrier 1hp Air-cooled split unit recorded 16% savings.
3. Dapenso Building using Carrier 21TR Water-cooled Packaged Unit recorded 32% savings.
4. Watson's Stores using Daikin Air-cooled Split Unit recorded 24% savings.
5. The Moomba Restaurant, Boat Quay using McQuay 8hp Air-cooled split unit recorded 16% savings

Malaysia

6. 7-eleven Stores Kuala Lumpur, Topaire Air-cooled Split Unit recorded 24% savings.
7. Flairis Kota Tinggi, Water-cooled Packaged Unit recorded 19% savings.
8. Nichicon Bangi, Topaire Water-cooled Packaged Unit recorded 20% savings.
9. Sumiden Electronics Shah Alam, Topaire Air-cooled Split Unit recorded 22% savings.
10. Hosiden Electronics Bangi, Air-cooled Split Unit recorded 25% savings
11. Alps Electric Nilai, Dunham-Bush Water-cooled Packaged Unit recorded 17% savings
12. Panasonic AVC Network Shah Alam, Air-cooled Split Unit recorded 19% savings
13. Venture Tebrau I Johor, Dunhan-Bush 65TR Water-cooled Packaged recorded 47% savings.
14. Panasonic Communication Senai Johor, National 20hp Water-cooled Packaged recorded 20% savings.
15. Celestica Electronics Tampoi Johor, Topaires 3 x 80TR Water-cooled Packaged recorded 24% savings.
16. Menara Ansar Johor, Carrier 23TR Water-cooled Packaged recorded 13% savings.
17. Bangunan PharmaCARE KL, Topaires 26TR Air-cooled Packaged recorded 23% savings.
18. Sumitomo Electronics Tebrau II Johor, York 32TR Water-cooled Packaged recorded 21% savings.
19. Taiko Electronics Senai Johor, York 21TR Water-cooled Packaged recorded 20% savings.
20. GG Circuits Industries Tampoi Johor, Carrier 35TR Water-cooled Packaged recorded 14% savings.
21. YKJ Industries Kulai Johor, Acson 4TR Air-cooled Split Unit recorded 27% savings.
22. Tru-Tech Electronics Ulu Tiram Johor, York 20TR Air-cooled Packaged recorded 19% Savings.
23. Matsushita Electric Company Shah Alam, Carrier 35TR Water-cooled Packaged recorded 15% savings.
24. Menara AmFinance KL, York 21TR Water-cooled Packaged recorded 16% savings.
25. Li Tat Mfg Masai Johor, York 17TR Air-cooled Ducted Type Split Unit recorded 29% savings.
26. OYL HQ (R&D Lab) where new 3TR split units recorded 27% savings.
27. UiTM Shah Alam Campus using Hitachi screw chiller recorded 19.7% savings.
28. Damansara Realty using Carrier 10TR Packaged units recorded 32% savings.
29. Pantai Medical Centre Bangsar, York 80TR Heat Recovery Unit recorded 24% savings.
30. Pantai Medical Centre Bangsar, York Air-cooled Chiller Packaged recorded 18% savings.
31. Lam Wah Ee Hospital Penag, Carrier Water-cooled Packaged recorded 20% savings.
32. Elecan SemiConductor Penang, Air-cooled Packaged recorded 14.8 % savings.
33. Comfort Engineering Puchong, Carrier Air-cooled Packaged recorded 18.5% savings.
34. Cekap Rea Johor, National Air-cooled Split Unit recorded 16.7% savings

Thailand

35. Carrier HQ Building using Carrier 150TR recip chiller recorded 14% savings.
36. Two 7-11 stores using split unit and walk-in-freezer recorded 20% savings.

Indonesia - Jakarta

37. Alfamart 649 stores in Jakarta using air-cooled split units recorded 25% savings.
38. ITC Mangga Dua using 208 tr Carrier recip chillers recorded 34.7% savings.
39. JW Marriott Hotel using 132 tr York recip chillers recorded 25% savings.
40. Supermal Karawaci using 60 tr Hitachi screw AHU recorded 30% savings.
41. Mulia Hotel using Copematic 5 tr semi-hermetic comp recorded 13.3% savings.
42. Sol Elite Marabella Hotel using 1.5 tr Sanyo split unit recorded 24.4% savings.
43. Maspion Plaza using 150 tr York recip chiller recorded 15% savings.
44. Kondominium Simpruk Teras using 10 tr Fair pckg unit recorded 22% savings.
45. Mal Kelapa Gading using 200 tr Carrier recip chillers recorded 28% savings.
46. Darmawangsa Square using 2 tr General split unit recorded 24% savings.
47. Siloam Gleneagles Hospital using 1 tr Mitsubishi split unit recorded 45% savings.
48. Yayasan Pendidikan Permai using 1 tr Gree split unit recorded 22% savings.

Indonesia - Bali

49. Maya Ubud Resort & Spa recorded 41% savings.
50. Sahid Jaya Hotel recorded 51% savings.
51. Ritz Carlton Hotel recorded 28% savings.
52. Kartika Plaza Beach Hotel recorded 55% savings

Indonesia - Lombok

53. Sahid Jaya Hotel recorded 72% savings.
54. Oberoi Hotel recorded 18% savings.
55. Novotel Hotel recorded 39% savings.
56. Lombok Raya Hotel recorded 27% savings.
57. Sheraton Senggigi Hotel recorded 53% savings.
58. Senggigi Beach Hotel recorded 36% savings.
59. Jayakarta Hotel recorded 25% savings.
60. Intan Lombok Hotel recorded 21% savings.
61. Holiday Inn Hotel recorded 20% savings

Philippines

62. Gaisano Country Mall - 50tr Hitachi Screw Type Compressor - 16%
63. Park Square One (Ayala Mall) - 7.5tr Frascold Semi - Hermetic Reciprocating Compressor - 12%
64. Delsa Chemicals Office - 5tr Maneurop Hermetic Reciprocating Compressor - 14%
65. McDonalds Restaurant - 7.5tr Maneurop Scroll Type Compressor - 12%
66. Legenda Hotel - 2tr Matsushita Rotary Type Compressor - 19%
67. Federal Express (Fedex) - 7tr Copeland Hermetic Reciprocating Compressor - 21%
68. Iglesia ni Cristo Church - 3tr Copeland Scroll Type Compressor - 15%
69. INARP Research Inc. - 2tr Matsushita Rotary Compressor - 12%
70. Building Care Corporation - 5tr Copeland Hermetic Reciprocating Compressor - 20%
71. Mandarin Restaurant - 40tr Century Screw Type Compressor - 17%

APPENDIX 2
Example of Conversion Report

Customer Name :	Far East Square Shopping Complex
Address :	43 Pekin Street, Singapore 048773
Air Conditioning System Data	
Pre-conversion Meter Installation Date :	19th February 2005
Baseline Monitoring Period :	19th February 2005 - 8th March 2005
Conversion Date :	28th March 2005
Post-conversion Monitoring Period :	1st April 2005 - 11th April 2005
Location :	Roof Top, Air-Cooled Chiller Unit No: 3
Brand :	York
Model :	YDAJ98MU7-50PA
Type :	Air-Cooled Chiller Unit
Capacity :	2,400,000 BTU/HR
Existing Refrigerant :	R22
Nat Energy Hydrocarbon Product :	MINUS 50

Data Recording					
Description	**Parameter Before**		**Parameter After**		**% Saving**
Start date of data recording	19th February 2005		1st April 2005		
End date of data recording	8th March 2005		11th April 2005		
Entering chilled water temp (ECWT) °C	10.1		11.2		
Leaving chilled water temp (LCWT) °C	7.7		6.4		
Water temperature difference (ΔT) K	**2.4**		**4.8**		
Average current, comp 1 (amp)	202.2		178.8		
Average current, comp 2 (amp)	167.1		145.6		
Total current (Amp)	**369.3**		**324.4**		***12.2%***
Low / high pressure, comp 1 (Psi)	59	251	52	221	
Low / high pressure, comp 2 (Psi)	65	237	53	208	
Starting kW-hr meter reading (Comp 1 and 2)	343,230		479,260		
Ending kW-hr meter reading (Comp 1 and 2)	397,900		499,920		
Total kW-hr consumed	**54,670**		**20,660**		
Starting running-Hr meter reading (Comp 1/2)	2,439.48	2,439.39	3,153.76	3,121.18	
Ending running-Hr meter reading (Comp 1/ 2)	2,726.83	2,716.15	3,281.08	3,247.92	
Average running hour	**282.06**		**127.03**		
Average power (kW per hour)	**193.83**		**162.64**		***16.1%***