Performance Comparison of CFC12, HCR12 and HCR12\textsuperscript{LFS} as Refrigerants

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ABSTRACT

Additional concern about warming of the global environment through the greenhouse effect has necessitated selection of compounds with shorter atmospheric lifetimes and higher energy efficiencies as substitute refrigerants for Heating, Air Conditioning, and refrigerating equipment.

Several substitute compounds of the hidrocarbon were identified by similarities in normal boiling points and corresponding saturated vapor pressure characteristics. Sample quantities were obtained from ITB (Two sample corresponds with CFC12 named Hycool HCR12 and Hycool HCR12\textsuperscript{LFS}). Performance comparisons among these refrigerants are performed utilizing Air Conditioning System test facility in Laboratory for Thermodynamics, Engines and Propulsion System (LTMP - BPP Teknologi). The results show that these alternatives refrigerants exhibit better performance than CFC12 at the predetermined operating conditions.

Introduction

Indonesia has ratified the Montreal Protocol and its Amendment in 1992, and has decided to ban the commercialization of the CFC started from January 1, 1997. CFC phase out has been creating a strong impact, particularly to those who use the refrigeration. To assist the users in solving to the problem in extending the use of existing refrigeration, various activities related to this purpose has been launched.

The use of R 134a and other equivalent HCFC blends are now becoming popular since most of refrigerators and Air Conditioning system manufacturers are Japanese companies who substitute the R12 with those refrigerants on new products. As an alternative, the Inter University Research Center for Engineering Sciences (IURC-ES, ITB) together with other institutions have launched a program to popularize the use of Hydrocarbon (HC) as R12 drop-in substitute with particular emphasize on the service sector through retrofitting of the already used equipments. The use of HC as substitute refrigerant of R12 for several applications such as for domestic refrigerators, large-scale milk cooling units, automobile Air Conditioning (AC), stationary AC and other related activities have been reported and discussed [1-3].

It was shown that the HC applications as refrigerants in those refrigeration units since 1996 have shown several advantages such as the improvement of performance, no need major replacement of equipment, more competitive refrigerant cost, etc. The disadvantageous flammability risk which is higher than CFC or HFC, for many cases can be avoided by implementing the appropriate standards. One among guideline to use HC safely is to avoid the Low Explosion Limit (LEL) when the HC leaks out from the refrigeration/AC units. The restriction of maximum refrigerant charge related to the volume of space to where refrigerant could leak out is one among the parameters be considered during the refrigerant conversion. For some
particular applications this restriction is becoming a constraint.

The development of HC based refrigerant with higher LEL has been developed by IURC-ES ITB on the name of HCR12\textsuperscript{LPS} and HCR22\textsuperscript{LPS}. The present of HC is only approximately 40% by weight therefore it will be appropriate to reduce the flammability of refrigerant at least from the HC charge reduction.

This paper presents the results of performance test of HCR12\textsuperscript{LPS} as refrigerant and its comparison to that of CFC12, and hydrocarbon refrigerant HCR12. The tests are performed as a co-operation program between IURC-ES ITB and Laboratory for Thermodynamics, Engines and Propulsion Systems (LTMP - BPP Teknologi).

Performance Testing of Air Conditioning System.

In order to compare the performance of an air conditioning system utilizing HCR12\textsuperscript{LPS} as refrigerant to that of CFC12 and HCR12, AC system test facility in LTMP - BPP Teknologi located in Serpong is used as the test object.

The system comprises of AC system components set up in a closed refrigerant loop/circuit as can be seen in Figure 1. The evaporator is installed at the end of an air tunnel providing regulated air-flow in accordance with the required condition. Air-flow, temperature and humidity across the evaporator is set in accordance with the test requirements, simulating the cooling load. Heat sink for the condenser is a closed water loop integrated with chilled water system as is seen as secondary circuit 1 in the figure.

Temperature and pressure sensors are installed at inlet and outlet sides of each component. For refrigerant flow measurement, a coriolis flowmeter is installed in condenser outlet. Specification of the main components in the test system are as follows:

1. Compressor: Open type/ reciprocating, 15 kW maximum power, 2980 rpm
2. Evaporator: Finned tube type, 16 kW max thermal capacity, with dimension of 890 x 531 x 270
3. Condenser: Vertical shell and coil type, 26 kW max thermal capacity, 400 mm length, 219 mm diameter

On refrigerant charging, water temperature in secondary circuit for condenser cooling is set to 26°C and water flow is set to 0.61 kg/s. Air temperature in secondary circuit for evaporator loading is set to 27°C with airflow of 0.6 kg/s and air humidity of 75%. The condition is maintained during the test.

To get approximately similar condition, refrigerant charging is performed until the following condition are achieved: condensation temperature of 39°C and evaporation temperature of 1°C. Ambient temperature during the test is 30 – 31°C, and humidity of 88%. This condition is set as basic test condition for performance comparison of the refrigerants.

Performance comparison of CFC12, HCR12 AND HCR12\textsuperscript{LPS}

Test conditions for comparison purposes are set to be similar for these three different refrigerants, and the results show the differences in performance parameters for these refrigerants.

Table 1 summarize the performance comparison between CFC12, HCR12 and HCR12\textsuperscript{LPS} for the above set condition. Limited information on physical properties for these alternative refrigerants make it difficult to evaluate the coefficient of performance for these refrigerants using the refrigerant side refrigerating effect and compressor thermal power. Therefore, the measured air-side refrigerating effect and measured compressor electrical power are used for determining system Coefficient of Performance (COP).

Parameters that are considered for comparison purpose are: system COP, and refrigerant flowrate/kW. Among CFC12, HCR12 AND HCR12\textsuperscript{LPS}, HCR12\textsuperscript{LPS} show the highest COP, and also the lowest refrigerant flow rate per kW of refrigeration effect. For first evaluation, HCR12\textsuperscript{LPS} can be considered to be the best refrigerant for the purpose, as it shows the best performance parameters among the tested refrigerants. Considering the safety aspect, the reduced HC concentration in the HCR12\textsuperscript{LPS} refrigerant, which will reduce the flammability of HC refrigerant, also makes it favourable for public unit applications.

Before, during and after each test, thorough checking of the system are performed. No leak or visible damage found, and no part replacement required.
### TABLE 1. PERFORMANCE COMPARISON OF CFC12, HCR12 AND HCR12LEPS

<table>
<thead>
<tr>
<th>Type of refrigerant</th>
<th>Compressor inlet temp. °C</th>
<th>Evaporation pressure kPa</th>
<th>Condensation pressure kPa</th>
<th>Compressor ratio</th>
<th>Refrigeration effect KW</th>
<th>Flow rate/kW Kg/s/kW</th>
<th>Electrical Power kW</th>
<th>COP</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFC12</td>
<td>28.2</td>
<td>320</td>
<td>1108</td>
<td>4.60</td>
<td>19.8</td>
<td>5.5 x 10⁻³</td>
<td>12.0</td>
<td>1.65</td>
</tr>
<tr>
<td>HCR12</td>
<td>25.4</td>
<td>326</td>
<td>1013</td>
<td>3.74</td>
<td>21.5</td>
<td>2.5 x 10⁻³</td>
<td>11.7</td>
<td>1.84</td>
</tr>
<tr>
<td>HCR12LEPS</td>
<td>25.2</td>
<td>332</td>
<td>1132</td>
<td>4.32</td>
<td>20.9</td>
<td>1.2 x 10⁻³</td>
<td>10.8</td>
<td>1.94</td>
</tr>
</tbody>
</table>

Figure 1. Schematic diagram of AC test installation
Conclusions

The test confirms that application of HCR12 and HCR12* refrigerants in air conditioning system improve the performance and there is no need of any replacement of equipment. The disadvantageous flammability risk which is higher than CFC or HFC, can be avoided by implementing the appropriate standards, and in the case of HCR12* this risk is lowered.

The results also show that HCR12 gives better performance improvement compare to HCR12. But it should be stressed that this test results are for tests done on this one specific piece of hardware, and may not be generalized to all situations. The relative rankings of the refrigerant may not hold true for conditions typical of other applications. Similar tests should be conducted for other application to confirm these results.

A performance comparison for CFC12, HCR12 and HCR12 refrigerants performed in air conditioning system test installation at this stage confirm the results gathered during previous studies. Further study for the impact of these alternative refrigerant application on broader aspects is still on-going, and should be continued.

Acknowledgement

The study that was done in LTMP and IURC-ES ITB was financially supported by Swisscontact. Therefore, the authors gratefully acknowledge those parties that have supported the research.

References:

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BACKGROUND

The growth of both world population and economic increases
the consumption of energy. Since the amounts of available
conventional energy resources become scarcer with time,
development of new or renewable energy technology and
improvements of conventional technology are needed to
fulfill the energy demand in the future. A good understanding
of the mechanisms involved in every step of energy
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energy is needed for both the improvements and innovations
of the technology. This conference provides an opportunity
for exchanging information among researchers working on
fluid and thermal energy conversion problems. The first
International Conference on Fluid and Thermal Energy
Conversions was held on December 1994 in Bali attended by
participants from more than 30 countries. The participants
agreed to hold the conference regularly in Indonesia every
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