UNIVERSITAT POLITÈCNICA
DE CATALUNYA
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Heat Engines Department

RS-50 (R442A)

A New Low Temperature Refrigerant

Performance Comparison with Five Existing Refrigerants

Summary

Independent tests were carried out on RS-50 (R442A) and five other refrigerants under identical conditions which show that R442A is superior to all the refrgerants tested under typical refrigeration condition:

- Under dynamic conditions R442A shows a faster pull-down time than any other low available temperature refrigerant.
- Under steady state conditions the COP of R442A is 44% higher than that of R404A and 10% better than that of R407F.
- Under steady state conditions the cooling capacity of R442A is 52% better than that of R404A and 16% better than that of R407F.

Abstract

Performance measurements on R442A (RS-50) in a calorimeter designed to emulate low temperature refrigeration conditions clearly demonstrate that its energy efficiency and cooling capacity are superior to those of R407F, R407A, R404A, R507, and R22.

1. Aim

The Technical University of Catalonia (UPC) was asked to test the comparative performances of six refrigerants for energy efficiency and other properties. The work was carried out in the University's Heat Engines Department where a suitable calorimeter was designed and built for these tests.

Two sets of trials were performed:

- Dynamic testing to compare the pull-down rates of the refrigerants.
- Steady state testing to compare the energy efficiencies and cooling capacities of selected refrigerants.

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2. Refrigerants

Six refrigerants were supplied to UPC of which five were provided as numbered samples only, and specifically not identified in any respect to those conducting the tests. Consequently, the first set of trials were in effect blind tests. The R404A sample was identified to enable the calorimeter to be commissioned.

3. Calorimeter circuit

The calorimeter circuit for conducting the tests was designed specifically to operate at temperatures down to -40^{0}C.

Compressor
Model 1,5 HP K7.2X GELPHA reciprocating designed for R22

Condenser
Air-cooled
Model Tipo HRT/4-400-5PN

Expansion device
Danfoss TES2 valve designed for R404A or R507 with an external balance and fitted with a three port distributor.

Evaporator and Cooling Load
The cooling load was a mixture of 25 L of propylene glycol and 17.1 L of water, contained in a 50 L cylinder[1] and stirred magnetically to ensure good heat transfer and rapid approach to thermal equilibrium. The evaporator consisted of three serpentine coils each 15m long wrapped around the cooling load and contained within an outer cylinder. The narrow gap between inner and outer cylinders was filled with an ethylene glycol/water mixture containing 3.66 L of each to provide good heat transfer from the cooling load to the evaporator coils.

Measurements
All tests were carried out under the same conditions with the same refrigeration circuit and the same monitoring equipment. Pressures were recorded with a Testo 570-2 logger; temperatures with a Testo 177-T4 logger fitted with four probes; and power consumption with Landis Gyr electricity meters.

4. Dynamic Tests

These tests were carried out to assess the ability of the pull down abilities of the refrigerants and also to provide an initial assessment of their COPs. Each refrigerant was tested using the following method:

With the whole system initially at ambient temperature, the compressor was switched on and the system monitored by recording the following pressures and temperatures:

- Condensation and evaporation pressures.
- Propylene glycol/water temperature.
- Surface temperature of the outer cylinder at the bottom, middle and top.
- Power consumption for each line of the 3-phase supply.

Suction Superheat
Because the identities of the refrigerants were unknown, except for R404A, when the tests were made, the suction superheats could not be calculated using thermodynamic tables. Multiple temperature probes attached to the evaporator were employed to establish the point in the evaporator where no liquid was present and superheat started. The temperature difference between this point and the thermostatic expansion valve bulb was determined to be the evaporator superheat and the valve was set to maintain a superheat of 5^{0}C to 7^{0}C for all refrigerants tested.

After the tests had been completed the identities of the refrigerants were revealed, thus allowing the temperature measurements logged with the Testo instrument to be compared with the temperatures calculated from REFPROP using the recorded pressure data. The data collected was recorded and analyzed in Excel. The following key parameters, characterising the performance of the system, were calculated.

- The compressor power input (w) was obtained by summing the readings of the three meters.
- The refrigerant cooling power (h) was obtained from the enthalpy loss of the cooling load minus the heat gain from the surroundings.

5. Steady State Trial

RS-50, R404A, R407F, R407A, R507 and R22 were tested under steady state conditions with the evaporator operating at -35^{0}C and the condenser at +35^{0}C, again with suction superheats in the range 5 to 7 K. Since the identities of the refrigerants were known for these tests, the superheat condition for each refrigerant was determined using thermodynamic information from REFPROP.

The cooling capacities of the 6 refrigerants proved to be different so the heat flows into the heat load and out from the condenser were controlled to maintain the temperatures at -35^{0}C and + 35^{0}C respectively. For R404A the equipment proved capable of maintaining the desired evaporator temperature, but the condenser needed to be throttled by restricting the air flow with card-board strips. For R407F a 500W electric resistance heater was placed in the propylene-glycol/water heat load and less throttling applied to the condenser air flow. For RS-50 the full condenser air flow was used and two 500W heaters were placed in the load.

6. Results and Discussions

6.1 Dynamic Trial

The results for each refrigerant from the dynamic tests are summarised in the following tables. In this report, the term "Cooling Capacity" refers to the rate at which heat is removed from the load and is thus given in watts.[2] "Coefficient of Performance" (COP) is the ratio of the "Cooling Capacity" to the electrical "Power Input".

Table 6.1.1 COP

Temp ^{0}C	R407F	R407A	R442A RS-50	R507	R404A	R22
-30	1.800	1.618	1.911	1.551	1.548	1.575
-20	2.385	2.144	2.533	2.056	2.052	2.087
-10	2.879	2.588	3.057	2.481	2.477	2.519

Table 6.1.2 Cooling Capacity (W)

Temp ^{0}C	R407F	R407A	R442A RS-50	R507	R404A	R22
-30	1384	1336	1552	1323	1308	1388
-20	2245	2168	2517	2147	2121	2252
-10	3353	3238	3761	3207	3169	3364

6.2 Steady State Trial

Table 6.2.1 summarises the results obtained under state conditions with the refrigerant nominally condensing at +35ºC and evaporating at -35ºC.

Table 6.2.1

	Refrigerant 1 R407F	Refrigerant 2 R407A	Refrigerant 3 R442A (RS-50)	Refrigerant 4 R507	Refrigerant 5 R404A	Refrigerant 6 R22
P evaporation (bar)	1.35	1.3	1.35	1.7	1.64	1.27
P condensation (bar)	16.1	14.8	16.2	17	16.05	12.68
P high / P low	11.93	11.33	12.00	10.00	9.78	9.98
Discharge temperature (ºC)	85	82	83	79	78	85
Cooling capacity (W)	1252	935	1477	1090	992	1263
Power input (W)	711	583	760	717	720	669
COP	1.76	1.6	1.94	1.37	1.37	1.89

[1] Dimensions; 40 cm x 20 cm radius

[2]In RSL literature capacity is often quoted as the suction specific volume in kW/m3, which is dependent upon operating conditions but mainly independent of the equipment design. For calorimetric it is more convenient and direct to compare the cooling powers of the different refrigerants.

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