2016

Performance Comparison of R32, R410A and R290 Refrigerant in Inverter Heat Pumps Application

Supharuek Konghuayrob
Siam Compressor Industry, Thailand, supharuekk@siamcompressor.com

Kornvalee Khositkullaporn
Siam Compressor Industry, Thailand, kornvaleek@siamcompressor.com

Konghuayrob, Supharuek and Khositkullaporn, Kornvalee, "Performance Comparison of R32, R410A and R290 Refrigerant in Inverter Heat Pumps Application" (2016). *International Refrigeration and Air Conditioning Conference.* Paper 1577.
http://docs.lib.purdue.edu/iracc/1577

Performance Comparison of R32, R410A and R290 Refrigerant in Inverter Heat pumps application.

Supharuek Konghuayrob [1*] , Kornvalee Khositkullaporn [2]

Siam Compressor Industry CO., LTD.
87/10 Moo2 Sukhumvit Rd., Tungsukhla Sriracha Chonburi Thailand 20230
Tel: +66-38-490900#643, Fax: +66-38-493821

[1] E-mail: supharuekk@siamcompressor.com
[2] E-mail: kornvaleek@siamcompressor.com

*Corresponding Author

ABSTRACT

Since low GWP matter rise up in the market, all heat pump manufacturers are searching for the refrigerants which are attractive for environment reasons. R290 is one of the player. It has a negligible GWP but it is flammable and dangerous to apply in commercial and split type of Heat pump application. In other words, R290 has been designated for Monobloc heat pump only. Thus, R32 is an alternative refrigerant for cooling application. Flammability of R32 is 80% burning velocity less than R290 and slightly flammable when compared with R410A. Although, R32 discharge gas temperature is around 20°C higher than R410A and this can damage compressor's motor at some heat pump condition especially at high compression zone. However, Discharge superheat control (DSH) concept could be implemented in the experiment to keep temperature of discharge gas within limit of 120°C. From the results, R32 has better heating performance 6% for BTW and 12% in ATW application when compared with both R410A and R-290. Consider to the refrigerant properties, the changing of R410A to R32 can keep compressors stoke volume. Meanwhile 57% stoke volume increasing of R290 must be implemented to keep the same capacity level, Consequently R32 is the candidate refrigerant for heat pump application when DSH control has been applied.

1. INTRODUCTION

Due to environmental reasons the heat pump manufacturer interested in GWP matter. Apart from the GWP reduction, the system's efficiency is also important. R32 is one of the candidates to make an environmentally - friendly heat pump because the lower GWP is one of the characteristics of R32. However, when focusing on discharge temperature of R32, this might be a problem if it is applied in heat pump application because of discharge temperature characteristic

As the high pressure shell type compressor can compress some small liquid portion at suction side (SSH = 0), the changing of expansion valve control from suction superheat to discharge superheat can be possible. This can also control discharge temperature lower than compressor's limitation. Therefore, the changing of control by discharge superheat with electronic expansion valve (EEV) can be applied with high pressure shell type compressor which using R32 in heat pump application.

By discharge superheat control concept, not only we can find the benefit of efficiency improvement but we can also apply R32 in heat pump application without the over limit problem of discharge temperature.

2. SYSTEM CONFIGURATION

The schematic diagram of heat pump with discharge superheat (DSH) control is shown in Figure 1. The system used electronic expansion valve (EEV) to control discharge superheat (DSH) by using Pd and Td for refrigerant flow adjustment.

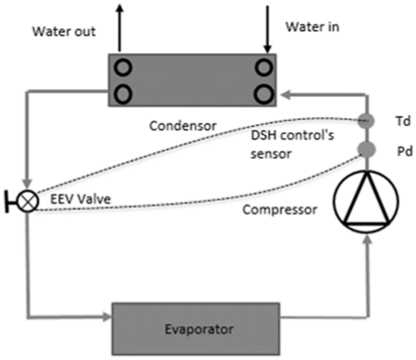


Figure 1 : The schematic diagram of heat pump with DSH control.

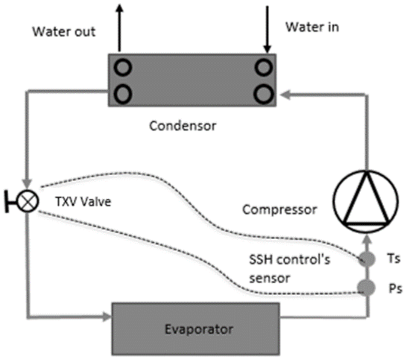


Figure 2 : The schematic diagram of heat pump with SSH control.

Figure 2 shows the system used suction superheat control (SSH). Thermostatic expansion valve (TXV) controls suction superheat by using Ps and Ts at ~5 K (R410A).

SCOP of the system can be calculated by equation (1)

$$SCOP = Q_H/Q_{HE} \quad (1)$$

Q_H is the reference annual heating demand, calculated as equation (2)

$$Q_H = PD*HH \quad (2)$$

Discharge superheat is calculated by Td and Pd as equation (3)

$$DSH = Td - Tsat\ (at\ Pd) \tag{3}$$

Figure 3 shows P-h diagram with DSH which can be calculated from equation 3.

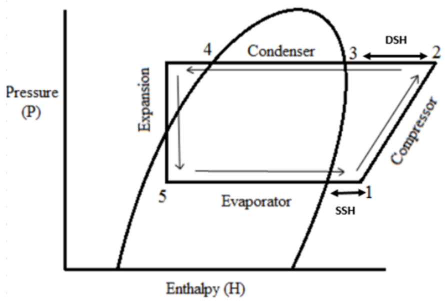


Figure 3: P-h diagram

Suction superheat was calculated by Ts and Ps as equation (4)

$$SSH = Ts - Tsat\ (at\ Ps) \tag{4}$$

This experiment considered 3 refrigerants. The focusing refrigerants were R410A, R290 and R32. All of them have different properties as shown in table 1.

Item	Type	Condensing pressure (Mpa)	Capacity (R410) ratio	COP (R410) ratio	ODP	GWP (IPCC4)	Flamma - bility	Toxicity
R410A	HFC	2.72	100	100	0	2090	No	Low
R290	Natural	1.53	59	107	0	<3	High	Low
R32	HFC	2.8	113	105	0	675	Low	Low

Table 1 : Refrigerant properties comparision.

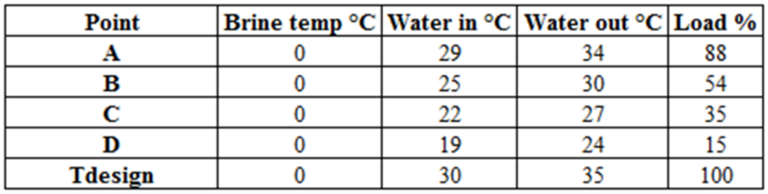
3. EXPERIMENTAL UNIT AND TESTING CONDITION

3.1 Type of testing unit

There are several types of heat pump unit in the market. This experiment only focused on the most famous heat pumps in the market that concern with environmental policy and efficiency standard following SCOP regulation at average zone.

3.1.1 Brine to water heat pump.

For experimental unit for Brine to water heat pump, the evaporator and condenser were plate heat exchangers. The compressor was a high pressure shell type hermetic scroll compressor. Expansion valve control was controlled by discharge superheat. Environmental temperature was around 30°C. The testing condition follow EN14825 is shown in Table 2.

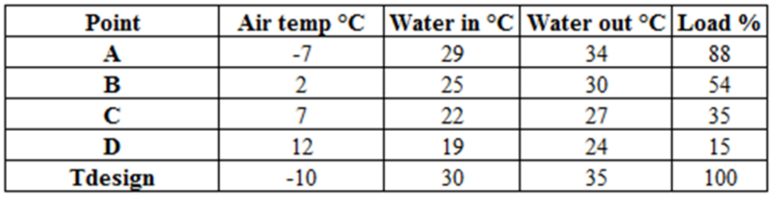


Point	Brine temp °C	Water in °C	Water out °C	Load %
A	0	29	34	88
B	0	25	30	54
C	0	22	27	35
D	0	19	24	15
Tdesign	0	30	35	100

Table 2 : Test temperature for Brine to water heat pump : Under floor heating

3.1.2 Air to water heat pump.

For experimental unit for Air to water heat pump. The condenser was a plate heat exchanger. The evaporator was an air type heat exchanger. The compressor was a high pressure shell type hermetic scroll compressor. Expansion valve control was controlled by discharge superheat. The testing condition follow EN14825 is shown in Table 3.

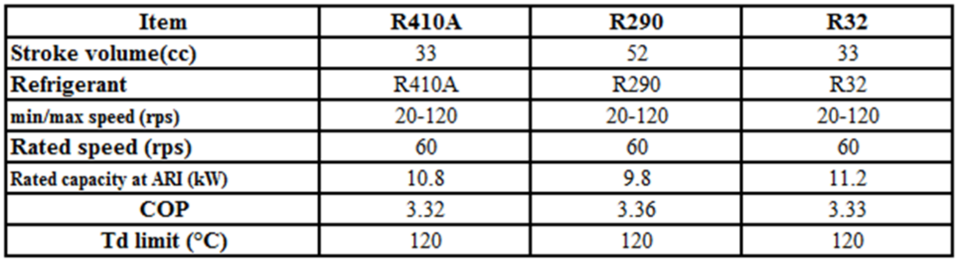


Point	Air temp °C	Water in °C	Water out °C	Load %
A	-7	29	34	88
B	2	25	30	54
C	7	22	27	35
D	12	19	24	15
Tdesign	-10	30	35	100

Table 3 : Test temperature for Air to water heat pump : Under floor heating

3.2 Type of compressor

Inverter driven scroll compressor with high pressure shell type was fixed with this experiment. There are different stroke volume but almost the same capacity level at rated condition. The specification is shown in table 4.



Item	R410A	R290	R32
Stroke volume(cc)	33	52	33
Refrigerant	R410A	R290	R32
min/max speed (rps)	20-120	20-120	20-120
Rated speed (rps)	60	60	60
Rated capacity at ARI (kW)	10.8	9.8	11.2
COP	3.32	3.36	3.33
Td limit (°C)	120	120	120

Table 4 : Specifiaction of refrigerant compressor comparision

4. TEST RESULTS

4.1 Refrigerant charge amount

The suitable refrigerant charge amounts compared between each refrigerant were confirmed at various compression ratio (Pd/Ps), from the shown results when discharge superheat control was implemented, refrigerant charge amount by discharge superheat control was increased when compared with suction superheat control up to 6.3% for R32, 13.5% for R290 and 10.9% for R410A.

4.1.1 Brine to water heat pump

Figure 4-6 show the refrigerant charge amount by varying compressor's compression ratio. (Pd/Ps)

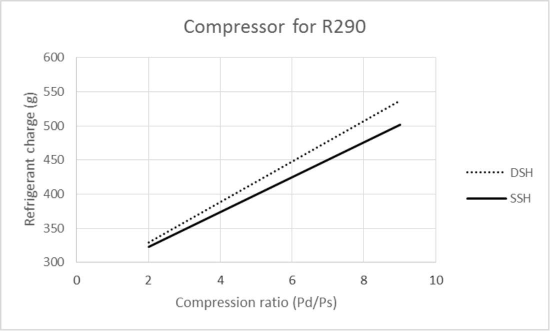


Figure 4: Testing result of BTW Heat Pump with R290

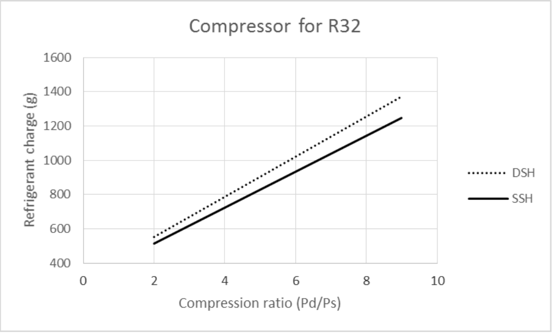


Figure 5: Testing result of BTW Heat Pump with R32

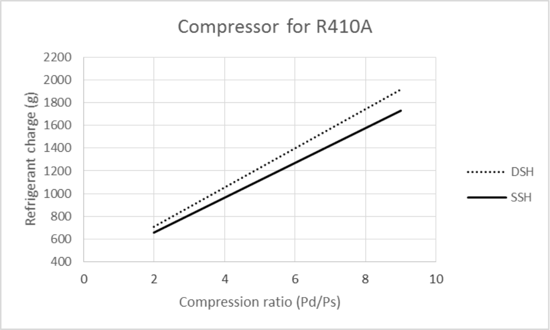


Figure 6: Testing result of BTW Heat Pump with R410A

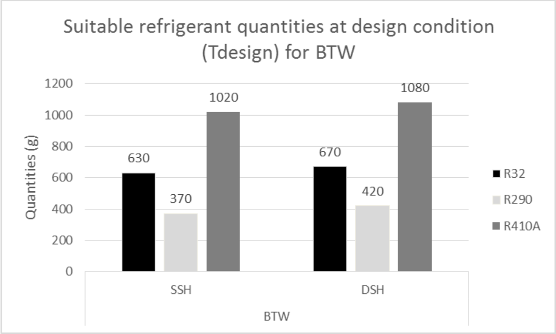


Figure 7: Refrigerant quantities at design condition for BTW

Figure 7 shows the suitable refrigerant quantities of Brine to water at design condition follow SCOP regulation.

4.1.2 Air to water heat pump

Figure 8-10 show the refrigerant charge amount by varying compressor's compression ratio (Pd/Ps).

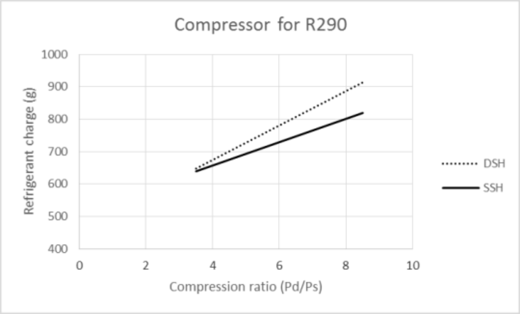


Figure 8: Testing result of ATW Heat Pump with R290

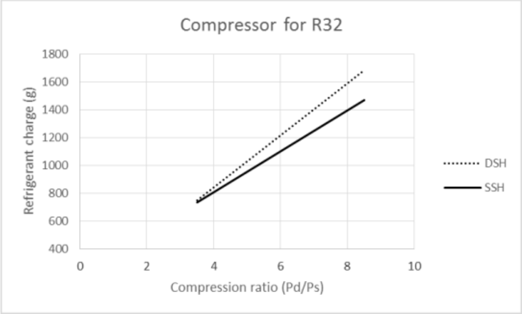


Figure 9: Testing result of ATW Heat Pump with R32

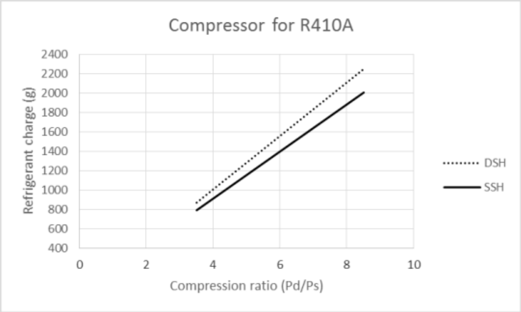


Figure 10: Testing result of ATW Heat Pump with R410A

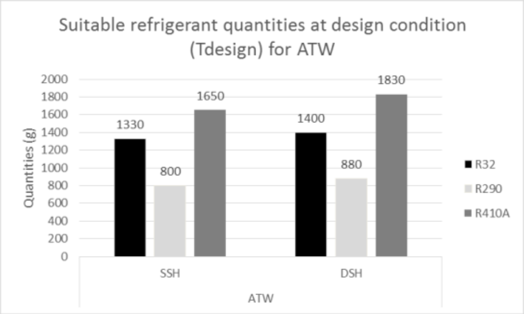


Figure 11: Refrigerant quantities at design condition for ATW

Figure 11 shows the suitable refrigerant quantities of Air to water at design condition follow SCOP regulation.

4.2 Discharge superheat set point

The optimum DSH value was related with Compression ratio (Pd/Ps) of compressor as shown in figure 12 - 13.

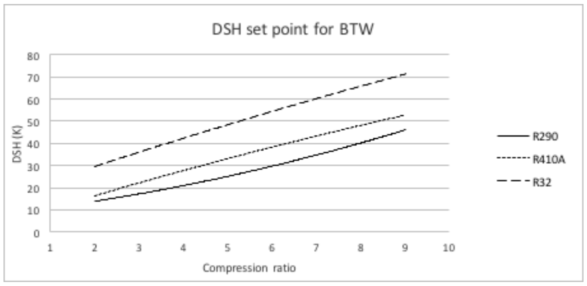


Figure 12: Discharge superheat set point for BTW Heat Pump

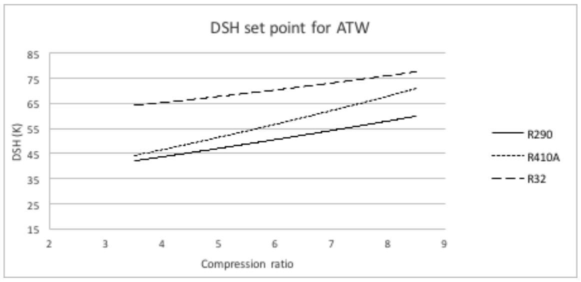


Figure 13: Discharge superheat set point for ATW Heat Pump

4.3 Discharge temperature

When discharge superheat control was applied, the discharge temperature could be controlled under the compressor limit at 120°C by expansion valve adjustment.

Figure 14 - 15 show the relation between compression ratio (Pd/Ps) and discharge temperature of R410A, R290 and R32 when they were controlled by discharge superheat.

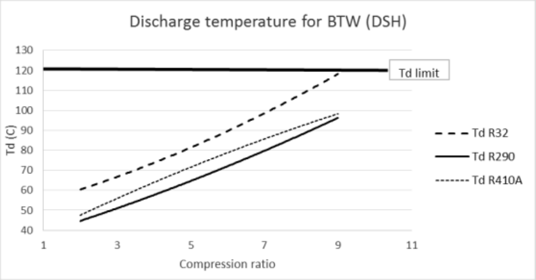


Figure 14: Test result of discharge temperature with discharge superheat control for BTW

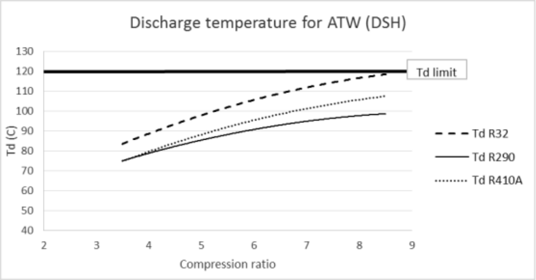


Figure 15: Test result of discharge temperature with discharge superheat control for ATW

Figure 16 – 17 show the relation between compression ratio (Pd/Ps) and discharge temperature of R410A, R290 and R32 when they were controlled by suction superheat. At high compression ratio condition, discharge temperature of R32 was over than compressor limitation.

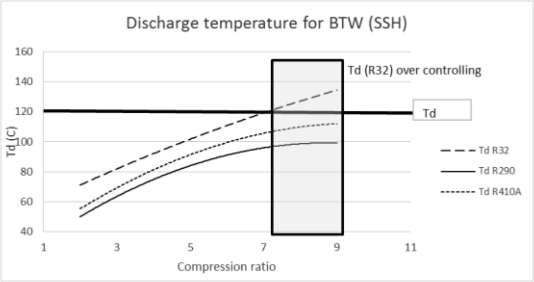


Figure 16: Test result of discharge temperature with suction superheat control for BTW

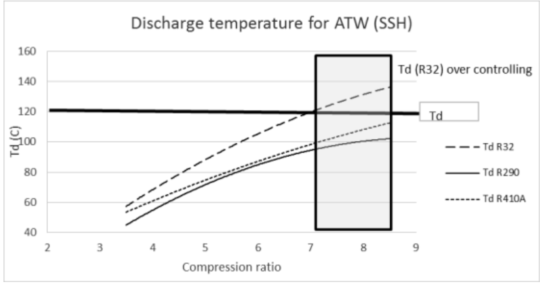


Figure 17: Test result of discharge temperature with suction superheat control for ATW

4.4 Unit performance

When discharge superheat control was applied, R32 was comparable with another alternative refrigerant in heat pump application without any restriction of high discharge temperature. The comparison of performance follow EN14825 in average zone is shown in figure 18 – 19.

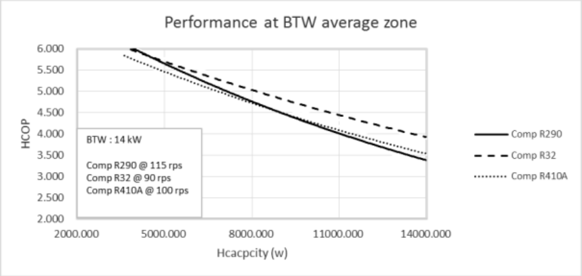


Figure 18: Performance comparison of BTW heat pump when discharge superheat control has been applied

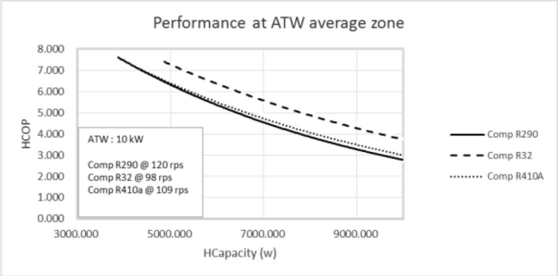


Figure 19: Performance comparison of ATW heat pump when discharge superheat control has been applied

Figure 20 shows SCOP in average zone, from the testing results, R32 could improve 6% of SCOP when compared with R410A in Brine to water system, and 12% improvement in Air to water system. Meanwhile, R290 cannot improve SCOP level when compare with R410A

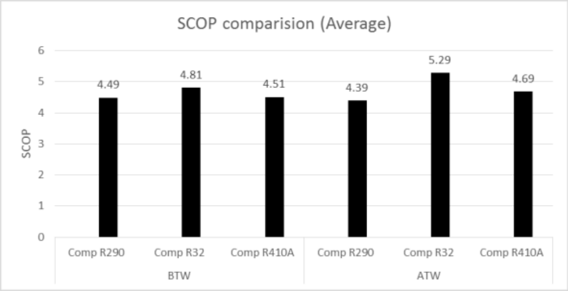


Figure 20: SCOP comparison in average zone

5. CONCLUSION

In this experiment, it was shown that the performance comparison between R410A R290 and R32 in heat pump application, which were controlled expansion device by discharge superheat.

1. For Brine to water system, the SCOP improvement of R32 when compared with R410A is 6% and 12% for Air to water system.
2. SCOP of R290 is same level as R410A in Brine to water system and 6% of SCOP lower than R410A in Air to water system.
3. The stroke volume of compressor, which was using R32 could be reduced when compared with the same capacity level of compressor which using R410A.
4. R32 can be applied in heat pump application when discharge superheat control has been implemented.

NOMENCLATURE

SSH	Suction Superheated		**Subscripts**
DSH	Discharge Superheated	d	Discharge
HCOP	Heating Coefficient of Performance	s	Suction
SCOP	Seasonal coefficient of performance	sat	Saturated
BTW	Brine to Water	H	reference annual heating demand
ATW	Air to Water	HE	seasonal electricity consumption
HP	Heat Pump		
EEV	Electronic Expansion Valve		
TXV	Thermostatic Expansion Valve		
P	Pressure (MpaG)		
T	Temperature (Celsius)		
PD	Design load for heating (kW)		
Q	Power (kWh)		
HH	Equivalent active mode hours for heating (hrs)		

REFERENCES

Willbert F.Stoecker / Jerold W.Jones. (1982). Refrigeration and Air Conditioning, Chapter 13, Expansion Devices, *McGraw-Hill Inc*, P.260-280

Stavros DIMAS. (2007). Establishing the ecological criteria for the award of the Community eco-label to electrically driven, *BTW&ATW HP Testing Condition*, P. 4-5

Siam Compressor Industry. (2002). General Specification of Scroll Compressor, VHIK-71676 revised F, Maximum Discharge Temperature, P.2

Tanawitayakorn Wasan / Phrajanpanich Paisarn / Siwapornphaisarn Supot. (2012). Heat Pump Efficiency Improvement by Discharge Superheated Control, *International Refrigeration and Air Conditioning Conference at Purdue 2012*, P.2

Siam Compressor Industry. (2010). Discharge Superheat Control Guideline, TDCS10D045 revise A, P.1