INTRODUCTION OF COMMERCIAL CO_2 HEAT PUMP APPLICATIONS IN SWITZERLAND AND JAPAN

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Abstract: Application of natural refrigerants in refrigeration and air conditioning has attracted considerable interest in the past decade because of environmental concerns attached with CFC, HCFC and HFCs. In the last ten years, small size compressors using CO_2 as the working fluid have been developed for hot water supply systems in Japan. Over 1,000,000 transcritical CO_2 heat pump hot water supply units have been installed in residential buildings in Japan.
This paper reports on the development of a commercial transcritical CO_2 compressor with a nominal power of 25kW and installation of a 60kW size water heat source CO_2 heat pump in Europe, Switzerland. The unit was supplied to Zurich City Electric Power Company for heat energy supply to a football training center in Niederhasli. It was supplied in September, 2005 and has been running with no major problems. The paper also introduces a CO_2 heat pump application using air as the heat source for producing hot water for a hostel in Japan. The heat pump system with a 30m^3 water storage tank and 130kW heating capacity is fully automated to match with load changes.

Key Words: CO_2 *heat pumps, transcritical compressor, hot water supply*

1 INTRODUCTION

Global warming and ozone depletion concerns have led to considerable interest in use and application of natural refrigerants and in the last ten years, small size compressors using CO_2 as the working fluid have been developed for hot water supply systems in Japan. Over 1,000,000 transcritical CO_2 heat pump hot water supply units have been installed in residential buildings. High oil prices have also drastically increased running costs of boiler driven hot water systems. There is, therefore, a growing interest in environmental and cost friendly heat pump systems.
This paper reports on the development of a commercial transcritical CO_2 compressor with a nominal power of 25kW , installation of a 60kW water source CO_2 heat pump in Switzerland and a130kW air source heat pump in Japan. A comparison of the CO_2 heat pump installed in Japan and a boiler driven hot water supply system showed 61% reduction in running costs and 42% reduction in CO_2 emissions.

2 Installation in Japan

Table 1 shows specifications of the compressor developed for CO_2 heat pump applications while figures 1 and 2 show the picture and cross section.

It is a semi hermetic two cylinder reciprocating compressor with an equal bore and stroke of 45mm. The suction and discharge design pressures are 70 and 150 barG respectively. It has a displacement of volume 12.5 and 8.3m^3/h at 1450rpm and 970rpm respectively. The maximum speed is 1800rpm while the minimum speed is 900rpm. A 25kW 4pole 3 phase induction motor is used.

Suction gas is used to cool the motor thereby increasing motor reliability and enabling the crank case to be designed at suction pressure. With the crank case designed at suction pressure the casing thickness is reduced.

Table 1; specifications of the CO_2 heat pump Compressor

Model		C 2 H T
Refrigerant		CO_2
Bore x Stroke		45.0 x 45.0 mm
Number of cylinders		2
Head cover cooling		Air cooled
Oil cooling		None
Speed		Max.1,800 Min.900 rpm
Motor	Type	3 phase induction motor
	Rating voltage	25kW-200/200/220V-50/60/60Hz 25kW-400/400/440V-50/60/60Hz
	Number of poles	4
Displacement volume		8.33 (m^3/h) (at 970 rpm) / 12.5 (m^3/h) (at 1,450 rpm)
Oil	Grade	Over ISO-VG46
	Charge	5.0 (L)
Pipe size	Suction	(25A)
	Discharge	(20A)
Net weight		410 kg
Suction pressure		Max. 70.0 barG
Discharge pressure		Max. 150 barG

Fig. 1: Picture of the CO_2 Compressor

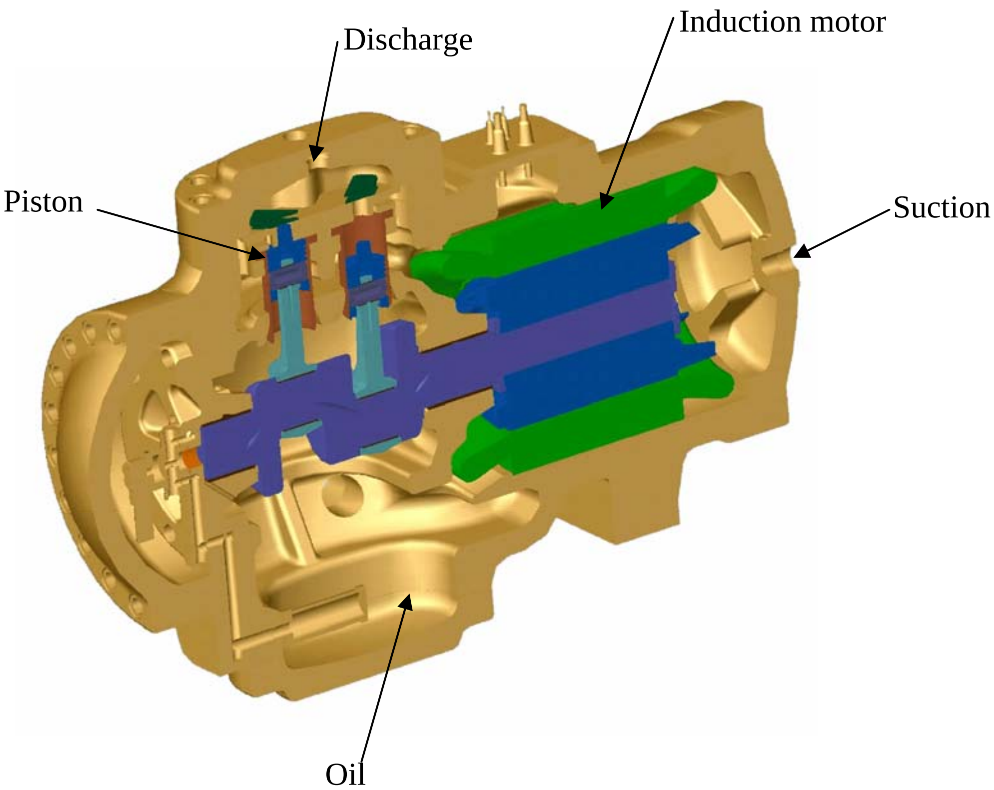

Fig. 2: Cross section of the CO_2 Compressor

Table 2 shows specifications of the MYCOM ECO-CUTE package while figures 3 and 4 show the flow and picture of the heat pump installed in Japan. The installation mainly consists of two sets of the heat pump packages, a 30 m^3.tank, circulation pumps, a heat exchanger and filter. The heat pump uses air as the heat source to produce hot water up 90C. Hot water is stored in a 30m^3 tank from where it is drawn to water baths and shower rooms. The heat pump system was designed to provide hot water to a maximum of 200 people for 22 hours with a bath size of 8.5m^3.

Table 2; Specifications of MYCOM ECO-CUTE (HWA-2HT)

Item	Specifications
Model	MYCOM HWA-2HT (2sets)
Refrigerant	R744
Heating Capacity	65kW (per set)
Air temperature	16C DB, 12C WB
Water supply temp.	17C
Hot water temp.	90C
Motor Power	25kW
Power supply	200V , 50Hz
Fan motor	0.75kW X 2
Water supply pump	0.393kW
Dimensions	W 140, L 2085, H 2070
Weight	Net 1545kg Gross 1570kg
Water Tank	Stainless water tank
Dimensions	L 4000, W 3000, H 3000
Storage Volume	30m^3

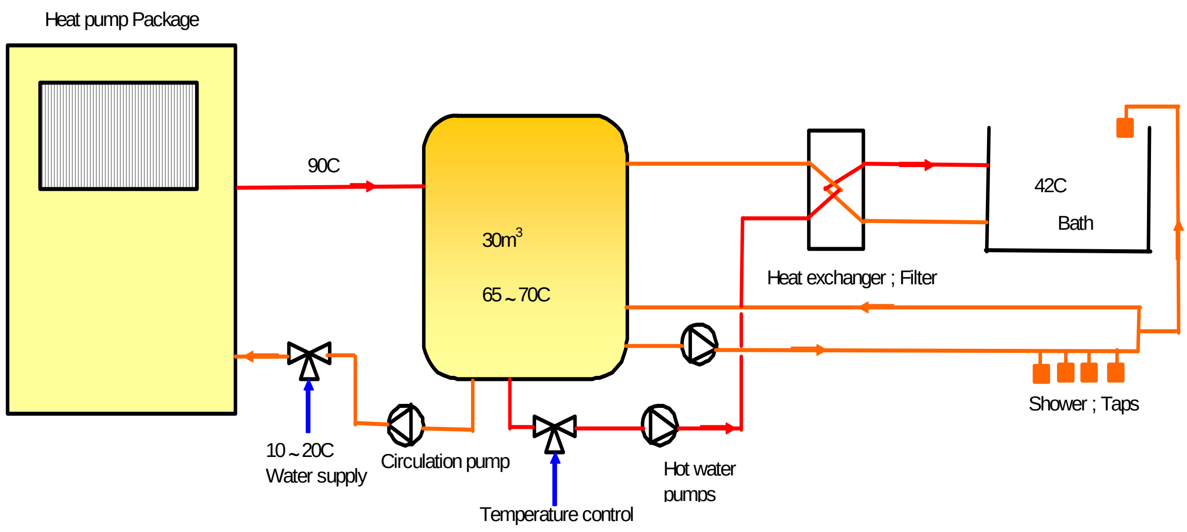

Figure 3: flow of the system

Figure 4: Picture of the Heat pump

Figure 5 shows an example of a day's operation. The heat pump usually operates from 5pm in the evening through 4am the following day. The peak demand for bath water is from 5pm to 10pm and the heat pump runs full time during this time. Mid night use power discount starts at 10pm. Therefore, from 10pm to 4am the following day hot water storage is done.

The heat pump operates at about 11.5MPaG and to produce water of about 90C which is stored in a tank and supplied for use at about 60C. During the peak demand (5pm to 10pm), water in the storage tank is supplied to the heat pump and re-heated, otherwise the water supply temperature is about 15C. The water level in the tank slightly drops during the peak time but water is replenished during storage operation in the midnight.

Figures 6 and 7 show operation data for summer and winter respectively. As seen from the figures there is more demand for hot water in winter and the heat pump operates for longer hours in winter.

The COP of the system has been improved and is currently as shown in table 3. The COPs were measured at the Japan refrigeration and air conditioning association standards, JRA 4050. Water inlet and outlet are set at 17 and 65C, while inlet air is set at 16 and 12C dry and wet bulbs respectively.

Table 3; COP of the system

Heating capacity	Power	COP	Hz
68.9	16.8	4.1	50
80	20.5	3.9	60

The heat pump has been running for more than one year with satisfactory results. The heat pump system replaced a boiler driven water supply system and table 3 shows a comparison of running costs and CO_2 emissions for the two systems.

Since the CO_2 heat pump takes advantage of the cheap mid night power to produce and store hot water, the cost of producing hot water for the facility was reduced by 40%. And a comparison of CO_2 emissions shows that CO_2 emissions are reduced by 50%.

From the table it can be deduced that, with increased fuel costs and global warming awareness, the CO_2 heat pump is clearly one of the optimum choices.

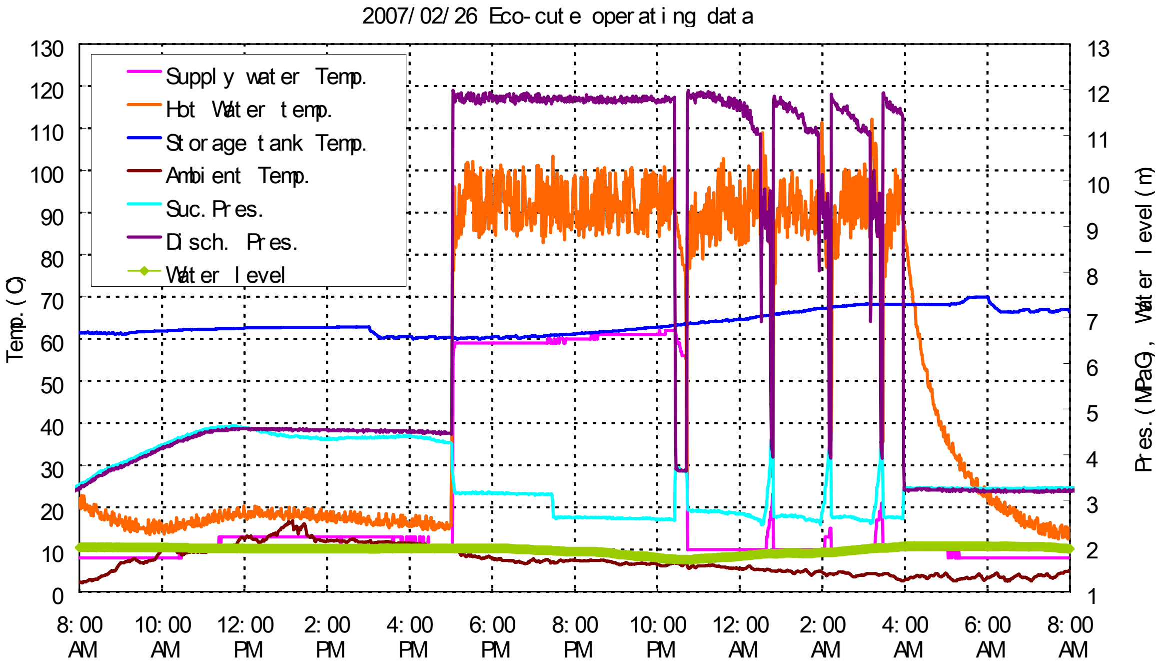

Figure 5: A day's operation example

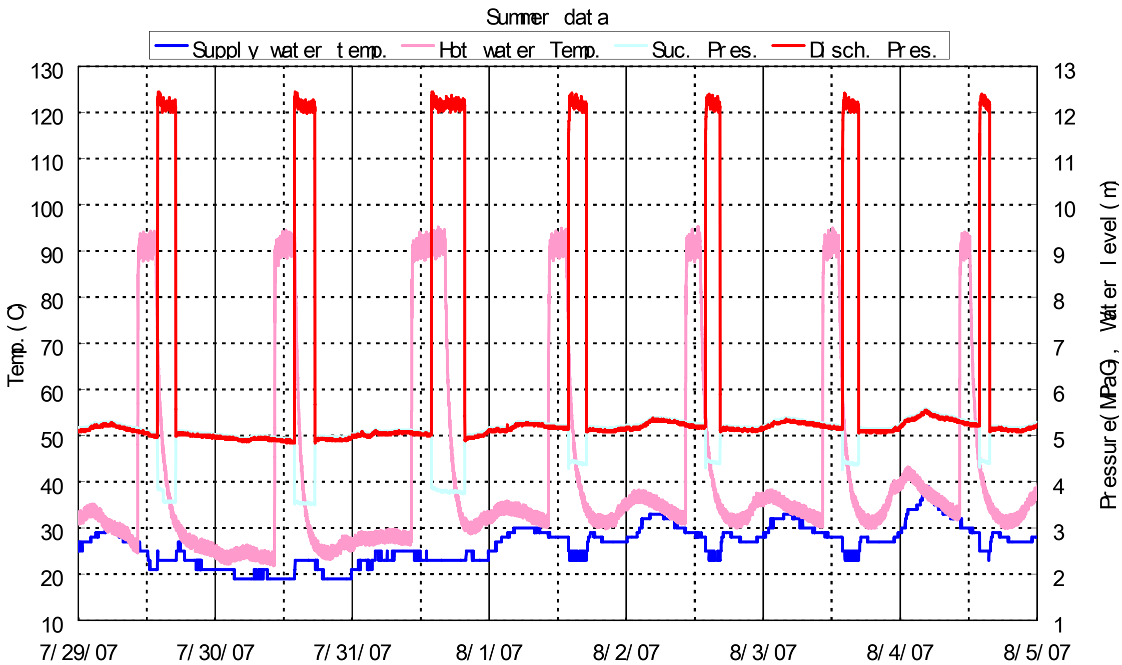

Figure 6: Summer operation data

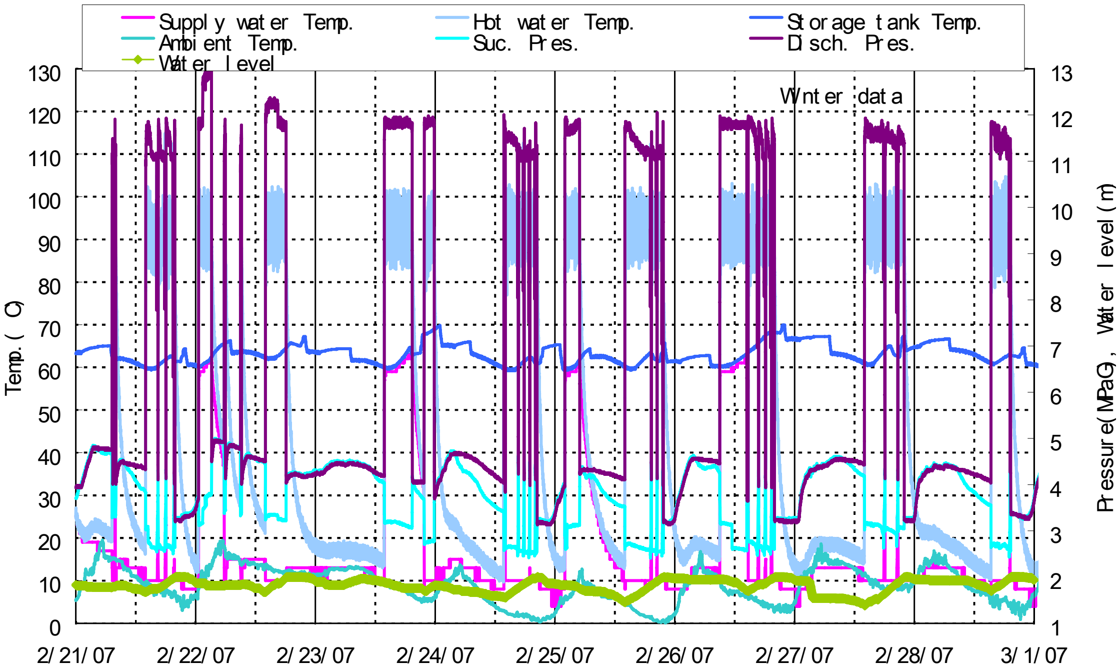

Figure 7: Winter operation data

Table 3; Comparison of Eco-cute and Boiler running costs and CO_2 emission

Amount of oil (grade A) used in 2006 (liters)	25000
Cost of oil (Yen/liter)	62.5
Total cost of oil in 2006	**1562700**
Eco-cute power consumption (kWh) in 2007	100725
Power cost (Yen/kWh)	12
Eco-cute power cost (Yen) (including mid night use)	1208700
Mid night use power consumption (kWh) in 2007	79613
Mid night use power cost (Yen/kWh)	7.2
Mid night use discount (Yen) 2007	573214
Eco-cute power cost after mid night use discount	**635486**
Eco-cute running cost as compared to boiler	**40.7%**
Grade A oil CO_2 emission (kg-CO_2/liter)	2.710 [*1]
Electric power CO_2 emission (kg-CO_2/liter)	0.339 [*2]
CO_2 emission (kg) in 2006 (Oil)	**67741**
CO_2 emission (kg) in 2007 (Electricity)	**34146**
Eco-cute CO2 emission as compared to boiler	**50.4%**
Primary energy conversion (oil use) 2006 (GJ) (boiler efficiency 100%)	977500
Primary energy conversion (Electricity use) 2007 (GJ)	990127
Comparison of primary energy	101.3%

[*1] Grade A oil calorific value 39.1MJ/liter, CO_2 emission 0.0693 kg-CO_2/MJ
[*2] Tokyo Electric power data
[*3] Electricity primary energy 9830kJ/kWh

3 Installation in Switzerland

Figure 8 shows a heat pump package installed in Switzerland. The package was sold to Zurich Electric Company and installed in a sports training facility to provide hot water at 60C for the facility. It is a water source heat pump with a heating capacity of 60kW. Water source inlet and outlet temperatures are 6 and 2C respectively.

It has been in operation since 2005 and the same company will be installing two more such heat pumps in a shopping mall in Zurich this year.

Figure 8: Heat pump package installed in Switzerland

4 Conclusions

Small size compressors using CO_2 as the working fluid have been developed for hot water supply systems in Japan and over 1,000,000 transcritical CO_2 heat pump hot water supply units have been installed in residential buildings.

MYCOM has developed and so far installed over 60 commercial CO_2 heat pumps in Japan and Europe.

And as illustrated with the comparison running costs between a CO_2 heat pump and boiler driven water supply systems, increased fuel costs make the CO_2 heat pump one of the optimum choices from the running costs point of view. The comparison also shows that a CO_2 heat pump is still the best choice for a friendly environment.

5 Acknowledgments

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