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ACTUAL ENERGY CONSERVATIONS BY USING NH3/CO2 REFRIGERATION SYSTEM

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ABSTRACT: Electrical power supply in Japan continues to be unstable since March 11th 2011 when the great Tohoku earthquake caused massive tsunamis that crippled the Fukushima nuclear power plant. The industrial world, therefore, is required to save energy. Since the refrigeration and storage industry consumes a lot of energy, power saving is urgently required. MYCOM has verified energy conservation in refrigeration plants using the NewTon series. The NewTon series uses environment friendly natural refrigerants NH_3 and CO_2 as primary and secondary refrigerants respectively to provide highly efficient cooling systems for the refrigeration industry. This paper reports on some examples of energy conservations (25 to 50%) realized in cold storage and freezing plants.

1. INTRODUCTION

Power supply in Japan continues to be unstable since March 11th 2011 when the great Tohoku earthquake caused massive tsunamis that crippled the Fukushima nuclear power plant. Almost all nuclear plants have been shut down because emphasis has shifted from steady power supply to safety. As a result steady power supply has become difficult and energy conservation is being required. Since the refrigeration and storage industry consumes a lot of energy, power saving is urgently required.

In 2008 and with funds from the ministry of environment, MYCOM developed the NewTon with the aim of reducing environmental load. The NewTon series uses environment friendly natural refrigerants NH_3 and CO_2 as primary and secondary refrigerants respectively to provide highly efficient cooling systems for the refrigeration industry. This paper reports on some examples of energy conservations (25% to 50%) realized in refrigeration, storage and freezing plants.

2. THE IDEAL REFRIGERATION CYCLE

Among the natural refrigerants, ammonia has the best physical and thermal properties with proved application. Figure 1 compares theoretical COPs of single, two stage and the CO_2 cascade systems working with ammonia.

The two stage system offers the best COP between evaporating temperatures of -10 degree C and-50 degree C. A two stage system manufactured with high efficiency, therefore, conserves the most energy.

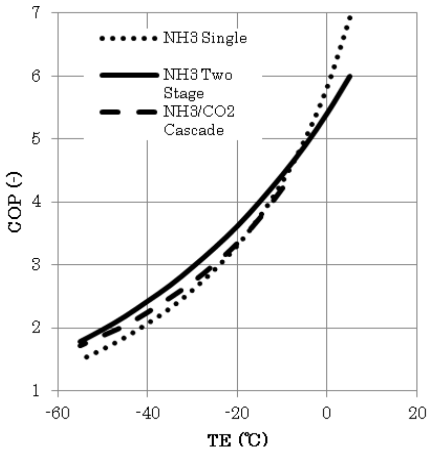

Fig.1 Theoretical COP

3. CHARACTERISTICS OF NewTon

NewTon was developed in 2008 with funds from the ministry of environment under "Power conservation natural refrigerant refrigerators" grant for the purpose of reducing CO_2 emissions. In order to reduce the environmental load, a natural refrigerant, ammonia was

Fig.2 NewTon R-3000

used. The aim was to achieve 20% energy conservation compared to the existing HCFC-22 systems.

3-1. NewTon CONCEPT

Figure 3 shows the basic concepts of the NewTon.

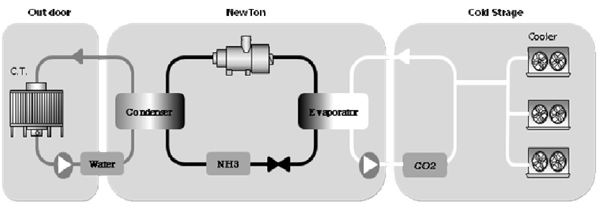

Fig.3 Basics concepts of the NewTon

1) Water cooled

NewTon uses a closed circuit cooling tower to lower the condensing temperature thus reducing power consumption. A water cooled type increases freedom of installation place and is easy to maintain. It also helps reduce the amount of ammonia charged.

2) Ammonia package

The ammonia package is factory fabricated and fully automated. The package includes an IPM motor and a screw compressor with a double economizer system and compact heat exchangers all specifically developed for this system.

3) CO_2 secondary refrigerant

CO_2 is used as the secondary refrigerant. It is non toxic, requires less transport power because of low viscosity, and requires less refrigerant circulation because latent heat is used. Since CO_2 has no contaminants, air cooler performance does not deteriorate.

3-2. SCREW COMPRESSOR

In order to increase the efficiency of the NewTon package, compound two stage screw was used. The compressor rotors have new profiles and are grinded for high precision finishing.

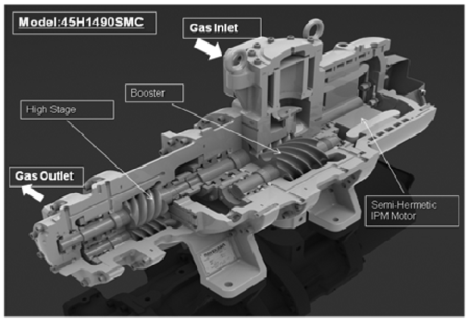

Fig.4 Screw Compressor

3-3. IPM MOTOR

The screw compressor is mounted with a semi hermetic IPM motor. As shown in figure 5, an IPM motor has higher efficiency, 10%~15%, compared to the conventional induction motors.

The IPM motor is a synchronized motor and uses an inverter as driver. Efficiency during part load operation is, therefore, improved compared to the conventional slide valve type.

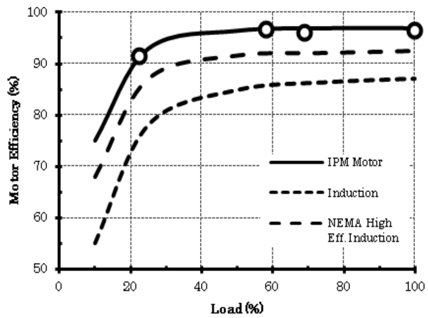

Fig.5 Motor efficiency

3-4. DOUBLE ECONOMIZER

After sub cooling liquid ammonia to the intermediate temperature, further sub cooling in the low stage economizer is done to improve the efficiency. Flush tanks are used to eliminate losses within heat exchangers.

3-5. SHELL & PLATE HEAT EXCHANGERS

In order to minimize approach temperature and refrigerant charge, at the same time realize a compact package shell and plate heat exchangers are used for the condensers and evaporators.

For example, approach temperature in evaporator is 1.7 degree and a 45kW motor model R-3000 uses only 25kg of ammonia. Refrigeration capacity per NH_3 charge is 3.9 kW/kg.

4. APPLICATIONS

More than 400 packages have been installed and energy conservation has been verified. About 67% of the installed NewTon series are used in cold storages while 26% are used in freezers and the rest in ice skate rinks. The NewTons used in cold storage in Japan currently accounts for 8% of the Japanese cold storage volume (2,500,000m^3).

5. VERIFICATION OF ENERGY CONSERVATION

Examples of energy conservation in cold storage ware houses and freezer are given here.

5-1. COLD STORAGE

The amount of electric power used for refrigeration in clod ware houses accounts for 60 ~70% of the total electric power. Figure 6 shows a breakdown electric power used in large cold storage around Tokyo.

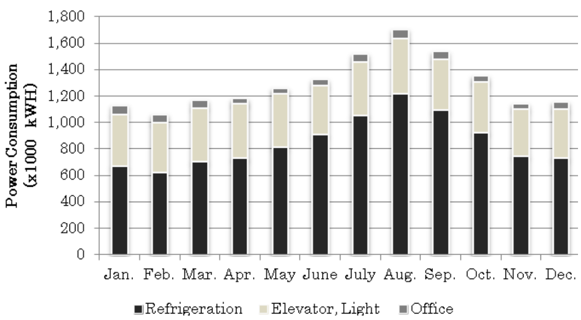

Fig.6 Electric power usage in ware houses

The graph shows that power is least consumed in February (winter) and most consumed in August (summer). The power used in February is nearly 60% of the power used in August. The graph also shows that refrigeration accounts for about 65% of the total power throughout the year. The rest of the power is used in lighting and conveying systems (30%) and office appliances (5%).

1) Specific power consumption

Electric consumption in cold storage ware houses is estimated by specific power consumption as shown in the equation below.

$$SPC = PCy/Vc \quad (1)$$

where:
SPC : Specific Power Consumption (kWH/year/m^3)
PCy : Annual Power Consumption (kWH/year)
Vc : Cold Storage Volume (m^3)

Annual power consumption is the total power consumption of the ware house which includes office appliances, lighting, conveying systems as well as refrigeration systems.

Specific power consumption is affected by the type of ware house (storage or distribution), its structure, insulation, storage volume, and type of refrigeration system used.

2) Comparison of refrigeration systems

Figure 7 shows a comparison of specific power consumption for various refrigeration systems. Data was collected from more than 100 ware houses. Data collected shows that specific power consumption decreases as the size of storage volume increases. The graph also shows that NewTon offers the lowest specific power consumption when compared to HCFC-22 and NH_3/Brine systems. Compared to HCFC-22 systems, specific power consumption is lower by 25% with NewTon.

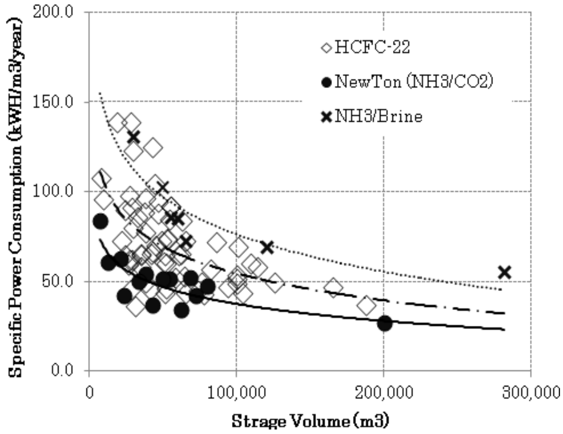

Fig.7 Cold storage specific power consumption

3) Renewal

More than half of the cold ware houses in Japan are more than 20 years old and almost all use HCFC-22 as the working fluid. There is a need for renewal of these systems.

Table 1 shows electric consumption in some of the ware houses replaced with NewTon.

Table 1. Power reduction through renewal with NewTon

Case	Volume	Age	Refrigerant formerly used		Power reduction
	(m^3)	(year)	Refrig.	Comp.	(%)
A	45,000	29	HCFC-22	Screw	31.1
B	10,000	33	HCFC-22	Recip	41.2
C	16,250	27	HCFC-22	Recip	24.9
D	6,125	38	HCFC-22	Screw	29.3
E	7,500	25	HCFC-22	Recip	28.0
F	30,000	30	HCFC-22	Screw	19.8
G	32,500	22	HCFC-22	Recip	28.0
H	30,000	25	NH_3/Brine	Recip	34.0

Power consumption shown in table 1 is for the whole ware house. Replacement with NewTon reduced power consumption by about 30%.

Figure 8 shows power consumption for Case A before and after replacement of the refrigeration system.

For Case A, average annual power consumption is reduced by 31.1%, while energy conservation for refriger ation is about 50%, because refrigeration system accou nts for about 65% of total power consumption.

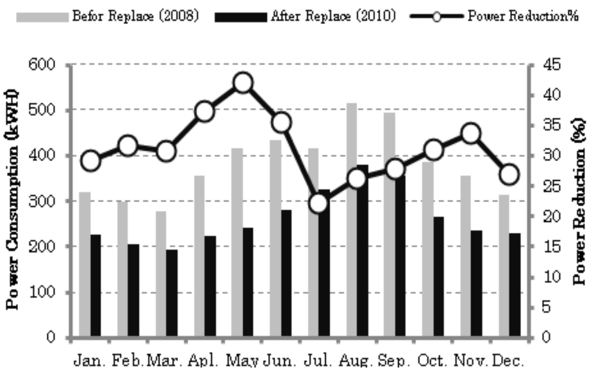

Fig.8 Energy conservation effect Case A

5-2. FREEZER

Power consumption data of freezer systems were measured at some customer sites to evaluate energy efficiency of them.

1) Application in Freezers

Table 2 shows a comparison of power consumption in a freezer with a newly installed NewTon and an IQF Freezer (FLoFREEZE) with an existing system using HCFC-22 liquid pump and a two stage screw compressor (F2016LSC) to freeze sweet potatoes cut into different sizes.

Table2. Comparison of power consumption in a Freezer

Potato cut size	NewTon	HCFC-22 (F2016C)	Power reduction
(mm)	(kWH/ton)		(-)
4.8/4.8/4.8	133.5	200.0	0.668
10/10/10	109.0	146.2	0.746
15/15/15	122.1	174.9	0.689

The table shows that use of NewTon reduces power consumption by about 30% when freezing one ton of sweet potatoes.

2) Definition of energy efficiency factor for freezers

A freezer system is evaluated by quality of frozen material, freezing time (speed) and energy efficiency. The energy efficiency factor for evaluating the freezer is defined in the equation below.

$$ECF = (LCt/Wa)Kca \qquad (2)$$

where:
ECF: Energy Efficiency Factor for Freezer system
LCt: Required Total Cooling Load
Wa: Actual Power consumption
Kta: Calibration of ambient temperature

The required Total Cooling Load is calculated as shown below.

$$LCt = LC1 + LC2 + LC3 \qquad (3)$$

where:
LC1: Cooling down load before freezing
LC2: Freezing load
LC3: Cooling down load after freezing

Equation 2 used to evaluate freezer efficiency takes into account the various frozen materials, various inlet and outlet temperatures of the frozen materials as well as power consumption which varies according ambient temperatures of the seasons.

3) Freezer Energy efficiency factor (Potatoes)

Table 3 shows energy efficiencies calculated using data when freezing potatoes in various potato cut sizes shown in table 2. Conditions used in the calculations are set as follows, freezer inlet and outlet temperatures are 25 degree C and -18 degree C, specific heat of potatoes before and after freezing is 0.813kcal/kgK and 0.407kcal/kgK respectively while the latent heat is 54.9kcal/kg and ambient temperature is 25degree C.

The table shows that using NewTon increases the energy efficiency from 34% to 50% compared to HCFC-22 liquid circulation system.

Table3. Freezer energy efficiency factor (Potatoes)

Size (mm)	**NewTon**	**HCFC-22 (F2016LSC)**	**Ratio**
4.8 x 4.8 x 4.8	0.622	0.415	1.50
10 x 10 x 10	0.761	0.568	1.34
15 x 15 x 15	0.680	0.475	1.43

4) Freezer energy efficiency factor (Salmon)

Table 4 compares energy efficiency when using NewTon and existing HCFC-22 dry expansion system in freezing salmon fillet.

Table4. Freezer energy efficiency factor (salmon)

Ref. system	Inlet temp.	Outlet temp.	Amb temp.	Power consump	ECF
NewTon	10.0	-8.5	18.5	77.5	0.773
HCFC-22	9.0	-10.0	10.0	85.7	0.577
Unit	(C)	(C)	(C)	(kWH/ton)	(-)

The table shows that compared with the existing system which uses HCFC-22, NewTon reduces power consumption by more than 10% and the energy efficiency factor is about 34% better.

6. CONCLUSIONS

The NewTon using natural refrigerants ammonia and carbon dioxide was initially developed to reduce the environmental load. However, since the Tohoku earthquake that disrupted electricity supply, NewTon has also been installed by many customers seeking to reduce power consumption.

A survey of NewTon systems in operation shows that compared to HCFC-22 systems, NewTon reduces power consumption by 25%~30% in cold ware houses and 10%~30% in freezers.

By using the specific power consumption for ware houses and energy efficiency factor for freezers, ware houses of different sizes and cooling systems can be compared and also freezers operating in various conditions can be compared.

7. REFERENCES

[1] HideyoAsano,2011, Safety and energy saving results of NewTon 3000 with NH_3/CO_2 refrigerant, *ICACR2011,* Yong Pyong, Korea

[2] Hideyo Asano, 2011, Energy conservation of Refrigerated warehouse using NH_3/CO_2, *Refrigeration*, Vol.86 No.1008