A DEVELOPMENT OF NEW HIGHLY EFFECTIVE ICE THERMAL STORAGE UNIT

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Abstract: As the effectiveness of leveling the electricity consumption of ice thermal storage is great, in order to obtain popularity in the market, new high efficiency ice thermal storage system 'Compact Cube Ice' was developed to meet both of high energy saving performance and simplified system constructions which are required by the market.
High efficiency Ice thermal storage unit, newly developed, has achieved both of 51% COP improvement for ice thermal storage mode and 34% COP improvement for cooling driving mode by introducing new technology for compressor, air-side heat-exchanger and refrigerant circuit compared with conventional model.
Furthermore, new system controller that is able to control both the heat pump chiller (non-thermal storage heat source machine) and the ice thermal storage unit, the plural unit system became easily to be applied to a large-scale project.
When the equipment replacement is assumed, the reduction of CO_2 emission is expected by 51% in the replacement from the existing absorption chiller.
Moreover, the reduction of CO_2 emission is expected by 31% by the replacement from the existing ice thermal storage unit.
We report on the energy conservation performance and the feature about 'Compact cube ICE' that adopts new technologies such as inverter driven scroll compressors, new refrigerating cycles composed of two evaporation temperatures, and new system controller that is able to become easily to be applied to a large-scale project

Key Words: Ice thermal storage unit, energy saving, efficiency,

1 INTRODUCTION

As the effectiveness of leveling the electricity consumption of ice thermal storage is great, in order to obtain popularity in the market, new high efficiency ice thermal storage system 'Compact Cube Ice' was developed to meet both of high energy saving performance and simplified system constructions which are required by the market.
In such a market trend, the new highly effective ice thermal storage unit that aimed at the performance gain of the ice thermal storage unit and the simplification of system construction

was developed(Figure 1). In this paper, we report about the highly effective ice thermal storage unit developed this time.

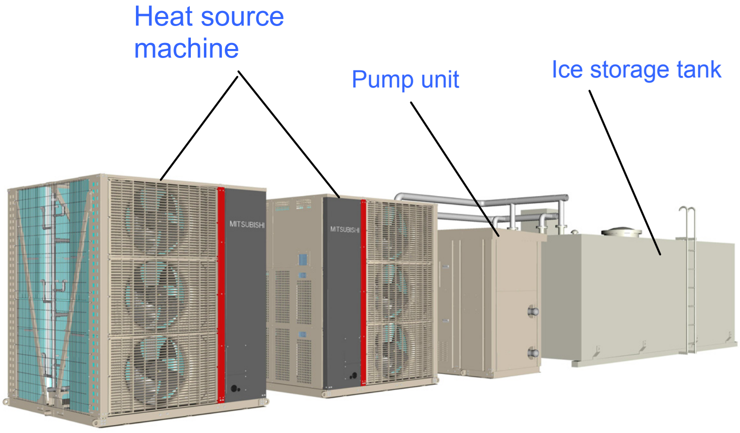

Figure 1: Externals of 'Compact Cube ICE'

2 Feature of product

The heat source machine of the ice thermal storage unit was developed based on a standard air cooling heat pump chiller. The cost reduction by part sharing was achieved because it had developed based on the standard machine. Moreover, a great improvement of COP was achieved. The ice storage tank adopted type of the air stir method. As a result, correspondence was enabled to the peak load only by driving that melted ice.

Table 1 shows the specification of the Developing Model.
'Compact Cube ICE' that had been developed this time has three models (40 and 60,120 horsepower) in lines. In 120HP unit, COP of the ice thermal storage driving has been improved by 51% compared with the conventional model. Moreover, COP of the air-conditioning driving has been improved by 34% compared with the conventional model.

Table 1: 'Compact Cube ICE' Product specification

		Model	MKHV-P1180AE-ST	MKHV-P1800AE-ST	MKHV-P3550AE-ST
Horse power			40	60	120
Power supply			Three-phase 200V 50/60Hz		
Daily cooling capacity		MJ/d	3,600	5,148	12,420
Daily coolng COP(without pump input)		–	4.32	4.09	3.83
Daytime capacity of oparation		kW	100.0	143.0	345.0
(cooling)	COP	–	4.61	4.29	3.93
Thermal storage capacity of operation		kW	39.2	44.5	110.2
	COP	–	3.77	3.68	3.61
Daytime capacity of oparation		kW	117.7	154.6	309.2
(heating)	COP	–	3.50	3.43	3.43
Mass of product	Heat source machine	kg	1,630	1,650	1650×2
	Ice storage tank	kg	4,470	4,470	9,090
	Pump unit	kg	1,550	1,550	1,650
Operating mass	Heat source machine	kg	1,680	1,700	1700×2
	Ice storage tank	kg	12,640	12,640	29,070
	Pump unit	kg	1,750	1,750	2,000

3 Simplification of system construction and equipment installation

To facilitate correspondence to a large-scale load, the system controller was developed. This system controller can drive in full automation, and use it with the system where both non-thermal storage heat source machine and the ice thermal storage unit exist together. As a result, it became easy to construct the system that combined non-thermal storage heat source machine with the ice thermal storage unit. Figure 2 shows the image of the piping system of the coexistence system of the highly effective ice thermal storage unit and non-thermal storage heat source machine. This system is composed of the combination of non-thermal storage heat source machine and the highly effective ice thermal storage unit. This system controller can control the number of each heat source machine by full automation in the air-conditioning driving.

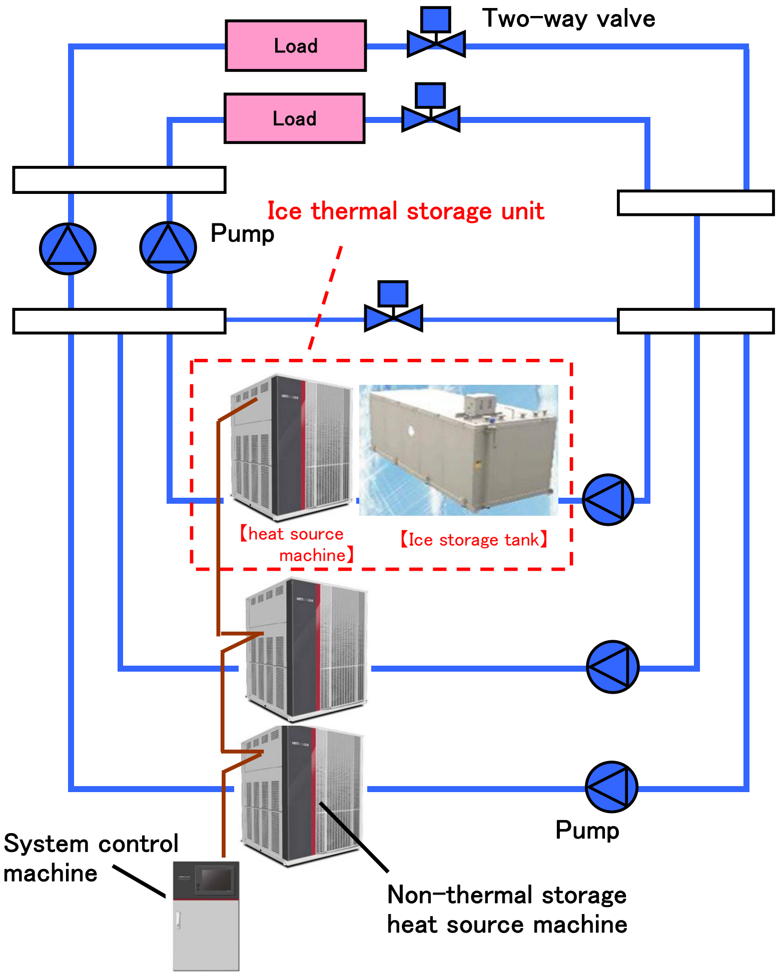

Figure 2: Coexistence system chart of ice storage + non-thermal storage heat source machine

Figure 3 shows the image for the peak cutting only by the ice thermal storage unit. Moreover, the image for the peak cutting with the coexistence system of the ice thermal storage unit and non-thermal storage heat source machine is shown in Figure 4. The system controller that developed this time can correspond also to either system. The heat source machine of the ice thermal storage unit stops automatically by this system controller while cutting the electric power peak. Ice is melted and it corresponds to the cooling load while the heat source machine is stopping. The electric energy of the peak load time zone can be reduced by this control.

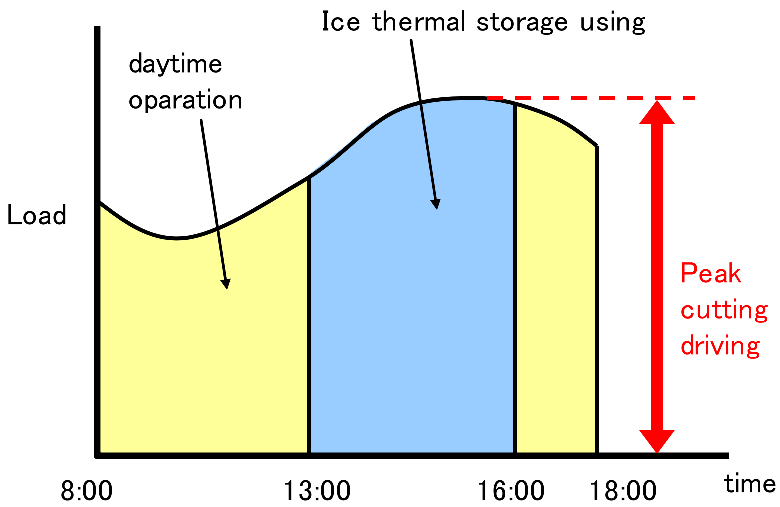

Figure 3: Correspondence to peak load (Only the ice storage system)

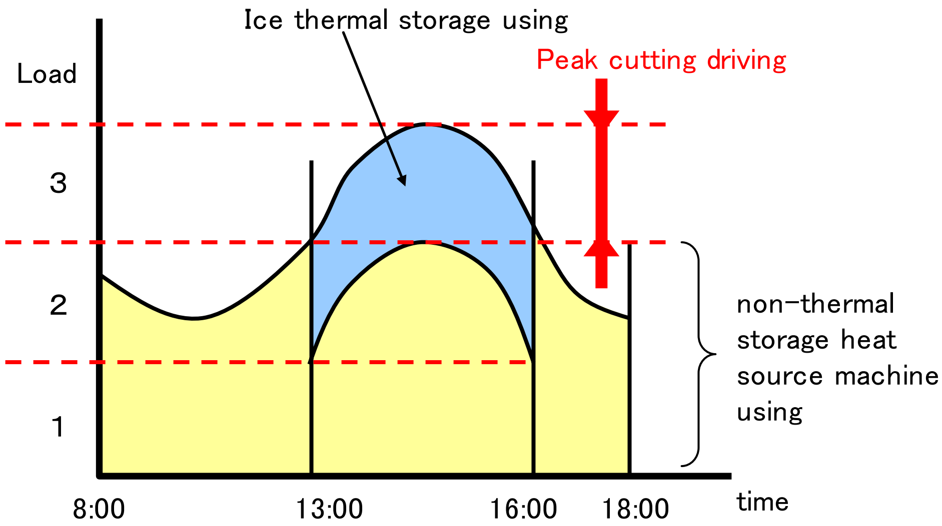

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Figure 4: Correspondence to peak load
(non-thermal storage heat source machine coexistence system)

4 Feature of unit in ice thermal storage driving

4.1 Making to highly effective

The DC inverter drive scroll compressors with high performance when capacity was decreased was adopted in the development machine.
Figure 5 shows the characteristic of the compressors, conventional model (Screw compressor) and development model (DC inverter driven scroll compressor). As for the screw compressor of the conventional model, COP when 100% driving is high, and COP when 60% driving becomes the maximum for the inverter compressor. A highly effective driving at a partial load was achieved by controlling the number of the compressors to drive as much as possible in the capacity of the compressor that COP rises.
Especially, when ice thermal storage mode, 30%COP is improved compared with the case to drive ice thermal storage in 100% capacity as shown in Figure 6 by making the best use of the characteristic of this inverter compressor. As for this, because the ice thermal storage was driven in the best capacity (drove by lowering the capacity of the compressor), a necessary storage of heat was achieved. As a result, 51%COP has been improved

compared with our conventional model (For 120-horsepower unit) in ice thermal storage mode.
The amount of power consumption of the ice thermal storage unit decreases by the efficiency gain of the heat source machine when the ice thermal storage driving becomes long though the amount of power consumption of the brine pump increases.
When the ice thermal storage will be driven in a long time in low capacity, it becomes efficiency that is higher to be going to drive the ice thermal storage by 100% in a short time. Because the amount of power consumption of the brine pump is smaller than the amount of power consumption of the heat source machine.
Because the brine flowing quantity of the ice thermal storage mode is decreased up to the flowing quantity of about 50% of the air-conditioning mode, the transportation power compared with 100% driving has been decreased to about 1/8. As a result, the efficiency when the ice thermal storage is driven has improved.

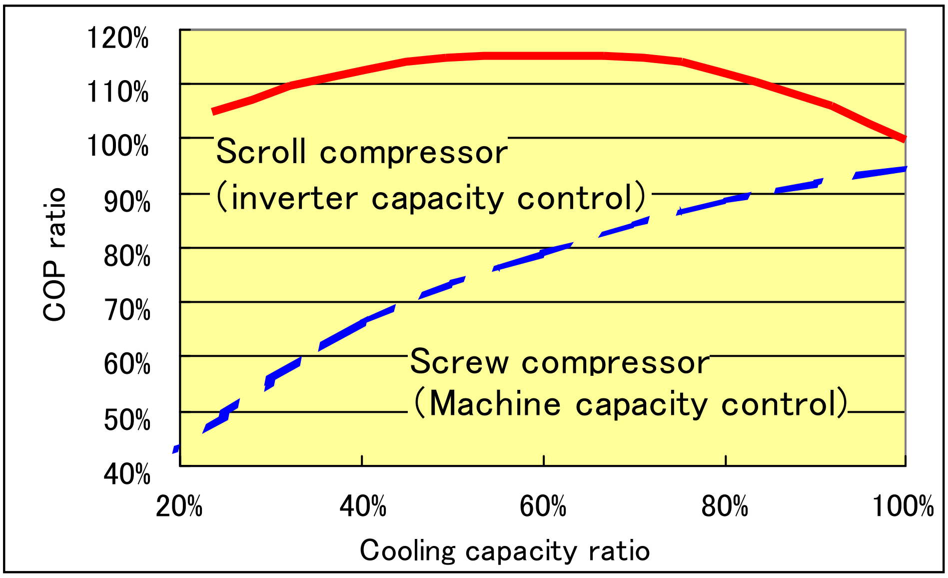

Figure 5: COP characteristic of compressors

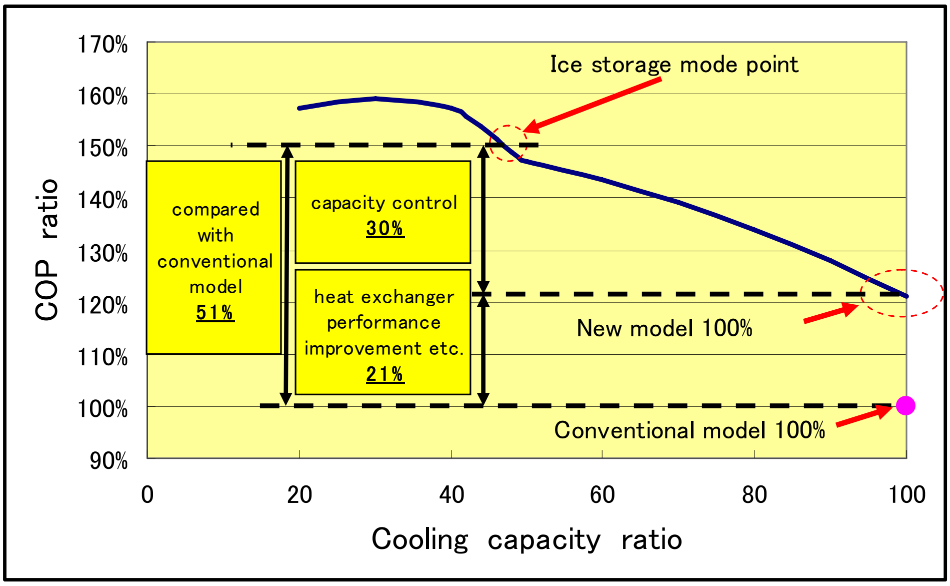

Figure 6: COP improvement in Ice thermal storage mode

4.2 Decreasing noise when ice thermal storage driving at night

Decreasing noise in ice thermal storage mode is requested, because the ice thermal storage unit is driven at nighttime.The new highly effective ice thermal storage unit enabled to be driven by "Low noise mode" that decreased about 3～5dB noise value from rating driving. The low noise driving was achieved by the inverter with controlling both the compressor and the blower by the low volume at nighttime.

4.3 Control in ice thermal storage mode

The ice thermal storage unit was set to be always driven to full thermal storage. To keep steady ice manufacture, the amount of ice manufacture of the target is set every time. And the heat source machine is controlled to match an actual amount of ice manufacture to the targeted value. Surely necessary amount of thermal storage becomes possible by this driving in regulated time irrespective of an external factor of the outside temperature degree etc. When the load decreases extremely, it drives in the low volume to become the amount of ice manufacture of the target every driving time. In addition, when thermal storage is completed, the ice manufacture driving is stopped when driving from there is a lot of remaining ices. A steady ice manufacture driving that did not become making ice (overice manufacture) too much and ice manufacture shortage was enabled by controlling the above-mentioned.

5 Technology of making to highly effective of heat source machine

5.1 Efficiency gain by two evaporation temperature refrigeration cycle

The heat source machine for the highly effective ice thermal storage unit implemented two evaporation temperature refrigeration cycle that consisted of two independent refrigerative circuits as shown in Figure 7.
When water temperature difference of the unit is 5℃, the evaporation temperature of the up stream heat exchanger rises 2.5℃ than downstream heat exchanger. And it improves unit efficiency by 2%～3% compared to conventional refrigerative circuit of one evaporation temperature.

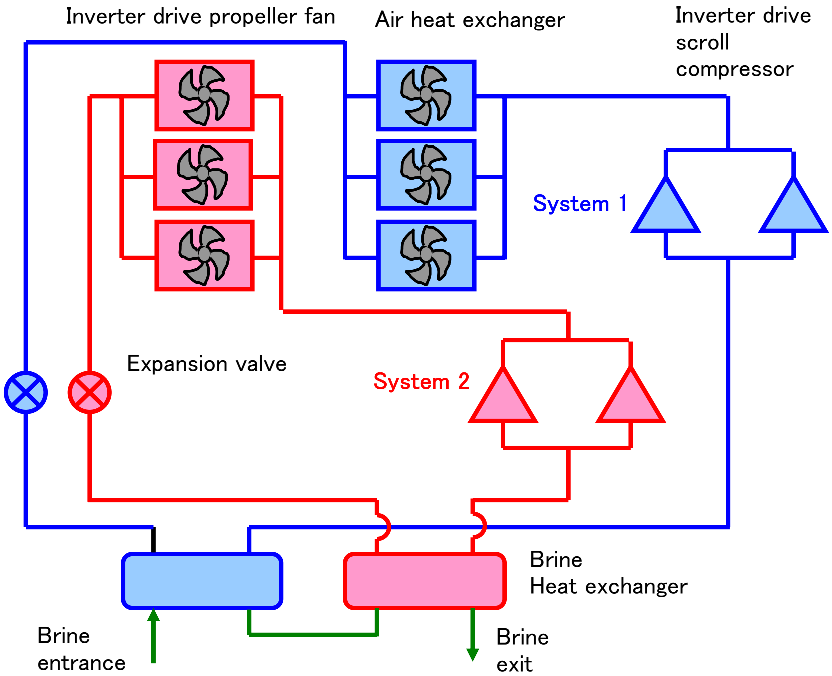

Figure 7: Two evaporation temperature refrigeration cycle

5.2 V-Flow new unit form

The improvement of the heat transfer performance was achieved by implementing U-shaped heat exchanger as an air heat exchanger of the heat source machine for the highly effective ice thermal storage unit, and mounting the air heat exchanger in a high density in the unit . Moreover, the current of air interference was prevented by installing the air guide on the unit blow side, and adopting the spouting 60° V-Flow form of the upper side. By this method, controlling the interference of the current of air, when two or more units is installed, the installation space for the machine became more small. (Figure 8)

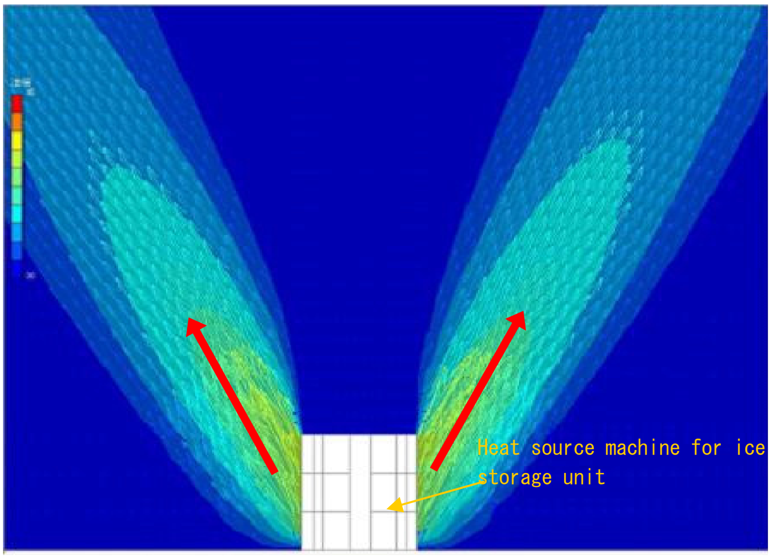

Figure 8: V-Flow current of air analysis result

6 Amount of CO2 exhaust, and economy comparison

The effect of the reduction of the amount of the CO_2 exhaust, and the economy (running cost) was calculated about the highly effective ice thermal storage unit that had been developed this time.
The comparison was targeted to the existing ice thermal storage unit, the new establishment absorption chiller, and the existing absorption chiller.
Table 2 shows the examination condition.

Table 2: 2 Examination condition

Item		Examination condition
Load condition	①Scale	12,000m^2
	②Usage	Office
	③Operation period	cooling(weekday May～October) 、heating(weekday, November～April)
	④Weather condition	Tokyo district :Average outside temperature degree and air humidity according to the month
Target model	①Highly effective ice thermal storage unit	40HP×3unit system :cool temperate water pump motor 18.5kW
	②absorption chiller (cooling capacity 1080kW)	Gas absorption chiller + cooling tower (new establishment machine/existing machine) <new establishment >: cooling ratings COP1.32, heating ratings COP0.88 < existing >: cooling ratings COP1.03,heating ratings COP0.86 :cool temperate water pump motor 18.5kW :cooling-water pump motor 37kW :cooling-tower fan motor 11kW
Fee system	①Electricity	Tokyo Electric Power Company commercial power
	②Water service	In 23 Tokyo waterworks bureau districts Water service: General 100mm and drainage: General sewage
	③Gas	Tokyo Gas Co., Ltd.: Industrial use A contract such as Tokyo the district
CO_2 exhaust unit requirement	①Electric power	0.339kg-CO_2/kWh
	②Utility gas	2.08kg-CO_2/Nm^3

7.1 Amount of CO2 exhaust

The comparison of the amounts of the CO_2 exhaust is shown in Figure 9 during year.
The effect of the CO_2 reduction of 55% can be expected by replacing it from the absorption chiller of existing to the highly effective ice thermal storage unit when the renewal is assumed. Moreover, the effect of the CO_2 reduction of 31% can be expected by the replacement from the ice thermal storage unit to the highly effective ice thermal storage unit of existing.
The effect of the CO_2 reduction of 48% can be expected, compared the new absorption chiller to the highly effective ice thermal storage unit .

7.3 Economy

Figure 10 shows the running cost trial calculation result in year.
The running cost becomes 29% of the existing absorption chiller, and can attempt the running cost decrease of 71% can be expected by replacing it from the absorption chiller of existing to the highly effective ice thermal storage unit when the renewal is assumed. The running cost decrease of 39% can be expected for the replacement from the existing ice thermal storage unit.
There is an effect of the running cost reduction of 69% can be expected, compared the new absorption chiller to the highly effective ice thermal storage unit .

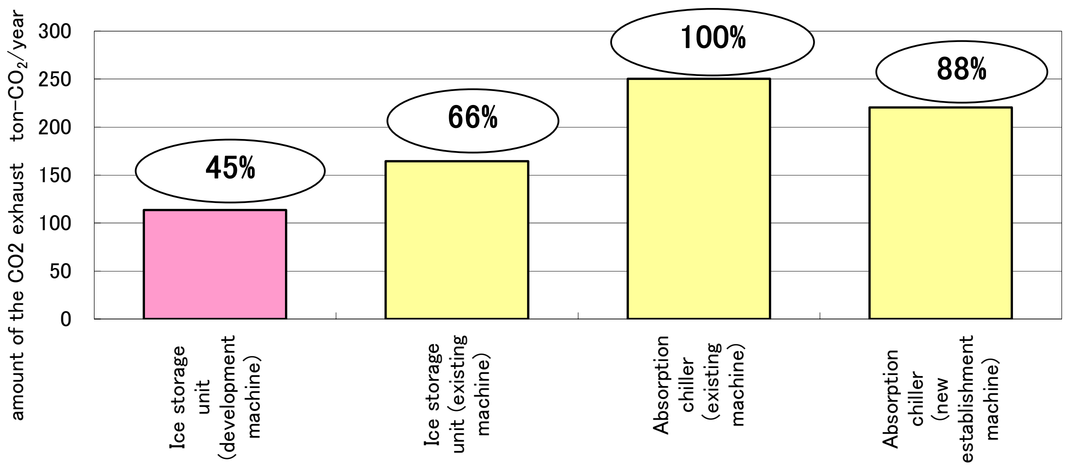

Figure 9: CO_2 exhaust amount comparison (year)

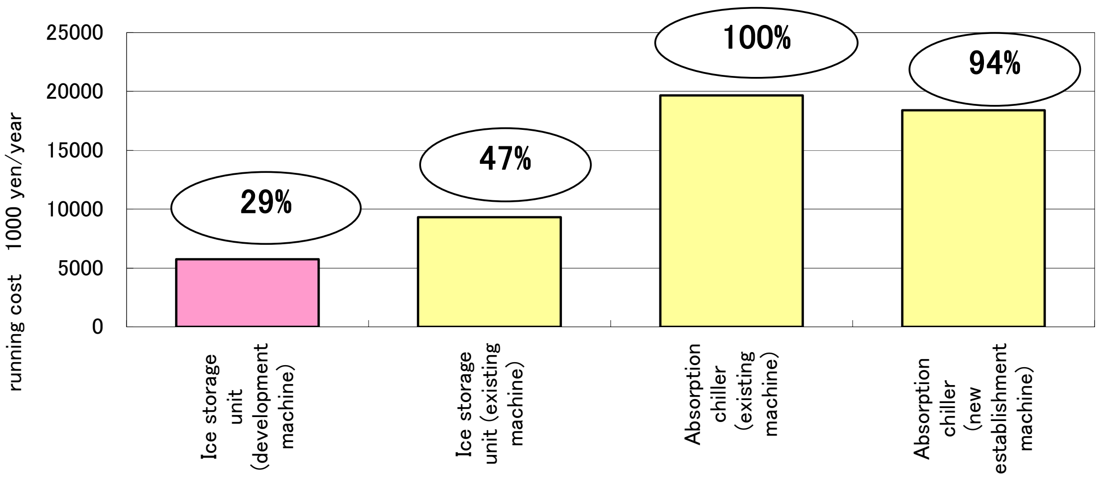

Figure 10: running costs comparison (year)

7 Conclusion

The ice thermal storage unit is thought to be an effective unit to level the electric-load leveling. And to spread the ice thermal storage unit, both of high energy saving performance and simplified system constructions are thought to be more and more demanded by the market. High efficiency Ice thermal storage unit, newly developed, has achieved both of 51% COP improvement for ice thermal storage mode and 34% COP improvement for cooling driving mode by introducing new technology for compressor, air-side heat-exchanger and refrigerant circuit compared with conventional model.
This system controller can drive in full automation, and use it with the system where both non-thermal storage heat source machine and the ice thermal storage unit exist together.
As a result, it became easy to construct the system that combined non-thermal storage heat source machine with the ice thermal storage unit. The expansion of the ice thermal storage spread will be advanced with the highly effective ice thermal storage unit that was developed and commercialized this time in the future.

5 REFERENCES

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