

## **Retro-Commissioning the Multi-Purpose Technical Building of Hitachi Building Systems Co., Ltd.**

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### **Synopsis**

In recent years, commissioning has become a point of great concern in Japanese business circles. In 1999, a committee for the Society of Heating, Air-Conditioning and Sanitary Engineers (SHASE) began to research the potential benefits of commissioning in Japan; and in 2004 an original guideline was made for commissioning in Japan. This was the backdrop against which Hitachi Building Systems Co., Ltd. (HBS) embarked upon an innovative retro commissioning of its multi-purpose technical building, preparing itself to enter the IT business milieu of the future, aiming to increase its reputation as a leading building management enterprise.

Hitachi Building Systems Co., Ltd. (HBS) recognized the importance of commissioning from the architectural, engineering and energy-saving aspects at an early stage and tried to apply these concepts to their building. The task was performed with the application of commissioning principles from the planning phase to operational readiness and successfully achieved significant energy-savings and lessened environmental impact.

The authority and members of the Commissioning Group (CG) assembled specialists from a variety of fields in order to innovate new solutions and to bridge jobs from the planning phase to the post-acceptance stage. This process being consistently verified by the CG, they determined that the potential existed for up to a 16% reduction of energy throughout the year for a reduction of 33% in the demand for electricity could be reduced by 33% through the use of ice thermal storage type air conditioning. These results and improvement in operational control were visualized and achieved through the use of the BEMS system.

### **About the Authors**

Masayoshi Omori is a licensed professional engineer in Japan, and a manager of Engineering Dept. of Building Techno-Service Co., Ltd. He specializes in mechanical engineering and HVAC system, and contributed to commissioning committee of SHASE as a member.

Kazuyuki Tsuruga is the senior engineer of BEMS development of HBS. He majors in electrical engineering. He has a significant amount of 20 years of experience designing and implementing energy saving systems (BEMS).

Satoshi Nouchi is the senior electric development engineer of HBS. He specializes in electrical engineering. He has 15 years experience of building facilities engineering.

Kazuo Watanabe is the environmental system consultant, and a director of Axeboard Co.,Ltd., a building management company. He contributed to the commissioning committee of SHASE as a member, and recently nominated to the Inspector of BSCA. His interests are in Legionella control and physical water treatment.

## **Introduction**

In recent years, commissioning has become a point of great concern in Japanese business circles. Hitachi Building Systems Co., Ltd. (HBS) recognized the importance of commissioning from the architectural, engineering and energy-saving aspects at an early stage and tried to apply these concepts to their building.

HBS is a multi-purpose technical building located in Northwest Tokyo. It is comprised of about 8,700 square meters (93,700 square feet) on eight levels.

Recently, due to the many expansions, such as a 24 hours customer service department and a telemarketing division, the building has required more varied and functional formation.

This paper describes the retro commissioning of the facility, considered mainly from the perspective of how it has improved employees' comfort and how the energy savings meets the new environmental requirements of the Japanese government.

As a result of these changes, energy savings throughout the year could amount to as much as 16% and the peak demand for electricity could be reduced to by 13%, mainly through the use of an ice storage type air conditioner. These improvements are accomplished with the aid of BEMS system and are shown in the graphic presentation today.

The average humidity of the interior of the building has satisfied the requirements of Sanitary Regulations. Further, the lighting systems have improved energy savings and increased illumination by use of inverter ballast and FHF fluorescent light.


## **Approach to the Commissioning Process**

### **Characteristics of the Existing Building**

A multi-purpose technical building of HBS was completed in 1988. Table 1 summarizes the building systems of the property. In those days, intelligent construction was only equivalent to a technical building, in general. The air-conditioning systems mainly consisted of multi type packaged air conditioners, and central type ice storage chilling units with fan coil units were partially applied for supplying chilled/hot water to interior rooms. The former was used in the office areas from the first floor to the seventh floor. The latter was used in the common areas of each floor, and in the testing area of the underground level.

The fresh air intake systems were central-duct type total heat exchangers with VAV units in interior rooms. Each total heat exchanger had a closed-pan type humidifier. All outdoor units were installed on the roof of the building. For the lighting systems, a recessed lighting fixture with three 40 W lamps were used in the office areas to provide direct lighting, and single-lamp batten with one 40 W lamp providing indirect lighting in the common areas.

**Table 1: Existing Conditions**

Item		Detail	
Building	Name & Appearance	Research & Development Center of HBS	
	Location	Adachi Ward, Tokyo	
	Completion	September, 1988	
	Floors	Seven Floors, One Level Underground	
	Total Floor Area	8,700 square-meters	
HVAC System	Office Area	Multi-type Packaged Air-conditioners (Total Cooling Capacity of 300 RT)	
	Common Area	Central Ice-storage Chilling Units (Heat Pump Type) (Total Cooling Capacity of 48 RT)	
	Fresh Air Intake	Central-duct Type Total Heat Exchangers (Total Air Volume of 30,000 m <sup>3</sup> /h)	
	Humidifier	Closed-Pan Type Humidifier (Total Humidifying Capacity of 94 kg/h)	
Lighting System	Office Area	Direct Lighting System (Recessed Lighting Fixtures)	
	Common Area	Indirect Lighting System (Single-Lamp Battens)	

### Organization of Commissioning Group

The primary scheme for the commissioning was planned by the Energy Conservation Center of HBS and proposed to the director's meeting of HBS. Mr. Tsuruga and Nouchi both were nominated by HBS to the part of commissioning authority (CA), and Mr. Omori joined the Group as the Commissioning Consultant. Mr. Watanabe acted as an advisory staff with the qualification of an inspector of the BSCA.

In the Commissioning Group, the Authorities and consultants played the role of representatives. The Commissioning Related Parties (CRP) was a skillful staff composed of professionals related to the project.

Table 2 shows the process of our commissioning.



the Protection of the Ozone layer. The use of a mixed refrigerant or non-Freon refrigerant was initiated in the Japanese market in early 2002. These were the preconditions of building construction and operations in Japan at the start of this project.

### Target of Energy Saving and Employees' Comfort

At the beginning of the project, the target of the energy saving was decided to follow the NEDO (New Energy and Industrial Technology Development Organization) regulations, to keep higher efficiency of more than 15% (based on primary energy) compared to previous systems. In response to these figures, we were given a subsidy by the NEDO.

The target was to conserve energy without compromising employees' comfort; this goal was reached by following the BESL. Japanese sanitary regulations require that the atmosphere contains more than 40% relative humidity. To upgrade air humidification, we looked for a more comfortable and suitable value referred to by the operation guidelines of the existing equipment.

## Commissioning of Program and Design Phase

### Program Phase Commissioning

#### Air Conditioning System

Several systems that had actual energy saving results and favorable reputations were carefully compared. These included an Ice Thermal Storage Packaged Air Conditioning System operated with electric energy, and a Gas Co-generation plus Absorption Chiller System with Exhaust Heat Utilization operated with gas energy. Evaluations are shown in Table 3.

**Table 3: Air Conditioning System Comparisons**

System Item	Ice Thermal Storage Type Packaged Air Conditioning System	Gas Co-generation plus Absorption Chiller System
Energy Saving Performance	<ul style="list-style-type: none"> <li>High Efficiency of COP=4.5 (Cooling) with ice storage utilization</li> <li>Reduces peak power consumption by 50%</li> </ul>	<ul style="list-style-type: none"> <li>High Efficiency of COP=0.98 (Cooling) with exhaust heat utilization</li> <li>Reduces peak power consumption by 95%</li> </ul>
Refrigerant	<ul style="list-style-type: none"> <li>Mixed Refrigerant of R-407C</li> </ul>	<ul style="list-style-type: none"> <li>Water</li> </ul>
Studied Matters	<ul style="list-style-type: none"> <li>Installation space available</li> <li>Enough strength to bear the ice storage tank weight on the roof</li> </ul>	<ul style="list-style-type: none"> <li>Necessity of new gas supply piping</li> <li>How to use the exhaust gas heat other than absorption chiller</li> </ul>
Initial Cost	1.0	1.7
Running Cost	1.0	0.95
Total Evaluation	◎	○

As a result of the evaluation, the Ice Thermal Storage Packaged Air Conditioners were adopted. For this decision, we were subsidized by the Heat Pump & Thermal Storage Technology Center of Japan (HPTCJ).

### ***Fresh Air Intake***

The existing air handler was a central duct system. Because continuous operation during the day was requested, regardless of whether the whole building or simply one office room is occupied, in order to conserve energy, scheduled operation of 16 hours per a day was incorporated. However, there were no savings in power consumption due to the futility of supplying fresh air to empty rooms. As a result, a new system was planned that would use a total heat exchanger with an internal zone control system.

### ***Humidifier***

In the past, the Public Health Center recommended adjusting lowering the level of humidity by improving humidifier performance. After surveying the related facility, the function of the traditional closed pan type humidifier installed in the Total Heat Exchanger on the roof is subject to default maintenance. As a result of the evaluation, a Vaporized Type Humidifier was to be installed in either the Indoor Air Conditioning units or the Total Heat Exchanger at each floor zone.

### ***Lighting System***

The current recessed lighting fixtures had been reduced from 3 fluorescent lights to 1 or 2 fluorescent lights by the action of the Energy Saving Group of the HBS building in October 2001. After careful consideration, Inverter Ballast and high frequency type (FHF) fluorescent lights were to be used for the lighting system of the retrofitted building.

### ***BEMS System***

BEMS was to be executed primarily for energy measurements and to automate controls for energy savings. Further, there was a request from the building owner concerning electricity charges for tenants. This plan was pushed forward with the participation of Hitachi specialists.

## **Design Phase Commissioning**

### ***Indoor Heat Load: Re-calculation for Varied and New Conditions***

Based on the committee's developing understanding of the energy needs of the building, the building's indoor heat load was changed from where it had been set at the initial completion of the construction. Based on their findings, the indoor heat loads were re-calculated using recent data provided from the number of visitors and personnel; the lighting and computer loads, and the numerical conditions selected from the actual and the most suitable operational and mechanical basis. Table 4 summarizes a model of actual and abstracted indoor heat load calculations in 2002 that will be useful as a basis of the forthcoming improvement.

**Table 4: Indoor Heat Load Calculations (Extracted Areas)**

Level	Usage	Area (m <sup>2</sup> )	Heat Load Calculation				Remarks
			Cooling (kW)	Heating (kW)	Cooling (kW/m <sup>2</sup> )	Heating (kW/m <sup>2</sup> )	
2F ~ 5F	Customer Center	199	48	12	0.241	0.060	24 hour Operation
	Monitoring Center	198	41	12	0.207	0.060	
	Contact Center	371	51	19	0.138	0.051	
4F ~ 7F	Office Room	199	36	13	0.181	0.065	
	Dining Room	172	38	15	0.221	0.090	

### Lighting Systems Design

The average illumination in an office using ordinary equipment was 785 lx. Recent trending data requires increased illumination. For example, the new recommendations of the Lighting Institute for a 'common' work place range from 500 lx to 750 lx, and from 1,000 lx to 1,500 lx for a 'precious' work place. Therefore, this building was designed to have an average illumination of 1,000 lx. Both of the Inverter Ballast and FHF fluorescent lights were adopted in order to improve illumination and increase energy savings. Table 5 summarizes the lighting design.

**Table 5: Lighting Design**

Items	Number of Light Fixture per Floor	Power Consumption (W/Piece)		Average Illumination (Lx)	
		Before	After	Before	After
3-Fluorescent Light	144	80	63	785	1,000
1-Fluorescent Light	21	42	33		

### Energy Saving Design for Total Building

Table 6 summarizes energy saving simulations based on the application of above retro commissioning plan. The calculated value of energy saving was amounted to 18.1%.

**Table 6: Simulated Energy Saving by Total Retro Commissioning Planning**

Items	Before Commissioning (GJ/year)	After Commissioning (GJ/year)	Energy Saving Value (GJ/year)	Energy Saving Rate (%)
HVAC	12,012,413	7,527,439	4,484,974	37.3
Lighting	15,342,414	14,276,270	1,066,144	20.0
Others	13,338,548	13,338,548	0	0
Total	30,693,375	25,142,257	5,551,118	18.1

### BEMS Design

In this stage of planning, BEMS is considered to be the most important constituent for the energy saving strategy for the future, because it is expected to promote advancement, popularization,

and harmonization of this planning. Table 7 summarizes BEMS design, selected mainly from daily availability than a prominent feature.

**Table 7: Essence of BEMS Design**

Items	Detail
Energy Saving Control for Air Conditioning	1. Rhythmic Temperature Setting Control according to Demand Alarm and Setting up Control 2. Compulsory Setting Systems of Indoor Temperature
Energy Management	1. Increase of Measurement Point 2. Make Available to See Energy Data at Each PC

## Commissioning of Construction Phase

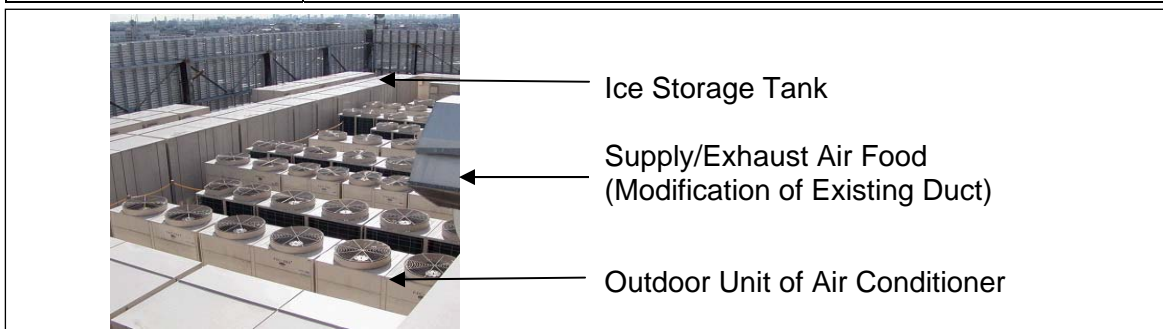
### Construction Step Commissioning

#### Installation of Air Conditioning System

Ice Storage Type Packaged Air Conditioning System was extremely efficient, with a COP of 4.5, and could reduce peak power consumption by 50% with the aid of thermal storage. However, it was necessary to prepare an installation space that could support the weight of the ice storage tank on the roof. Table 8 shows the calculation method for the structural requirements of the roof. An initial installation plan was drawn by project staff and it was sent to the original design-company for the structural checking. After the final planning check, the final installation schemes were completed. Figure 1 shows the outdoor-side HVAC equipment on the roof.

**Table 8: Structural Calculation of Roof Strength**

Items	Burden
Total Weight of Equipment	Results of check: * :Installation Space A1: Total Weight of Equipment =98 (ton) A2: Design Strength Loads =150 (kg/m <sup>2</sup> ) x (m <sup>2</sup> ) <sup>*</sup> + 80 (ton) =0.15 (ton/m <sup>2</sup> ) x 394 (m <sup>2</sup> ) +80 (ton) =139 (ton) Conclusion: A1<A2, Duration is no Problem
Layout of Installation	Results of layout check: Examining layout design on the original structural steel members, a considerable enforcement could be confirmed. The final layout: By re-location for fitting to original structural steel members recessed in concrete.



**Figure 1: Outdoor-look of HVAC Equipment**

## **Compatibility of Retro Commissioning Work and Daily Usage of the Building**

Retro commissioning work was not permitted during normal office hours, because of concerns that construction noise would decrease office efficiency; therefore, communicating the work schedule to the owner two weeks in advance, permission was given for retro commissioning work to be performed on weekday-nights, Saturdays, Sundays and Holidays.

### **Acceptance Step Commissioning**

#### **Acceptance of the HVAC and the Lighting System**

The final inspection of HVAC system, including humidification, was conducted by the owner on 30 January and the lighting system on 31 January 2003. Acceptance of the HVAC and the Lighting System was assigned at the end of February 2003.

The data that was offered to the owner at the final inspections were first running records. The performance data will be checked throughout the year after a year's insurance period.

#### **Acceptance of the BEMS System**

The owner conducted the final inspections at the end of July 2003. At the same time, the final documents and drawings were prepared. The BEMS system was accepted at the end of August 2003, and data collection and measurement began in September. After the installation of main tools, the measuring points increased from 54 to 118 points.

## **Commissioning of Operation Phase**

### **Post-Acceptance Commissioning**

#### **Training of Operation Members**

Retro-commissioned systems require new operation manuals and training. These confirmed by the commissioning group with cooperation of the staff of the R & D center.

#### **Energy Saving Verification**

Energy saving verification commenced in March 2003. Table 9 shows the reduction of maximum power input. And the results to date are shown in Table 10. The total energy saving ratio is expected to be around 16.0% a year. The verification process is ongoing and will be continued by the BEMS.

**Table 9: Reduction of Maximum Power Input**

<b>Year</b>	<b>Max. Power Input (kW)</b>	<b>Month</b>	<b>Outdoor Temp (°C)</b>
2001	1,318	July	38.1
2002	1,270	July	35.0

2003	881	August	35.5
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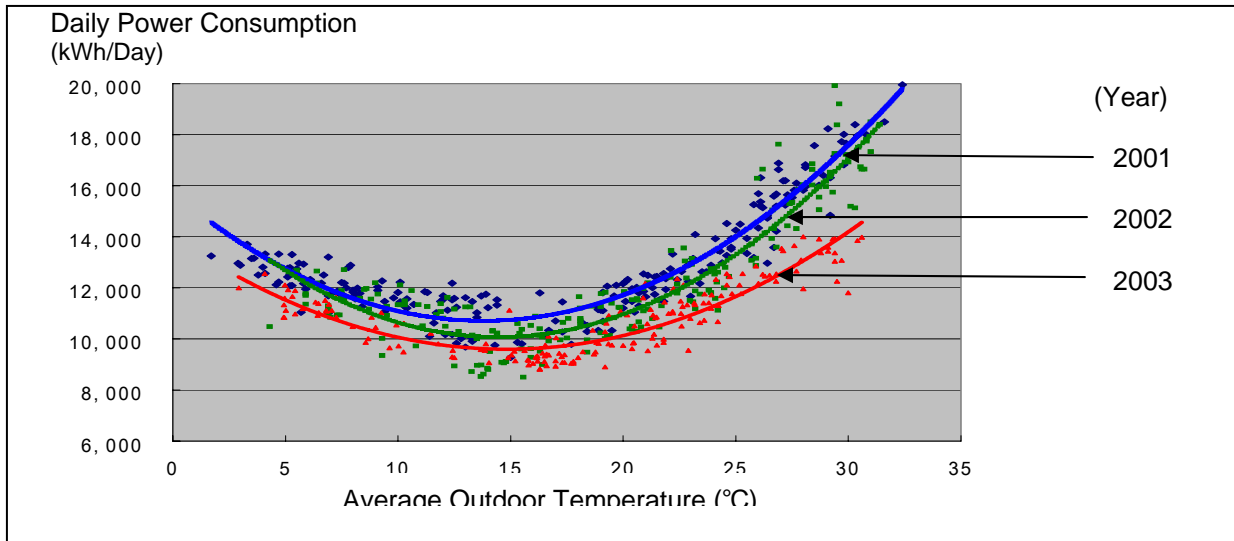
**Table 10: Verification of Energy Saving**

Year Month	1999 ~ 2001	2003	E.S.R <sup>(3)</sup> (%)
	P.C. <sup>(1)</sup> (kWh/month)	P.C. <sup>(2)</sup> (kWh/month)	
March	239,074	208,950	12.6
April	221,025	187,600	15.1
May	225,560	203,580	9.8
June	265,946	228,494	14.1
July	321,748	228,540	29.0
August	328,514	252,790	23.0
September	285,416	235,840	17.4
October	229,766	195,280	15.0
November	212,658	185,740	12.7
December	232,996	198,780	14.7
January	233,319	215,404	7.7
February	229,977	201,760	12.3
Total	3,025,998	2,542,758	16.0

Notes;  
 (1): 3 year Average Power Consumption  
 (2): Power Consumption  
 (3): Energy Saving Ratio

**Effect of Ice Storage Type Air Conditioning Systems**

Figure 2 shows the effect of ice storage type air conditioners. In the higher outdoor temperature range, the effect of lowering daily power consumption appears remarkable.



**Figure 2: Daily Power Consumption by Outdoor Temperatures**

**Checking the Performance of the Humidifier**

In order to improve the environment of the building, a Vaporization Type Humidifier was installed. Testing was performed at a typical floor in order to evaluate its performance under normal and increased humidity conditions. The results are shown in Table 11.

**Table 11: Performance of Humidifier on Typical Floors**

Period	Floor	Temperature (°C)	Judgement	Humidity (%RH)	Judgement
03 Feb. ~ 12 Feb.	7F Office Room	26.6 ~ 17.7	✓	49 ~ 31	✓
	2F Remote-Monitor Center	28.6 ~ 25.3	✓	34 ~ 15	X

On the seventh floor, the average humidity was 41.8%. This value satisfied the requirements of the Building Environmental Sanitation Law that humidity should not drop below 40%. But, at the remote monitor center on the second floor, average humidity was 24.1% and failed to satisfy the requirements. After checking systems, we found the wiring was at fault. After the wiring problem was corrected, relative humidity of the spot was adjusted and thereafter reflected correct measurements.

### **Effect of New Lighting Systems**

The lighting systems could introduce dual improvements of energy saving and illumination upgrading. The results are shown in Table 12.

**Table 12: Improvement in Power Consumption and Illumination**

Amperes Consumption			Average Illumination		
Before (A)	After (A)	Rate (%)	Before (Lx)	After (Lx)	Rate (%)
497.2	394.3	21.0	784	1,200	53

A target value for energy consumption was achieved, as well as the target value of 1,000 lx for illumination. Renewing and cleaning of the lighting fixtures was performed simultaneously. As the result, the average illumination increased approximately by 53%. The final average illumination was 1,200 lx.

### **Estimation of Pay Back Period**

The pay back period of the retro commissioning of the R & D center is estimated to take place over 3.3 years, based on the calculation of an additional charge for energy saving facilities.

## **The Results**

In the retrofitting of the HBS R&D center, the commissioning authorities and the Group could collaborate from the program phase to the operational phase in order to study how the commissioning process should operate. The owner recognized their contribution.

The key points of this commissioning work are described below:

- (1) Establishment of commissioning process – As was expected the retro commissioning process progressed with difficulty. This was the result of the enforcement of the design review. In

all cases, the standard of quality conformed to the requirements of the ISO9001 documentation. The process of bridging from program phase to operation phase was comparatively difficult. A bridging procedure is necessary and useful for consulting engineers in all situations. Establishment of CA system in Japan should be promoted with a view to arranging education with the authorized qualifications in actual commissioning situations.

- (2) Selection of HVAC System - the key point was the adoption of the an ice storage type of packaged air conditioning system and a total heat exchanger with zone control, that resulted in energy savings of 16.0%. This decision was made with the agreement of the commissioning group. This was the most important decision of the program phase of commissioning.
- (3) Design of Lighting fixtures and Humidification – The installation of the inverter ballast improved both energy savings and the level of illumination; appropriate humidification ensured employees' comfort.
- (4) Cooperation with the tenants and personnel – Compatibility of retro commissioning work and daily business work was the most important factor for the systematic progression of the project.

### **Next Steps**

The retro commissioning of the HBS R&D Center was undertaken in order to provide a model in response to the energy saving proposal and to gain knowledge from the process. This work was performed as the initial trial of commissioning the business group. The next step should be the widespread promotion of commissioning as an architectural marketing feature of the HBS and BTS business group.

As was stated at the beginning of this presentation, activity for the research into the possibility of implementing commissioning in Japan has begun in 1999 by a committee of SHASE, which published guidelines and manuals for actual commissioning work in 2003. Mr. Omori and Mr. Watanabe are the members of the SHASE commissioning committee, BSCA. The NPO is organizing seminars and symposiums in several cities. Magazines featuring commissioning information are reporting the benefits of the process and as a result, the concept and application of commissioning is now being discussed among the many people and groups in this country.

### **Acknowledgements**

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