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MEASUREMENT OF HEAT DISCHARGE OF AN OFFICE BUILDING BY ENERGY CONSUMPTION

Toru Yamamoto[1), Minoru Tanaka[1), Masaru Tsudagawa[2), and Shigeru Takayama[2)

1) E & E planning Co.Ltd., Tokyo, JAPAN
2) Ritsumeikan University BKC, Shiga, JAPAN

Abstract - To estimate a thermal environment of city, it is necessary to know and evaluate a state of heat discharge of buildings, cars and a solar radiation. This paper shows an estimation method of the heat discharge of an actual office building by using measurement results of the amount data of energy consumption and energy demand for one year per hour, and the efficiency of energy supply equipments. And also, from the estimation, the dynamic characteristics of the heat discharge of an actual office building in a year are evaluated.

Keywords: heat discharge, energy consumption, city warming

1. INTRODUCTION

In recent years, a city warming concerned in a heat island phenomenon is paid attentions as a social problem. It is pointed out that a principle factor of the warming is the artificial heat discharge from cars and air-conditioning of buildings. In this situation, many studies on the evaluation of heat discharge from a building have been presented. Examples of the typical evaluation in Tokyo are the dynamic characteristics of heat discharge from an office building and the amount of heat discharge from a city in summer[1-2]. However, these are studied on the evaluation of the amount of energy demand of standardized buildings. They use modeled data, do not measure and evaluate the actual data of heat discharge from buildings directly. The reason is that, in the measurement of temperature and humidity of the circumference of an actual building, it is difficult to separate and measure only the artificial heat discharge of building from other heat discharges by a solar radiation and from cars. However, to estimate the thermal environment of city, it is very important to observe an actual amount of heat discharge of an actual building.

This paper describes a proposal of measurement method for 1) the amount data of energy consumption, manufacturing energy and energy demand for one year per hour, and 2) the efficiency of energy supply equipments. In addition to that, it shows a calculation of the amount of heat discharge by using these measured energy data, and an evaluation of dynamic characteristics of heat discharge of an actual office building.

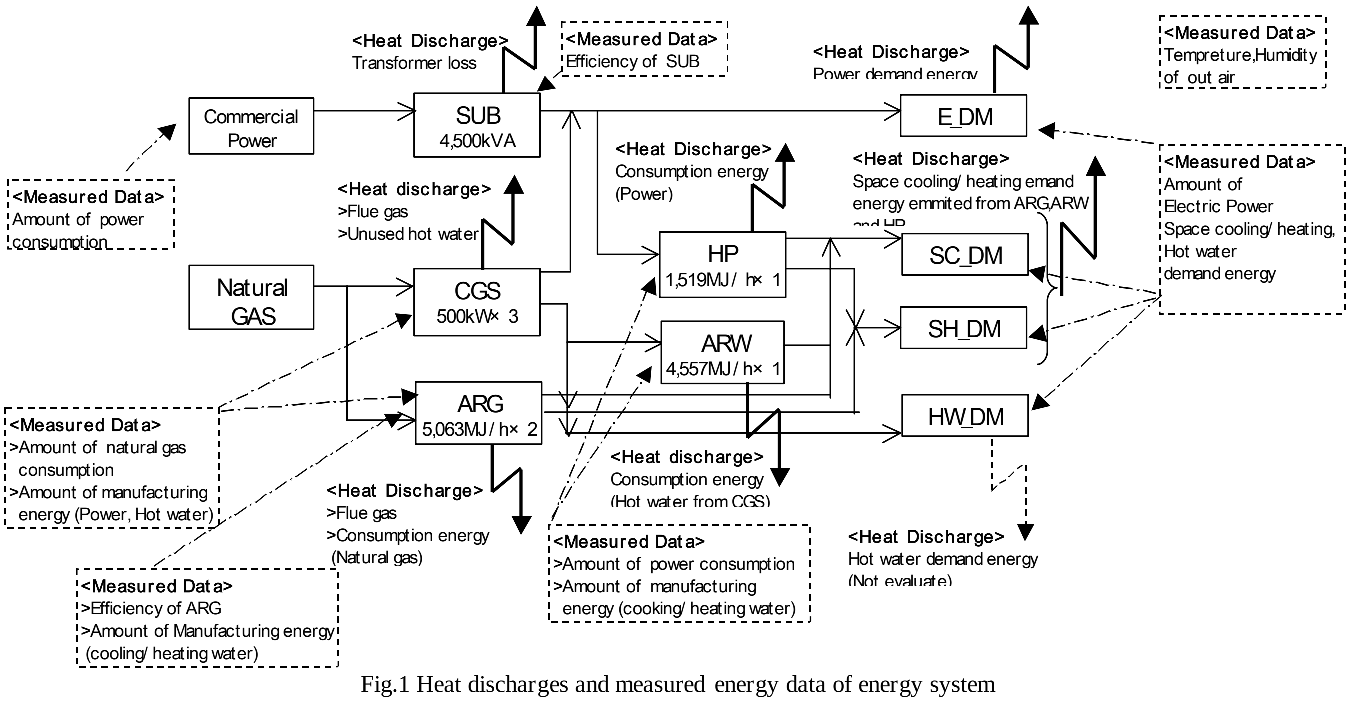

Fig.1 Heat discharges and measured energy data of energy system

2 .CONDITIONS OF BUILDING AND HEAT DISCHARGE

2.1 Building as a measurement object

The building we measured is a large scaled office building (total square; 47,000m^2 , 26 floors) in Tokyo Japan. The energy supply system (Fig.1) is composed of Substation of Electric Power (SUB), Cogeneration System (CGS), Absorption Refrigerating Machine using Natural Gas (ARG), Absorption Refrigerating Machine using Hot Water (ARW) and Heat Pump Machine with Ice Storage Tank (HP). And energy supply system is very efficient by using CGS. Their capacities are as follows;

SUB : 4500kW,
CGS : 500kW *3, ARG : 5063MJ/h *2,
HP : 1519MJ/h * 1, ARW : 4557MJh * 1.

And the energy demands are Electric energy (E_DM), Space cooling/heating energy (SC_DM/ SH_DM) and Hot water energy (HW_DM).

2.2 Heat discharge classification

Fig.1 also shows the classification of heat discharge of this building. In this classification, there are 2 types of heat discharge. One is the heat discharge, emitted in the process changed into demand energy from energy sources (energy system heat discharge). And the other one is the energy demand (space cooling/heating demand and the hot-water demand) emitted as heat discharge (energy demand heat discharge). A kind of heat discharge is showed in Table 1 as actual example. There are 10 heat discharge in energy system heat discharge, and there are 5 heat discharge in demand heat discharge in this building. In the table 1, heat discharge from hot water demand is not evaluated. Because this heat discharge is emitted into sewer, and it is not emitted to the air.

3 . THE CALUCULATION METHOD OF EACH HEAT DISCHARGE

Each heat discharge is able to calculated based on energy consumption, manufacturing energy, energy demand and the efficiency of each equipm ents.

3.1Heat discharge of transformer loss of substation

There are no-load loss and load loss as transformer loss. And these loss are calculated by form ula 1 and 2.

No-load loss (kWh) = Pi * CAP (formula 1)
Pi : Coefficient of no-load loss (W/kVA)
CAP : Capacity of transformer (kVA)
Load loss (kWh) = Pc * Lo^2 (formula 2)
Pc : Coefficient of load loss in full load (W)
Lo : Rate of load

And the kind of these heat discharge is sensible heat. In this building, transformer loss is 81MJ/h in maximum and heat discharge of this loss is very small and able to ignore, compared with other heat discharge. Therefore in this paper, this heat discharge is not evaluated.

3.2 Heat discharge of flue gas

Flue gas is emitted from CGS and ARG. The amount of this heat discharge is defined as the difference of consumption energy and manufacture energy, showing formula 3.

The amount of flue gas (MJ/h) (formula 3)
= [consumption energy] – [manufacture energy]
Consumption energy : Natural gas (m^3)
Manufacture energy:
Power and hot water (kWh , MJ/h : CGS)
Heating to water (MJ/h : ARG)
Natural gas (m^3) = 46.0 MJ/m^3 , kWh = 3.6 MJ/h

The kind of this heat discharge by flue gas is sensible heat and latent heat. And we defined the rate of latent heat in the gross flue gas is 46%, by calculation of sensible heat of flue gas in 250 degree and latent heat of steam in 30 degree. And the other condition is follows.

1) The ingredient of flue gas is CO_2, H_2O, N_2, O_2
2) The ingredient of natural gas is methane
3) Rate of O_2 in the flue gas is 7%

Therefore, formula 4 shows the amount of latent heat and sensible heat of flue gas.

Latent heat (MJ/h) = [The amount of flue gas] * 46%
Sensible heat (MJ/h)= [The amount of flue gas] *54%
(formula 4)

Table 1 Heat discharge classification

Equipment/ Demand	Heat Discharge	Type	Note
SUB	Transformer loss	Not evaluate	This heat idischarge is very small
CGS	Flue gas	Sensible Heat, Latent Heat	Exhausted from flue
	Unused Hot water	Sensible Heat, Latent Heat	Exhausted from cooling tower
	Hot Water, drive energy for ARW	Not evaluate	Evaluated in ARW
	Hot Water, used for space heating	Not evaluate	Evaluated in space heating demand
	Hot Water, used for hot water supply	Not evaluate	Exhausted to sewer
ARG	Flue gas	Sensible Heat, Latent Heat	Exhausted from flue
	Consumed natural gas	Sensible Heat, Latent Heat	Exhausted from cooling tower
ARW	Hot Water, drive energy for ARW	Sensible Heat, Latent Heat	Exhausted from cooling tower
HP	Electric power, used for space cooling	Sensible heat	Exhausted from heat exchanger
	Electric power, used for space heating	Sensible heat	
E_DM	Electric power converting into heat	Sensible heat	Evaluated 37%of consumed power
SC_DM	Space cooling energy	Sensible Heat, Latent Heat	Exhausted from cooling tower(ARG, ARW) and heat exchange(HP)
SH_DM	Space heating energy	Sensible Heat, Latent Heat	Exhausted from HP
	Ventilation air (space cooling and heating)	Not evaluate	Ventilation volume is not mesured
Hot Water supply	Hot Water, used for hot water supply	Not evaluate	Exhausted to sewer

3.3 Heat discharge from cooling tower

Unused hot water and hot water driving ARW, manufacturing by CGS and consumed gas of ARG is emitted from cooling tower. The kind of this heat discharge is sensible heat and latent heat. But rate of sensible heat and latent heat is changeable in condition of air enthalpy, removal volume of heat, filling of cooling tower. In this paper, amount of sensible and latent heat are calculated using simulation method. In this simulation, serial analysis of the amount of states of the air from an entrance to an exit in cooling tower was performed, considering of heat exchange of cooling water and air [1].

3.4Heat discharge of HP

Power consumption of HP become sensible heat and emitted to the air at that point HP exists.

3.5Electric power converting into heat discharge

Consumed electric power beco me heat in final. And the consumed power using in the area of air conditioning, for example the light, socket and so on, is converting into the heat discharge. And this heat discharge is considering as one of the heat discharge from space cooling demand. On the other hand, the consumed power using in the area of except air conditioning, for example pump elevator and so on, become sensible heat. The amount of this heat is 37% of consumed power in this building.

3.6Heat discharge removed by space cooling and heating demand

The amount of space cooling/heating demand is same as amount of manufacturing energy by ARG, ARW and HP. And space cooling demand which is removed by ARG, ARW is emitted from cooling tower as sensible and latent heat. The rate of sensible and latent heat is able to calculate using simulation method described in 3.3. On the other hand, space cooling demand which is removed by HP is emitted from heat exchanger as sensible heat.

On the other, heating demand is emitted from heat exchanger of HP as sensible heat.

3.7Heat discharge of ventilation

When the air, inside the building is exhausted to the outside the building by ventilation, the heat is also emitted. The amount of his heat discharge is calculated based on exhausted air volume and temperature. In this building, and almost buildings are same condition, it is not measuring these data,. And this heat discharge is not able to be evaluated. But we guess the amount of this heat discharge is 10-30% of space cooling/heating energy.

4. THE MEASURMENT DATA

The measuring objects in th is building are the amount data of energy consumption, energy demand and manufacturing energy, showing Fig..1. The data is measured for one year per hour in 2001.01-2001.12. By using the measured data, each amount of heat discharge is calculated.

In measurement of natural gas consumption of ARG, it is not able to measure in each AR G individually. Because there is only one gas meter established which is aimed to measure total gas consumption of two ARG. Then we measured efficiency of each ARG, and intend to measure the consumption of gas indirectly. Formula 5 shows calculation method of gas consumption of ARG. Especially, efficiency of manufacturing cooling water is given as the function of temperature of cooling water.

Gas consumption (m^3) = [Manufacturing energy]/Ef (formula 5)

Manufacturing energy (MJ/h) : Cooling/heating water for air conditioning

Gas (m^3) = 46.0 MJ/m^3

Ef : Efficiency of ARG

Ef (cooling) = 0.0100*Tw + 0.7880 (ARG No.1)

= 0.0471*Tw + 0.4294 (ARG No.2)

Ef (heating) = 0.83 (ARG No.1/2)

Tw : cooling temperature

5. MEASUREMENT RESULTS AND EVALUATION

Fig.2 shows the heat discharge of actual building through one year per hour. And each data of Fig..2 is averaged in a day of each month. The amount of heat discharge is changing in each times, working together energy consumption. The amount of heat discharge in summer (from Jun to October) is larger than in winter (from December to March). Because space cooling demand is also emitted as heat discharge with heat discharge from energy consumption. Especially, from March to October, amount of heat discharge is lager than the amount of energy consumption in same reason. The maximum volume of heat discharge is 955kJ/m^2h (in total square), recorded in 2001.08.24, showing in Fig.3. This volume is similar to about 1/4 of solar radiation, but this building has 26 floors, and conversion in the area of building (4,091m^2), the amount of heat discharge is 10,966kJ/m^2h. And this volume is similar to 3.3 times of solar radiation. In the day time (9:00-19:00), the volume of heat discharge is 40,000MJ/h, and emitted on average. Therefore in summer, heat discharge from building is very influential in city worming.

Heat discharge in winter is about 1/2-1/3 of summer heat discharge, and average peak heat volume is 200-300 kJ/m^2h (in total square). This volume is same as solar radiation in area of building, it is not small to ignore in global worming. Heat discharge in January is s howed in Fig..4. as example.

Sensible heat is emitted constantly through the year, and the volume is about 50 MJ/m^2month. On the other hand, latent heat is large in summer. Because most heat discharge of energy supply equipment is emitted from cooling tower, and the amount of latent heat of gross heat is over 80% in the calculation result.

6. CONCLUSIONS

It is difficult to measure directly the heat discharge released to atmosphere of an actual building. This paper shows a calculation method of the heat discharge by measuring the amount data of energy consumption and energy demand for one year per hour, and the efficiency of energy supply equipments. Using the calculation method, the transition of heat discharge released from an office building for one year per hour has bee estimated. And several kinds of dynamical ch aracteristics are confirmed and evaluated.

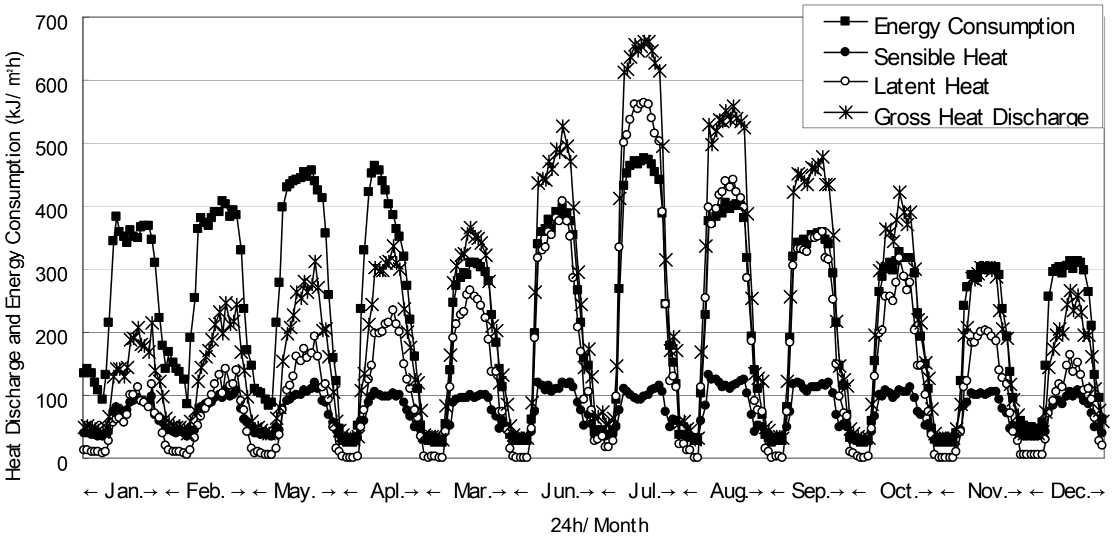

Fig.2 Averaged amount of heat discharge in a day each month

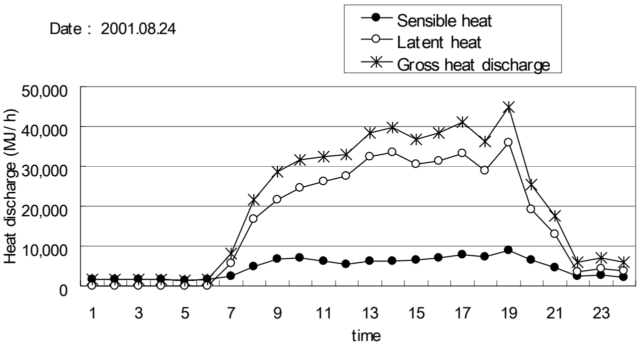

Fig.3 Heat discharge in each time (2001. 08.24)

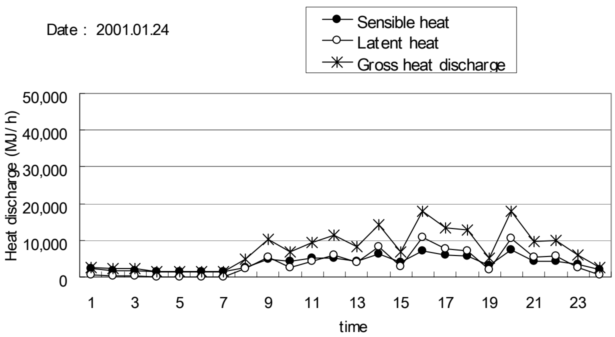

Fig.4 Heat discharge in each time (2001. 01.24)

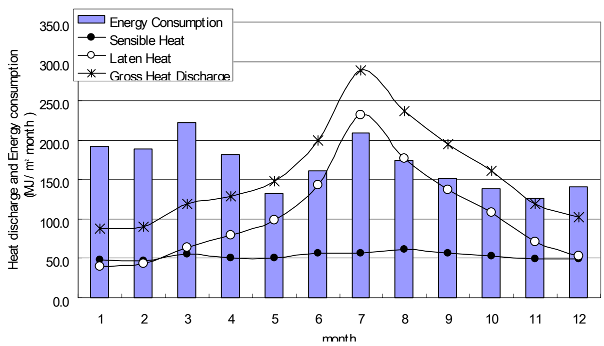

Fig.5 Heat discharge in each month

Through the measurement results and the evaluation, it is confirmed obviously that

(1) the maximum amount of heat discharge of the summer in this building is 955kJ/m^{2}h similar to about 3.3 times of solar radiation,
(2) the amount of heat discharge of winter is 200 - 300kJ/ m^{2}h correspondent with the half of summer,
(3) the amount of heat discharge becomes larger than the amount of energy consumption by exhausting of indoor air cooling demand from March to October,
(4) the latent heat discharge in summer is lager than other seasons,
(5) the sensible heat discharge was exhausted constantly in a year

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Authors:
Toru YAMAMOTO, Minoru TANAKA, E & E Planning Co.Ltd., Uchikanda 2-8-7, Chiyoda, Tokyo 101-0047, JAPAN
E-mail : yamamoto@e-eplan.com, tanaka@e-eplan.com
Phone : +81-3-5297-5404, FAX : +81-3-5297-5405
Masaru TSUDAGAWA: Dept.E.E.Engng., Fac.Sci.&Engng., Ritsumeikan Univ. BKC, Noji, Kusatsu, Shiga 525-8577, JAPAN
E-mail : tsudagaw@se.ritsumei.ac.jp
Phone : +81-77-561-2683, FAX : +81-77-561-2663
Shigeru TAKAYAMA: Dept.E.E.Engng., Fac.Sci.&Engng., Ritsumeikan Univ. BKC, Noji, Kusatsu, Shiga 525-8577, JAPAN
E-mail : s-tkym@se.ritsumei.ac.jp
Phone : +81-77-561-2685, FAX : +81-77-561-2663