SURVEY OF SIMULATION TECHNOLOGY-IN JAPAN AND ASIA

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ABSTRACT

The present status of building energy simulation technology in Japan and neighboring countries is reported. The names are listed which are leading research organizations in this field in Korea, Taiwan and main land China. In Japan, a lot of effort was made in the past fifteen years to establish energy simulation technology. Dynamic heat load program and weather data for 25 main cities were developed in the first half of 1970s. There were nine computer programs which predict year round energy consumption of a building through the simulation of air conditioning system operation, in 1980. They were investigated in detail. An example problem was prepaired to test them. The comparison of results was made between above nine programs, DOE-2.1 program and the newest HASP/ACSS program.

FOREWORD

According to the authors understanding, the energy simulation technology represents a series of computational procedures, which are to calculate building heat load, to simulate the operating condition of an air conditioning system based on the heat load obtained, and finally to estimate the energy consumption in a certain period. There are some techniques needed in the above procedure such as a data description method enabling a computer to recognize the design content of a building and air conditioning system, the arrangement of weather data and calculation result, and the evaluation method of the design by using the calculation result. Those may also be included in the energy simulation technology.

The author has been asked to report the present state of energy simulation technology in Asian district. Unfortunately, however, the author has on information enough to respond this requirement, since Asian district is extremely wide, and the exchange of information in this field has scarcely been made. Under the circumstances, the author has no other way than to report the state in Japan mainly,by adding some information on the neighboring countries.

STUDY ON ENERGY SIMULATION IN JAPAN

In Japan, a study relating to the transient heat conduction of building structures was initiatad by MAEDA in 1950s with a purpose to analyze the room temperature variation caused by the atmospheric weather coditions. Studies on the dynamic heat load calculation applicable for actual use utilizing a computer were made after the response factor method by STEPHENSON and MITALAS was announced. It was in 1970 when the Heat Load Subcomittee of The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan completed a program based on the response factor method under the name of HASP/ACLD. Thereafter, this program was revised in three times. In addition, the FORTRAN language was converted into the BASIC language allowing calculation in fair precision even with a personal computer. Further, development of the standerd weather data to be used in this program was promoted from 1970 to 1980. As a result, the standard weather data of 25 major cities in Japan have been prepared. The computer programs introduced above consist the HASP-family, which are fully opened to the public so that anybody can obtain them through an organization named Japan Building Mechanical Engineers Association.

HASP is a computer program mainly applicable for commercial buildings. Besides, heat load calculation programs for residences have been developed in which RESCOM-80, MALTEP and BRIMAP are popular. Among them, RESCOM-80 and BRIMAP use the sponse factor method, while MALTEP uses the finite difference method. The main difference between the program for commercial building and for residence is that the former uses a single room assumption that each room is thermally isolated, while the latter solves all rooms simultaneously considering that each room is affected by the temperatures of other rooms.

For the consistent calculation program covering heat load calculation, air conditioning system simulation and energy consumption estimation, the study was initiated around 1970, and approximately ten programs were existed according to the author's investigation in 1980. The number of the programs developed is considered as increased now. Those programs have been developed by consultants, general contractors and sub-contractors, and they have not been opened to the public. Some of the programs completed are used for the calculation requested by external clients, ile some of them are remained in a trial stage. The further details will be referred later.

NEIGHBORING COUNTRIES OF JAPAN

The knowledge of the author is limited to the neighboring countries of Japan ; Korea,main land China and Taiwan.

In these countries, there are researchers keenly interested in the energy simulation although the number is limited. They are endeavoring to achieve the study level of the world by investigating the literatures written in English and Japanese. However, the author has heard neither information on the completion of a computer program nor that on the actual application.

In Korea, following institutes are very active in building energy problems.

- Korea Institute of Energy and Resources, Buildings Research Division (Chungnam, Daedeok-Gun).
- Korea Institute of Construction Technology, Architecture and Engineering Dept. (Inchon).
- Korea Advanced Institute of Science and Technology (Seoul).

The standard weather data of Seoul city has been prepared.

In Taiwan, national institutes and university listed below are known to be interested in building energy simulation.

- Ministry of Domestic Administration, Bureau of Construction (Taipei).
- Research Institute of Industry, Energy Research Station (Taipei).
- National Institute of Technology, Dept. Construction (Taipei).
- National Cheng-kung University, Dept.of Archtecture (Tainan).

And the standerd weather data of Taipei and Tainan are developed.

Remarkably keen interest is shown to this field in China, and the researchers are supposed to exist all over the country although the author does not know the entire picture. They seem to be on the phase to make the weather data for peak load calculation, and are promoting to check the reliability of the transient calculation by referring the experiment. It may not take so long time before they will reach to the stage of practical use.

- The Air-Cconditioning Research Institute of Chinese Architecutural Academy of Sciences.
- The Department of Heat Energy Engineering of Qinghua University (Peking).
- The Depertment of Environment Engineering, Tongji University (Shang-hai).
- The Department of Environmental Engineering, Xian Institute of Metallurgy and Construction Engineering (Xi-an).
- The Depertment of Environment Engineering, Hunan University (Chang-sha).

ENERGY SIMULATION PROGRAMS IN JAPAN

Nine system simulation programs developed and being actually used in Japan are investigated. Table 1 shows the outline of them, and Table 2 shows the load calculation part of each program more in detail.

The details of the air conditioning system part is indicated in Table 3.

BENCH MARK TEST

An example of the building shown in Fig.1 is prepared, and the same problem is solved by using nine calculation programs mentioned above. A result of the benchmark test is shown in Table 4. This Table includes a result obtained by DOE-2 program of the U.S. as well as the latest HASP/ACSS program accomplished in the spring of this year in addition to the existing nine programs.

PRECEPTS OBTAINED AND DEVELOPMENT OF NEW PROGRAM

Thanks to the avove investigation, benchmark test and the information obtained through questionnairing to the relative engineers of each firm, some precepte to be observed in developing future programs have been secured.

(1) In order to utilize a program effectively and economically, the calculation cost should be within an appropriate range at first. The program developed with excessive minuteness and strictness frequently exceed this range. Second, The user's manual book should be perfect. Sometimes, the input data could not be prepared except by developer himself, because of imcomplete manual book.

(2) The processer is desired to be small as possible since mechanical system designers calculate by themselves with their own machines more frequently than to entrust specialists with the calculation in Japan. It is desired to have an overlay structure in 2 or 3 times with 512 KB or less memory size. Allowing the use of a personal computer for the calculation is most desirable.

(3) It is very important to make the data description clear and easy to understand for computers to memory the details of air conditioning system designed. When the data which are not shown in ordinary design drawings or specifications are required, appropriate default values should be prepared.

(4) Although the partial load characteristics of equipment are needed for the calculation, the catalog data announced by the manufacturers are quite insufficient for this purpose. The manufacturers themselves do not fully understand such need also. The equipment are shipped with their warranty for use under a certain operating conditions, however, they are frequently used out of such conditions. This induces the present problem.

(5) In the calculation, some parts are remained unsolved theoretically. For example, the estimation of air leakage from ducting can be raised. There will be no other way than to set an appropriate assumption in this case, however, the developer is anxious to know how the leakage will affect on the final result.

Backed by the investigation results as described above, a standerd version of energy simulation program was planned to develop. After three years work from 1982 to 1985 by MATSUO ,YOKOYAMA , INOOKA and others, the new program has been completed sponsored by Tokyo Electric Power Co., Japan. This new program named HASP/ACSS will be opened to the public at the end of this year as a member of the HASP-family. This new program will be presented by INOOKA in the separate session.

Table-1. General Aspects

No.	Ownner	Program Name		Year of Completion	Outline			Processer	Computer Time (seconds for 1zone, 1year)
		Load Calculation	System Simulation		Language	Statement Lines	Memory Size (KB)		
1	Shin-nihon Kucho	DYLD	ASIM	1972	FORTRAN	1,500 3,000	65 (overlay)	OUK 90-300	900 1140
2	Nikken Sekkei	ALFA-1	ACSS-03	1974	FORTRAN	7,000 8,500	510 300	IBM S/4341	60 100
3	Taisei Kensetsu	TAISEI		1980	FORTRAN	5,000 4,400	736	IBM S/370-158	70 60
4	Obayashi Gumi	DYLOAD	E-SAVER	1976	FORTRAN	4,300 8,000	420 490	IBM S/370-158	22 16
5	Shimizu Kensetsu	LOAD-80	ECC	1979	FORTRAN	4,500 8,500	1060 450	IBM 3033	2 15
6	N. T. T.	AIRCON-3	AIRCON-E	1977	FORTRAN	1,100 20,000	512	DIPS 11	3-6 10-15
7	Kajima Kensetsu	AIRCON		1972	FORTRAN	4,000 3,000	370 (overlay)	HITAC 8500	200
8	Mitsui Kensetsu	ACL-400	MEC-10	1980	FORTRAN	2,600 1,800	200 150	UNIVAC 1100/11	15 20
9	Takasago Netsugaku	TACSSP-1	TACSSP-3	1979	FORTRAN	2,500 2,000	230 100	IBM 370-125	unfamilier

Table-2 Heat Load Calculation Part

No. Program Name	Total Steps Weather Data	Convolution Algorithm	Unconditioned Adjacent Room	Infiltration	Solar Shading				Condition to Shut Venetian Blind	2 Spaces without Partition
					Over Hung	Side Fin	Adjacent Building	Tree		
1 DYLD	365*24 HASP-Format	Response F. Transient	*1 or *2	Crack Method +0.3 times/h Air Change	○	○	-	-	Critical Solar Gain	Independent
2 ALFA-1	365*24 HASP-Format	Response F. Transient	*2 or *3	Air Change Modified by Temperature	○	○	○	-	Schedule and C. S. G.	Independent
3 TAISEI	126*24 Compressed HASP-Format	Response F. Transient	Ignored	Crack Method	○	○	-	-	Schedule and C. S. G.	Independent
4 DYLOAD	26*24 2 Design Days per Month	Response F. Daily Periodic	*1 or *2	Constant Air Volume or Crack Method	○	○	-	-	Critical Solar Gain	Independent or Perfect Air Mixture
5 LOAD-80	365*24 HASP-Format	Response F. Transient	Ignored	Crack Method	○	○	-	-	Critical Solar Gain	Mixing Ratio in Daytime Perfect Mix at Night
6 AIRCON-3	(36~120)*24 3~10 Design Days per Month	Response F. Daily Periodic	*1 or *2	Constant Air Volume or Crack Method	○	○	-	-	Critical Solar Gain	Mixing Ratio
7 AIRCON	365*24 HASP Format Solar Position	Response F. Transient	*1 or *2	Air Change	-	-	-	-	Always Shut	Independent
8 ACL-400	365*24 HASP Format	Response F. Transient	*1 or *2	Crack Method or Air Change	○	○	-	-	C. S. G. when Occupied	Merge into One Room
9 TACSSP-1	365*24 HASP-Format	Response F. Transient	*2	Crack Method or Air Change	○	○	-	-	Critacal Solar Gain	Independent

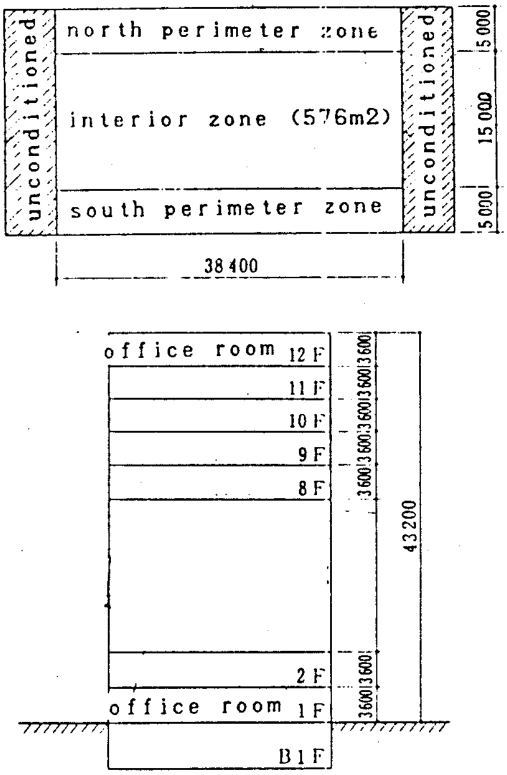
*1: Constant Temperature Difference is Assumed.
*2: Given as a Function of Outdoor Air Temperature.
*3: Rigorous Solution by Multi-room Equation.

Table-3 System Simulation Part

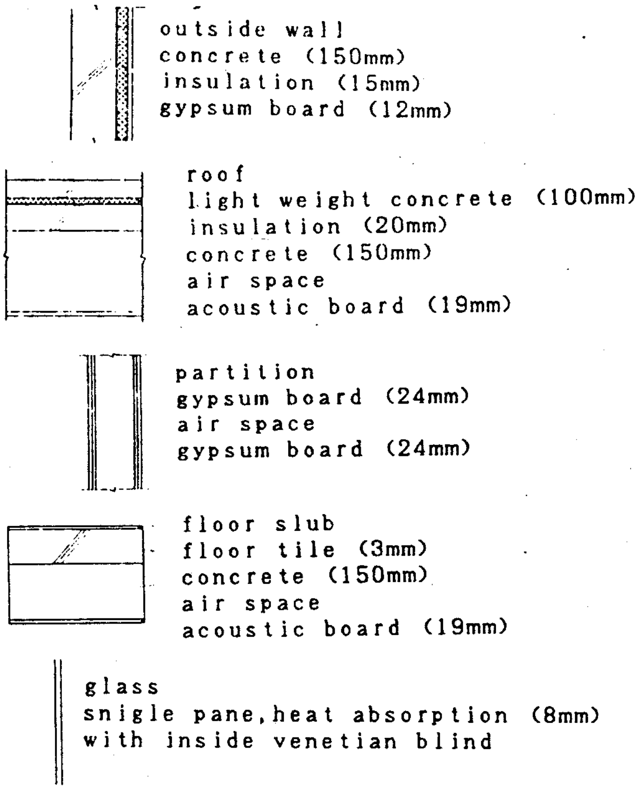
No. Program Name	Air Conditioning System														O.A. Volume Control					Air Handling Unit		Heat Source System											
	A	B	C	D	E	F	G	H	I	J	K	L	M	Combination	N	O	P	Q	R	Algorithm	Over Load	a	b	c	d	e	f	g	h	i	j	k	Over Load
1 ASIM	○	○		○	○	○	○	○						16 Types	○		○			*1	*5	Not Specified									○		Ignored
2 ACSS-03	○	○	○	○	○	○	○	○		○				Free			○	○		*2	*5	○	○	○		○		○	○	○	○	○	*6
3 TAISEI	○			○	○					○							○	○		*3	Impossible	○	○	○		○		○	○	○	○	○	*7
4 E-SAVER	○	○		○	○	○				○					○		○	○	○	*4	*5	○	○	○		○		○	○	○	○	○	*8
5 ECC	○			○	○	○			○					Free	○	○	○	○	○	*2	*5	○	○	○	○	○		○	○	○	○	○	*9
6 AIRCON-E	○	○	○	○	○	○	○			○				Free	Unfamilier					*1	*5	○	○	○		○	○	○			○	○	Ignored
7 AIRCON	○	○			○	○	○	○										○		*1	Ignored	○	○			○	○		○	○			*8
8 MEC-10	○			○	○					○					○	○		○		*1	Ignored	○	○			○		○		○		○	*8
9 TACSSP-2	○			○	○					○	○				○		○	○	○	*3	Impossible	○	○	○		○		○		○			*8

A:Single Duct System
B:Terminal Reheat System
C:Dual Duct System
D:VAV Fan System
E:2-Pipe Fan Coil Unit System
F:4-Pipe Fan Coil Unit System
G:2-Pipe Induction Unit System
H:4-Pipe Induction Unit System
I:Radiater Heating
J:Package Unit System
K:Terminal Package Unit System
L:Floor Panel Heating
M:Multi Zone Unit
N:Minimum O.A. Control
O:Maximum O.A. Control
P:O.A. Cooling
Q:Shut off at Pre-heating Stage
R:CO2 Concentration
a:Boiler
b:Refrigerator(Electric Turbo)
c:Refrigerator(Absorption)
d:Refrigerator(Screw)
e:Heat Pump(Air Source)
f:Heat Pump(Water Source)
g:Cooling Tower
h:Heat Storage Tank
i:Heat Recovery System
j:Total Heat Exchanger
k:VWV Pump System

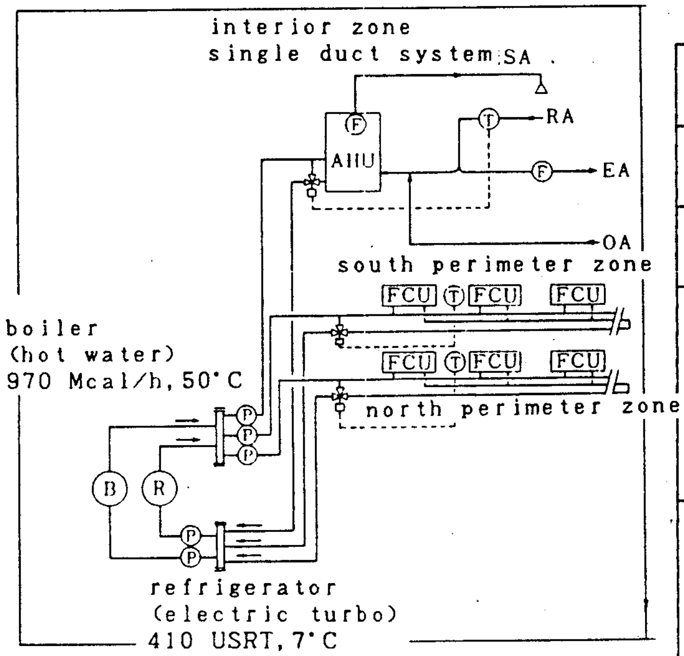
*1:By-pass Facter Method
*2:Approximate Function
*3:To assume any requirement will be satisfied regardless of physical condition.
*4:To solve coil equation.
*5:Feeded back to change room air condition.
*6:Feeded back to change downstream condition.
*7:Excess load is added to next time step.
*8:To assume sufficient heat source capscity.
*9:Ignored,but the occurence is warned in print-out.



Model Building



Construction of Enclosures



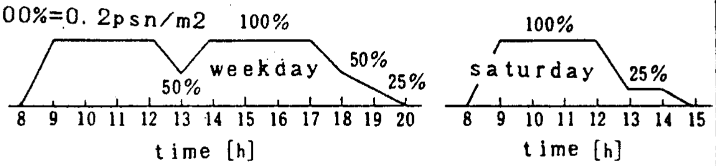
Air Cconditioning System

Condition of System Operation

Seasonal Schedule	Cooling: Jun, 1---Sep, 30 Heating: Nov, 1---Apr, 30
Daily schedule	Weekday: 8:00---18:00 Saturday: 8:00---13:00
Design Temperature	Cooling Seazon: 26°C Heating Seazon: 22°C

Occupancy Schedule

100%=0.2psn/m2



Illumination Schedule

100%=25watt/m2

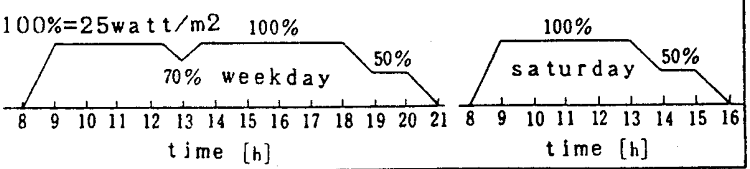


Figure-1 Example Building Used in Bench Mark Test

Table-4 Results of Benchmark Test (Conventional Design Case)

No. Program Name	Total Heat Exchange				Fuel Consumption				Primary Energy per Conditioned Floor Area (Mcal/m2)
	Cooling		Heating		Electric Power		Gas	Water	
	A. H. U. (Gcal)	F. C. U. (Gcal)	A. H. U. (Gcal)	F. C. U. (Gcal)	Heat Source (MWH)	Circulation (MWH)	(1000m3)	(Ton)	
1 ASIM	407.2	210.2	20.0	117.5	246.7	185.6	16.4	4190	107.6
2 ACSS-03	625.5	47.7	8.1	137.7	257.4	194.0	19.9	3155	115.0
3 TAISEI	388.8	193.2	69.5	50.4	243.4	157.2	13.3	5970	97.9
4 E-SAVER	583.9		95.0		249.2	195.8	9.5	1772	103.7
5 ECC	360.4	179.3	87.4	43.1	207.4	191.6	26.3	5206	109.9
6 AIRCON-E	406.0	190.7	4.0	108.5	250.1	177.9	8.9		100.3
7 AIRCON	370.7	195.1	23.2	104.3	224.1	190.1	15.3	4331	102.7
8 MEC-10	385.0	220.5	46.6	107.8	257.3	193.0	14.8	5978	109.9
9 TACSSP-2	402.0	210.0	70.0	99.0	260.0	186.0	18.5	2142	112.5
10 DOE-2	420.8	194.1	202.6	90.2	246.0	183.5	42.7		132.1
11 HASP/ASCC	511.3	112.1	16.3	143.2	225.2	198.0	18.8	1291	107.1