

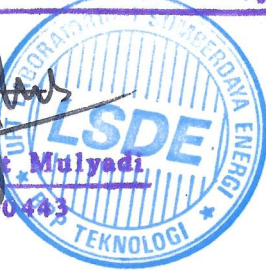
Intern Report
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ARCHITECTURAL DESIGN ANALYSIS ON
THERMAL BEHAVIOR AND NATURAL DAYLIGHT IN BCA BUILDING

Mengetahui:
UPT-Laboratorium Sumber Daya dan Energi

Kepala


Dr. Rachmat Mulyadi
NIP. 680000443



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by:

Jerrino Soedarno, M.EP Arch.

Ir. Daryanto, M.Arch

Ir. Moh. Ramlan

TELAH DIPERIKSA,

KELOMPOK SISTEM TEKNOLOGI ENERGI

KETUA





DRS. HARRY NUGROHO MSEE

NIP 680000807

*) UPT-LSDE, BPP TEKNOLOGI

***) UNIVERSITAS TRISAKTI

Serpong, Tangerang 15320 Jawa Barat

Grogol, Jakarta Barat

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ARCHITECTURAL DESIGN ANALYSIS ON THERMAL BEHAVIOR AND NATURAL DAYLIGHT

Jerrino; Daryanto; Ramlan

I. GENERAL DESCRIPTION OF THE TASK

This section is responsible for analyzing the architectural design aspects of the building regarding heat gain, due to the building geometry with respect to solar geometry, faktor-faktor luar (external factors), and other related aspects such as materials, building construction, and natural daylighting etc. Heat gain due to the internal factors: artificial lighting systems, appliances, and occupancies are not discussed specifically since they contribute only relatively small number compare to the caused by external factors, although they consume a great amount of electric energy.

Measurements are implemented from 25 - 30 May, 1990 so that, data and analysis presented in this report are only valid for the dates stated, and the building performance likewise.

Complete monitoring throughout the year is recommended to see the actual overall thermal building performance. Retrofitting and simulation of modifications are out of this context. Other information but more closely related to other subjects will only be discussed in general.

Building form and orientation, building materials and construction, and spatial management are the major issues in

energy conservation and management meanwhile control, operation and scheduling are other supporting issues that have to be appropriately considered as a whole concepts of building design strategies.

II. SCOPE OF INVESTIGATION

The scope of this task is limited to the design contribution to the overall thermal building performance due to the architectural design aspects.

Architectural design and spaces are observed carefully to determine such factors need to be assessed. The activities include the measurements of : temperatures, natural daylight, solar radiation, and an Overall Thermal Transfer Value to get an overall view of energy transfer and design strategies due to the solar radiation with respect to material selection, building orientation, and building construction.

III. BUILDING DESCRIPTION

Building name	:	BCA
Location	:	Jl. Jenderal Sudirman, Kav. 22-23 Jakarta 12920
Built	:	1985/86
Owner	:	Bank Central Asia Group
Managed by	:	PT. Bahana Dharma Utama
# of floor(s)	:	18 3 penthouses 2 basements

Space Usage : 1 fl. (lobby & banking)
 2 - partly 17 fl. (offices)
 18 - partly 17 fl. (restaurants)

Building dimension : 36.6 m x 43.2 m.
 3.90 m floor to floor.
 3.50 m floor to ceiling.

Gross area per floor : 1555.2 m²
 Core area per floor : 311.0 m²
 Plenum : 0.90 m
 Building orientation : facing Northwest
 Building structure : post & beam, concrete columns
 Building construction : steel & concrete

Floor : concrete platform.
 Exterior wall : white gypsum board, insulation.
 Main corridor finishing : black granite
 Office floor finishing : various types (tiles, carpet, granite)
 Exterior finishing : reflective glass (8 mm), ground floor
 (12 mm)

IV. MEASUREMENTS

IV.1. Temperatures.

Due to the major heat gain comes from the solar radiation mainly through building envelope, several readings of temperature measurements are taken directly, simultaneously and automatically by a data acquisition system. As a sample for the entire floor, in a vacant space in the 4th floor is installed 10 sensors in predetermined spots on the wall (fig.A10). Readings are recorded continuously from 7:00 a.m. to 5:00 p.m. Those temperatures are:

- indoor wall surface
- indoor glass surface
- between wall & glass (in wall)
- outside ambient air

In addition, indoor thermal conditions are also taken manually from different selected floors (North & South) in accordance with the measurement done in air handling units (AHU). These values are drybulb and wetbulb temperatures of the rooms and diffusers.

IV.2. Natural Daylight.

The maximum use of natural light without ignoring the excessive heat gain is significant; therefore, to optimize the utilization of natural daylight into architectural space will not only give more meaning to the space but also reduce the need of electricity for indoor lighting. Moreover, it is purposely studied to provide such architectural functional analysis according to the amount of luminous or light distribution during the day.

For this purpose, in the Northern side of the building at an ordinary desk height in the fourth floor, the natural daylight intensities are measured by using a luxmeter. Nine points are geometrically determined so that natural light distribution is evenly recorded. The measurement is recorded every 30 minutes interval from 8:00 a.m. to 4:30 p.m. on a fairly bright day (fig.A10.0).

Condition of the space during the measurements :

- Neither indoor nor outdoor sun shading devices
- Large undivided space (not yet been divided into rooms)
- None of the artificial lights is turned on
- Space assignment has not yet been determined.

Simple approximation of daylight and lux requirement will be provided.

IV.3. Direct Solar Beam Into The Space

Direct solar beam falling on the glass windows is transmitted as part of heat gain into the space. It also causes a glare during certain hours of the day. Measurements are implemented hourly since early morning when it reaches the farthest distance in the Northeast (NE) and Southeast (SE) sides, and late in the evening in the Northwest (NW) side. The investigation is expected in such a way to bring about an idea for spatial improvement comparable to natural light.

V. RESULT and DISCUSSION.

V.A. Data Analysis

V.A.1. Temperatures.

Basically two temperatures are measured: drybulb and wetbulb temperatures. Thermal conditions of the rooms and walls are discussed separately although they are obviously interrelated each other.

V.A.1.1. Wall Thermal Condition.

Increasing wall temperatures are mainly caused by both outside ambient temperature and solar radiation. In general, even though the Northeast (NE) surface receives the largest amount of solar radiation during the day while the Southeast (SE) and the Northwest (NW) sides receive only during the first and second half day respectively, the NE and SE peak temperature occurs between 8:30 - 11:00 a.m. and between 14:30 - 15:30 p.m. in the

NW side due to the building geometry and orientation with respect to solar geometry (fig.A10.1,A10.2,A10.3).

Figures A10.4,A10.5,A10.6 depict that temperature increase in the glass surface in peak condition is about 8 to 10 deg.C. higher than the wall which can be assumed that heat gain through glass is about double (discussed later). The inside glass surface can reach a temperature up to in the mid 40's deg.C. when the outside air temperature only about 32 deg.C. It is caused by the capability of the glass itself to absorb heat rather than transmits it through. The condition reconciles with the cut off of the instantaneous heat gain about 40% (discussed in V.B).

Temperature drop of the NE and SE sides of the glass surface in the later time causes heat dissipation into the room due to the lower room temperature than the outside ambient air temperature. Considering these critical conditions by ignoring heat gain caused by occupancies and others, a proper scheduling of temperature set up is important.

From the same figures (A10.2,A10.4,A10.5,A10.6), in wall temperatures show the highest value among the others. The Northeast and Northwest wall temperatures rise as high as 60 deg.C., and 50 deg.C. in the Southeast wall. This air space however acts as a heat sink in the wall structure.

V.A.1.2. Room Thermal Condition.

From the measurements obtained, the average temperature of the North zone rooms is approximately 22.34 deg.C. drybulb and 16.88

deg.C. wetbulb (Rh= 50%) while 21.50 deg.C. drybulb and 16.08 deg.C. wetbulb in the South zone (Rh= 55%). Compare to the Webb Singapore Standard of 25.60 deg.C. of Effective Temperature, or to ASHRAE Standard 55 - 1981, 25.00 deg.C. drybulb and 50 % Rh or even to the Institut Teknologi Bandung (1942) research of 25.00 deg.C. drybulb temperature and 60% Rh, the condition of the room in this building is lower than the standard.

In fact when room temperature goes near the standard, the room feels a bit warm. This condition indicates either large amount of heat built up in the space due to the design failure or it needs such adjustment on the A/C or control system. This will certainly cause high energy demand.

When the fan coil units (FCU's) are turned off, room temperature measured about 3 meters from the exterior wall during the day is about 2 to 3 degrees Celsius higher than the inner part of the space. It is ultimately caused by heat gain through the wall especially from the windows (discussed later).

V.A.2. Natural daylight.

The amount of natural daylight is various during the day depending upon time of the day, day of the year and climate in that day. However, the ratio of the light level in a point in a room to the level of light in an open space is constant, both is from the sky and direct solar beam. This ratio the so called daylighting factor (fp) that is expressed in % relies on :

- Area and geometry of windows
- Surface reflectivity
- Overhangs

In average at any point about 4 meters from the window (A,C,D,F,G) receives approximately above 300 lux and points B,E,H lower than 300 lux. Points F and G receive the largest daylight intensity especially in the afternoon compare to others (table A10.1). These values do not yet account for direct sunlight into the space causing glare and heat gain. Light transmitted screens are absolutely required namely during low solar altitude in the morning up to 10:00 a.m. in the SE side and 1:00 p.m. in the NE side, while starting at around 12:30 p.m. in the NW side.

Figures A10.7 and A10.8 show that light intensity profiles in the respective points are similar and only different in the magnitude. Comparing the results given in table A10.1 to the data given in the table A10.2, architecturally, interior design should be in conform with the actual daylight condition such as point A can be provided for a task that requires medium light level whereas private working rooms should not be arranged near the natural light source to optimize the day light utilization.

For instance, around a respective area of point A of 307.22 lux average light intensity, the best fit is for a general working space. For 150 m², the wattage required is approximately 2250 Watts or equal to 29 artificial lights of double 40 Watts flourentcent light without natural daylight. When special assignment of space requires higher amount of light, higher efficiency artificial light is highly recommended.

V.B. Relative Heat Gain Through Glass

Since there is no specific data of the installed glass available, as a given sample, similar products of PPG Industries, Inc. are employed to approximate some significant values as required (table A10.3); for reference see appendix 1.

From the values given in table 3 and the ASHRAE Solar Heat Gain Factor, the relative heat gain (RHG) of the glass is calculated.

$$\text{RHG} = (\text{SHGF} * \text{SC}) + (T * U) \quad (1)$$

Where :

SHGF, solar heat gain factor
SC , shading coefficient
T , temperature difference
U , overall coefficient of the heat transmission

When the glass material is in this range, it is clearly shown that in general the Northeast windows receive more solar heat than the other two, Southeast and Northwest. Two hours before solar noon or at 10:00 a.m. solar time for instance the NE windows get 291 W/m² in average while the SE and NW windows gain 62 W/m² and 58 W/m² respectively. When they are individually compared to the standard 8 mm ordinary clear glass using the same data and procedure, it is obvious that this glass cuts down the heat gain into the architectural space about 30 - 40% (table A10.4).

V.C. Overall Thermal Transfer Value

The building envelope contains elements which, although they do not consume energy directly, do affect the amount of energy which

must be supplied to the building to maintain thermal comfort. The values given here regarding the building envelope are the measure of a building design criterion, not the amount, expressed as watts per square meter.

Based upon the design constructions and other technical specifications, the Overall Thermal Transfer Value is calculated.

$$\text{OTTV opq.} = \frac{A * U * T}{A \text{ tot.}} \quad (2)$$

$$\text{OTTV trs.} = \frac{A (U * T * SC * SFC)}{A \text{ tot.}} \quad (3)$$

where :

OTTV opq, overall thermal transfer value for opaque surface
 OTTV trs, overall thermal transfer value for transparent
 A , area
 U , overall coefficient of heat transmission
 SC , shading coefficient
 SFC , solar factor correction
 T , temperature different in Deg. K due to the weight
 A tot, total area

The Southwest and the Northwest walls has the highest and the lowest values of approximately 50 and 48 W/m² respectively. The Northeast and Southeast walls are about 49 W/m². Contrarily to the maximum standard of 45 W/m² for the Asian countries, these values in average are still high which means the building envelope (construction and material use)especially the windows is not yet quite effective in blocking out the incoming heat from the outside and needs to be further investigated.

When they are individually compared per watt per square meter per total wall surface area, The glass itself in this context contributes about 70-75% of the total heat gain (table A10.5). This circumstance refers primarily to the wall-glass ratio and construction, the geometry and optical property of materials. While high value of the wall refers to the heat capacity of the air acting as a heat storage within the wall as discussed early.

VI. CONCLUSION and RECOMMENDATION

An ideal building in which all indoor activities take place should not only serve its function well but also should protect the occupants from being thermally discomfort. It means that the building should be able to provide itself from requiring or consuming more electrical energy and encourage the idea of energy efficient.

In contrast, this building does not assure this condition. The average temperature of the conditioned space is 22 deg.C or about 3 deg.C lower than the comfort standard (25 deg.C. drybulb temperature). Since lower room's temperature demand is inevitable, consequently, larger amount of electrical power namely for air-conditioning to fulfill the need of the occupants to thermally comfort is in effect.

Other factors affecting large electric power consumption are:

- improper space assignment or usage
- interior lay
- does not take full advantage of natural daylight

- large heat gain through windows (70% of the total heat. gain through wall surface)
- heat storage in the building structure
- Building form and orientation

Energy waste cannot be only measured by the amount of energy used but also their applications such as the tasks, frequency of space usage, control over the lighting etc. An open or partially open and integrated room's layout to take full advantage of natural daylight is highly recommended. It is necessary to reduce a drastic temperature gap among rooms and the work of air-conditioning likewise.

References:

1. Laporan Diskusi Ilmiah Konservasi Energi di Bangunan Komersial
2. PPG Industries, Inc. Pittsburgh, Pennsylvania.
3. Rancangan Pedoman Teknis Konservasi Pada Bangunan Gedung.
4. Handbook on Energy Conservation in Buildings and Building Services. The development and building control division (P.W.D), Singapore.
5. 1985 ASHRAE Handbook.
6. Carrier Handbook of Air Conditioning System Design, McGraw-Hill Book Company.

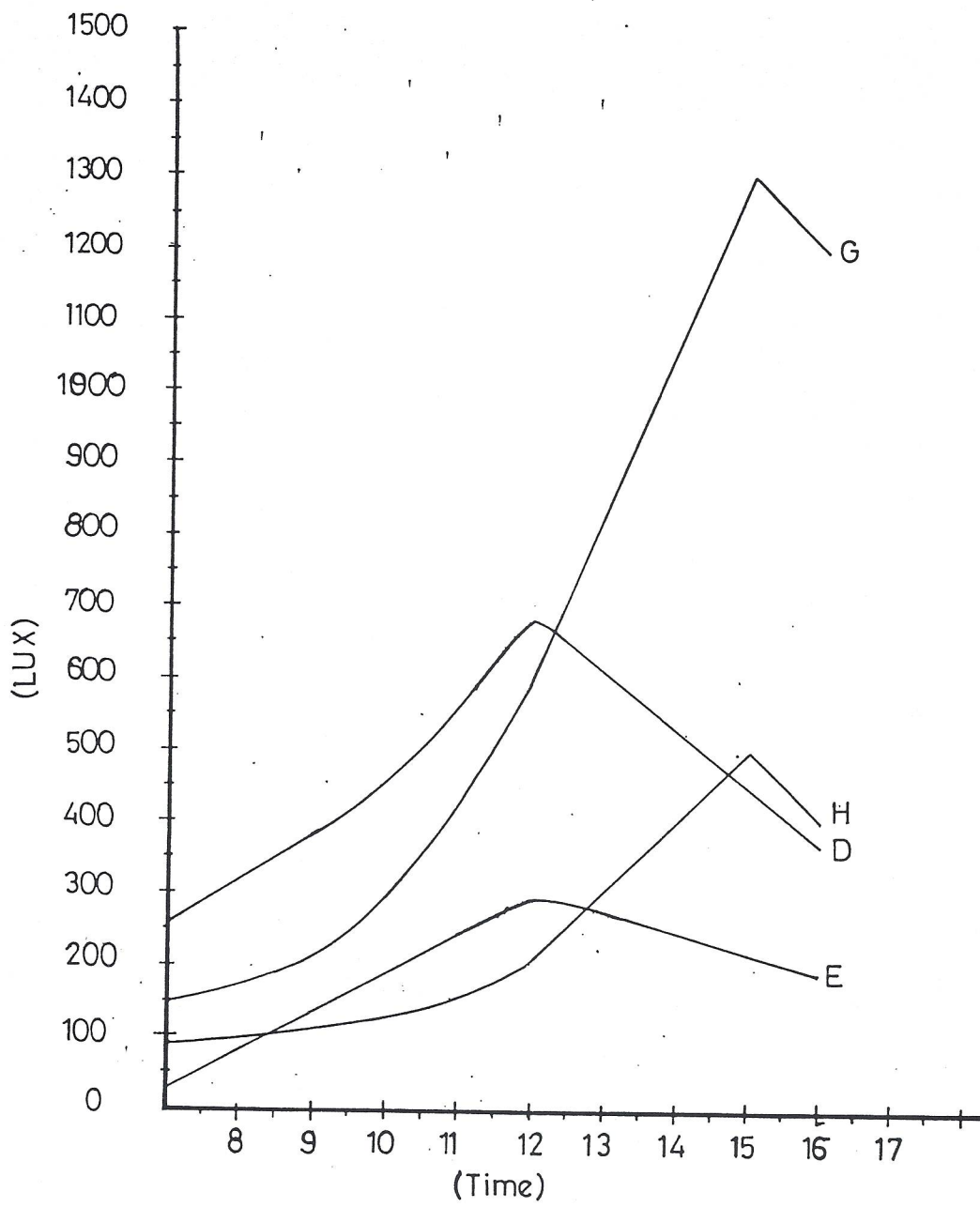


Fig. A.10.7

Light intensity in the room at different hours.

As points indicated, please refer to figure 2.

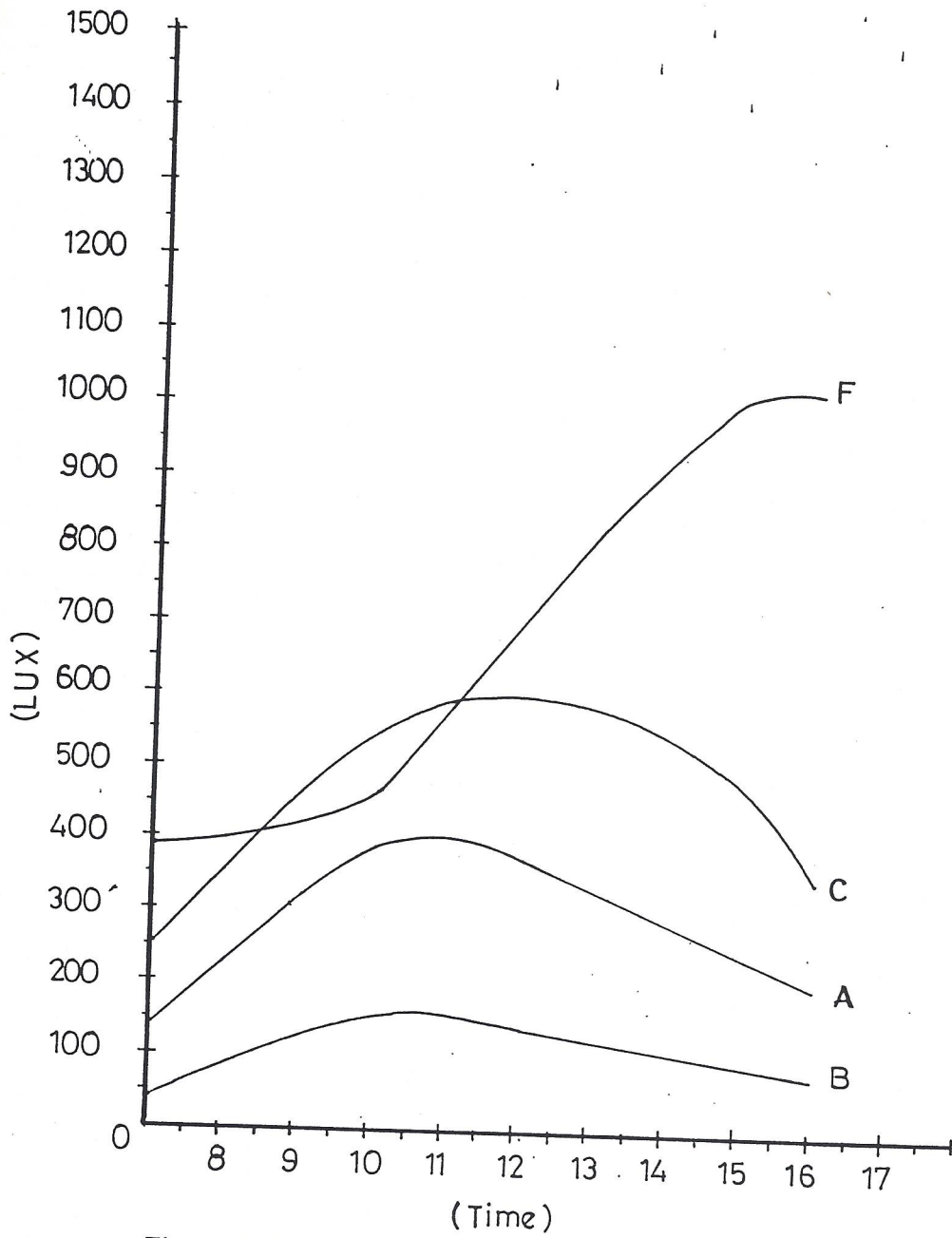


Fig.A.10.8

Natural light intensity in the room at different hours.

As points indicated please refer to figure 2

Temperature VS Time May 28, 1990

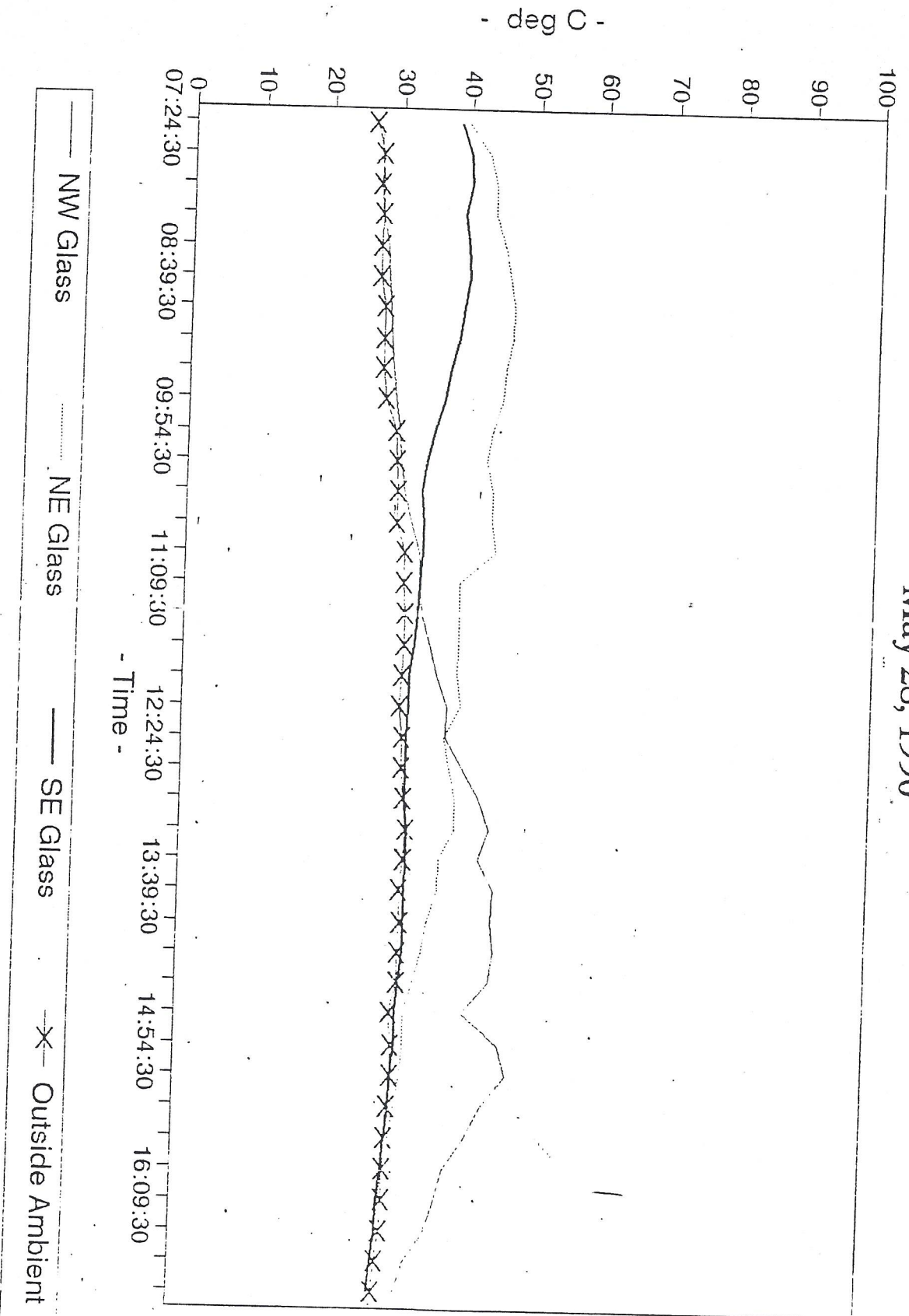


Fig.A10.1. Comparative performance of three different glass surfaces

Temperature VS Time
 May 28, 1990

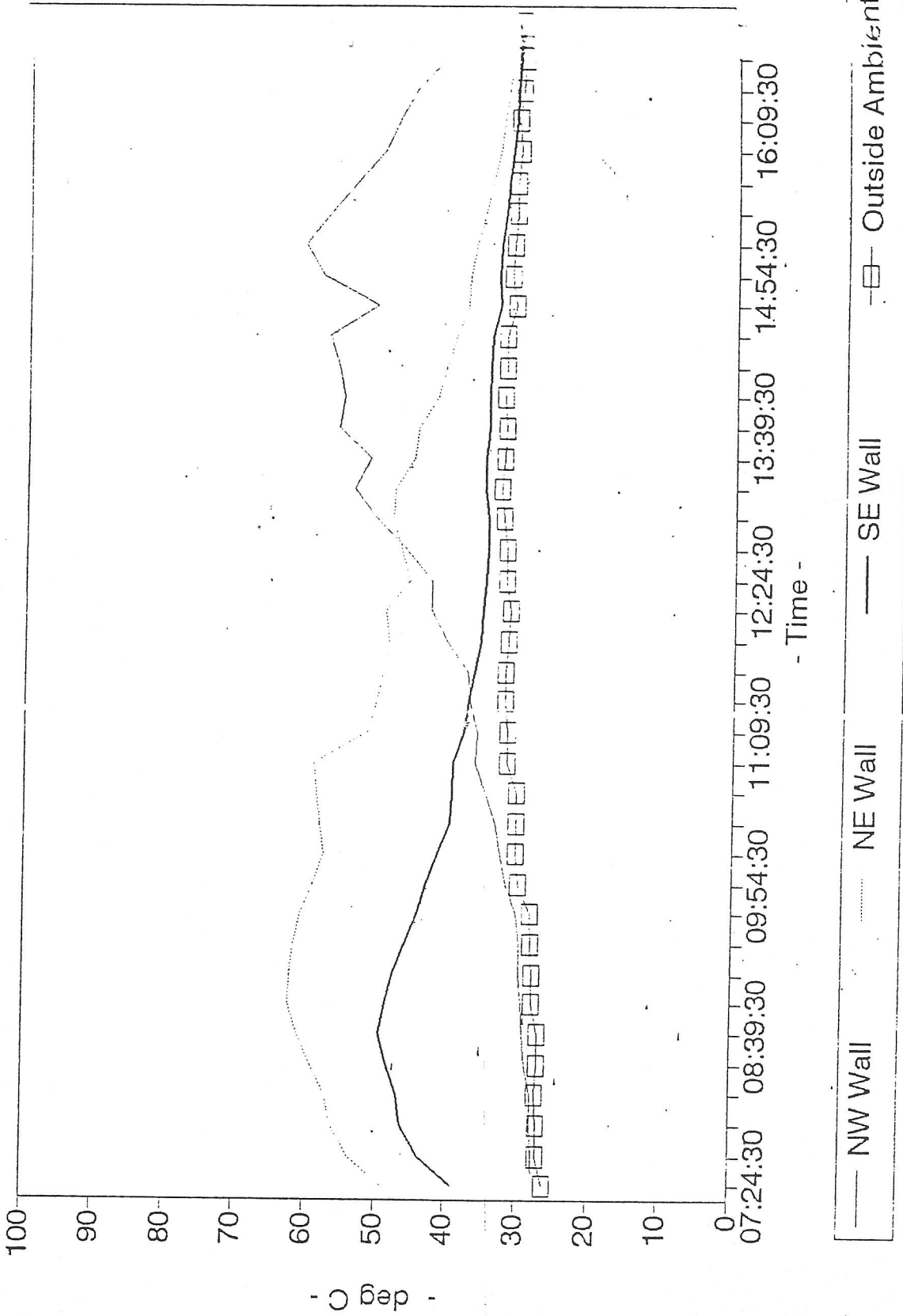


Fig.A10.2. Comparative performance of three different In wall measurements

Temperature VS Time

May 28, 1990

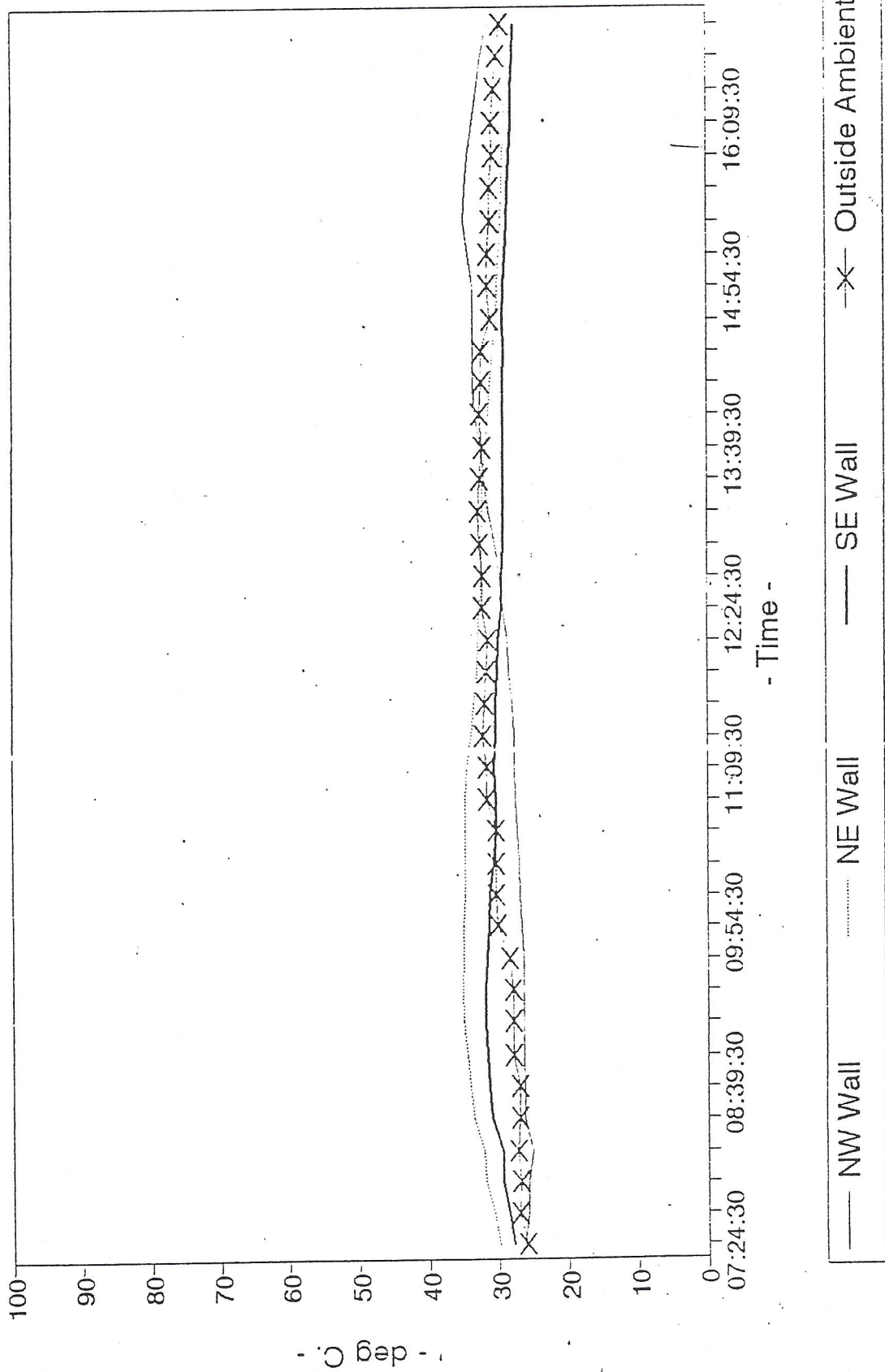
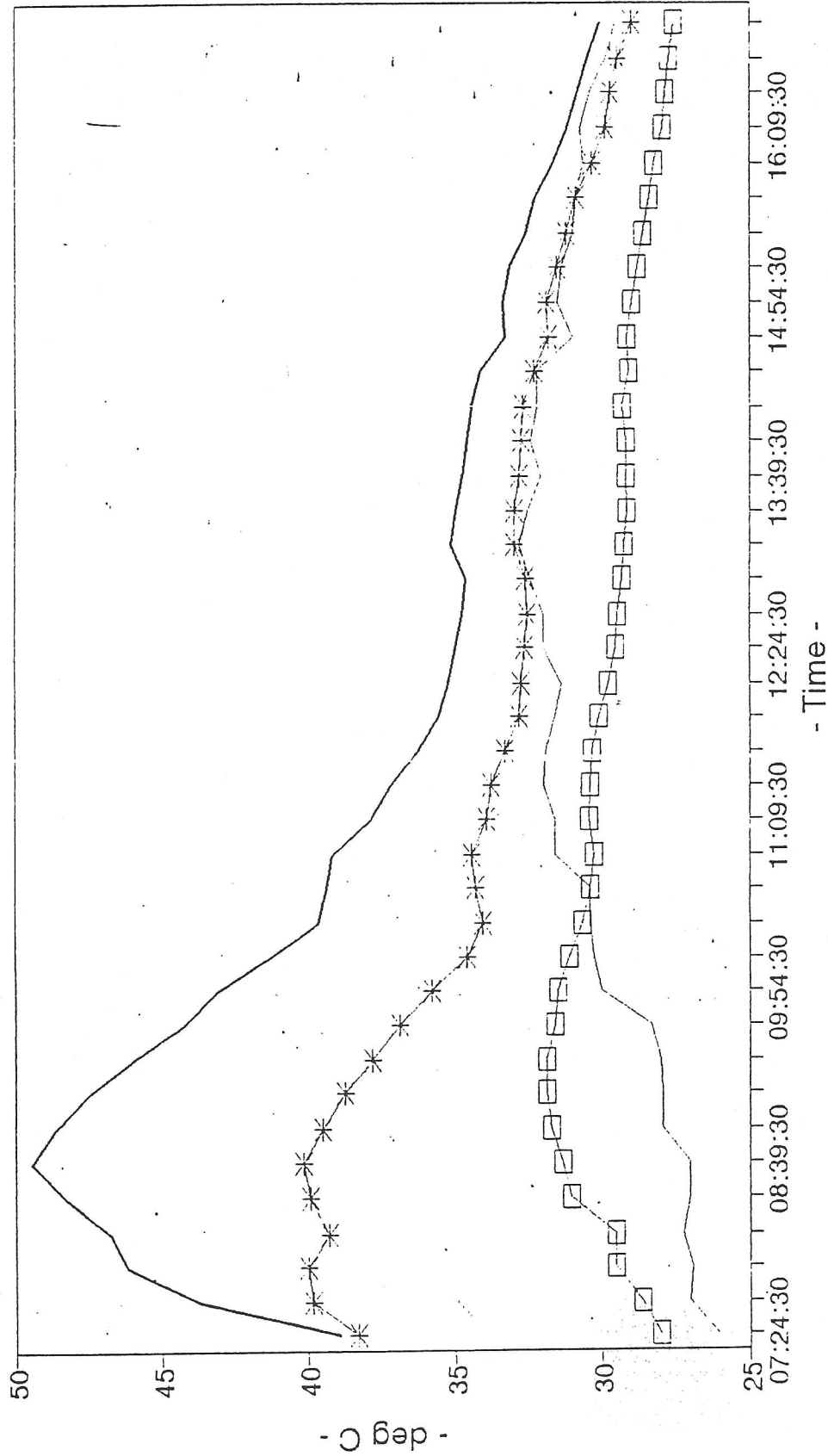


Fig.A10.3. Comparative performance of three different wall surfaces

Temperature VS Time

(Southeast Wall)

May 28, 1990



— Outside Ambient — In Wall —*— Glass Surface —□— Wall Surface

- Time -

Fig.A10.4. Performance of wall facing due Southeast

Temperature VS Time

(Northwest Wall)

May 28, 1990

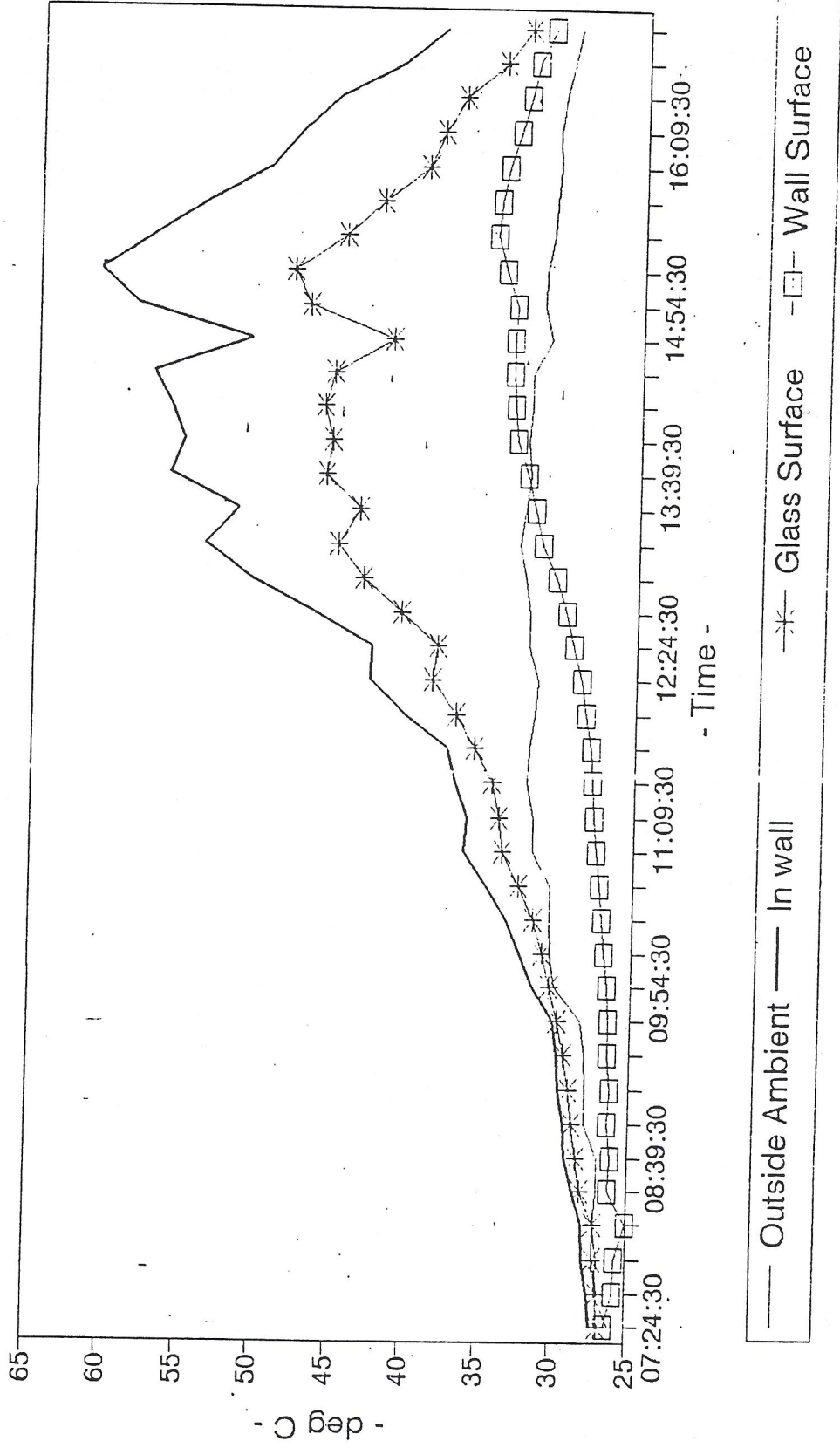


Fig.A10.5. Performance of wall facing due Northwest

Temperature VS Time

(Northeast wall)
May 28, 1990

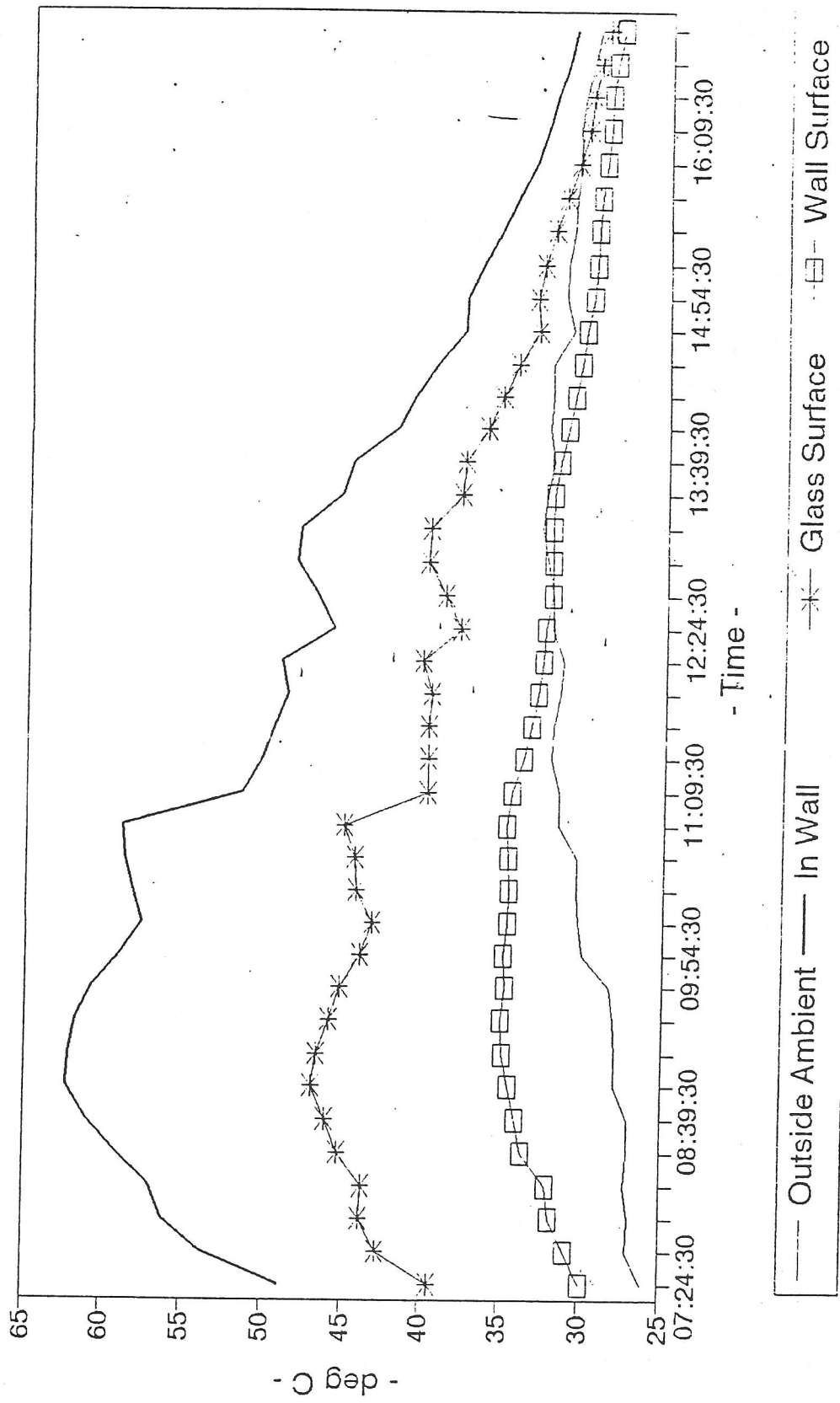


Fig.A10.6. Performance of wall facing due Northeast

Table A10.1. *Measurement of light intensity.*

Natural Daylight

Artificial
Light

Local Time (WIB)	Light Intensity (Lux)								
	A	B	C	D	E	F	G	H	I
08.00 - 08.30	230	80	360	320	80	400	175	100	60
09.00 - 09.30	320	120	460	380	130	420	210	110	60
10.00 - 10.30	390	150	550	450	190	450	290	125	60
11.00 - 11.30	400	155	590	560	240	570	425	150	60
12.00 - 12.30	370	140	600	680	290	700	590	200	60
13.00 - 13.30	330	122	580	610	275	830	830	300	60
14.00 - 14.30	285	109	545	530	245	925	1150	400	60
15.00 - 15.30	240	90	480	445	210	1100	1300	500	60
16.00 - 16.30	200	80	350	370	190	1150	1200	600	60
Average	307.2	116.2	501.7	482.8	205.6	727.2	685.6	276.1	60

Table A10.2. Lighting Standard for Offices.

CLASIFICATION	SYSTEM			
	SPECIAL (LUX)	W/M2	GENERAL (LUX)	W/M2
GENERAL OFFICES				
1. Corridor			30 - 50	1.5 - 2.5
2. Working Space			300	15
3. Private Working Space			300	15
4. Special Allignment Working Space	500-1000	25 - 50	300	15
5. Meeting Room			200	10
6. Laboratorium			300	15
7. Storage			200	10
8. Toilets			100	5
9. Kitchen			200	10

SOURCE : Laporan Diskusi Ilmiah Konservasi Energi
di Bidang Bangunan Komersial, 1982

Table A10.3. SAMPLE FOR DIFFERENT GLASS TYPES

Table 3

Glass Type	Glass thickness (mm)	Aesthetic Affect	Daylight		Summer Daytime R (m ² oC/W)	Shading Coefficient	U Values (W/m ²)	
			Transmittance (%)	Reflectance (%)				
Ordinary Clear Glass	8.0	Transparent	89	8	8	0.215	0.92	2.012
BLUE								
Solarban 570.30 clear	8.0	Sapphire Blue	30	15	28	0.226	0.46	1.969
Solarban 570.20 clear	8.0	Quartz Blue	21	23	33	0.230	0.36	1.953
GREEN								
Solex Tinted	8.0	Light Green	75	7	7	0.204	0.69	2.057
LHR(2) Solex	8.0	Maize Green	43	20	32	0.199	0.55	2.079
Solarban 570.30(2) solex	8.0	Blue Green	27	12	28	0.220	0.41	1.992
Solarban 570.20(2) solex	8.0	Blue Green	18	19	33	0.226	0.35	1.969
Solarban 560.20(2) solex	8.0	Dark Green	16	20	33	0.229	0.35	1.957
Solarban 560.14(2) solex	8.0	Dark Green	11	25	38	0.237	0.30	1.927
Solarban 560.8(2) solex	8.0	Dark Green	7	33	42	0.251	0.26	1.876

Ref: 1985 The Right Glass, 8.26/Pp, PPG Industries, Inc.

Table A10.5. Overall Thermal Transfer Value by Building Elements.

ORIENTATION	TOTAL WALL AREA (m ²)	INDIVIDUAL VALUE (W/M ²)				CTTV (W/M ²)
		REINFORCED CONCRETE BEAM	TCP & BOTTOM SPANDREL	GLASS	ALUMINIUM FRAME	
Southwest	168.48	1.147	5.427	42.408	1.274	50.255
Northeast	168.48	1.147	5.427	41.767	1.274	49.611
Southeast	138.84	1.179	3.057	43.599	1.254	49.089
Northwest	138.84	1.179	3.057	42.940	1.254	48.430

For The Same Category Given in Table 3

Table.4

Glass Type	Glass thickness (mm)	Hours (Solar Time)															
		10:00 a.m				12:00 Noon				02:00 p.m							
		NE	SE	NW	NE	SE	NW	NE	SE	NW	NE	SE	NW				
Ordinary Clear Glass	8.0	622.72	113.96	104.76	316.36	117.64	316.36	622.72	104.76	113.96	104.76	316.36	117.64	316.36	622.72	104.76	113.96
BLUE.																	
Solarban 570.30 clear	8.0	320.99	66.61	62.01	167.81	68.45	167.81	320.99	62.01	66.61	62.01	167.81	68.45	167.81	320.99	62.01	66.61
Solarban 570.20 clear	8.0	255.33	56.25	52.65	135.45	57.69	135.45	255.33	52.65	56.25	52.65	135.45	57.69	135.45	255.33	52.65	56.25
GREEN.																	
Solex Tinted	8.0	472.52	90.95	84.05	242.75	93.71	242.75	472.52	84.05	90.95	84.05	242.75	93.71	242.75	472.52	84.05	90.95
LIIR(2) Solex	8.0	381.04	76.89	71.39	197.89	79.99	197.89	381.04	71.39	76.89	71.39	197.89	79.99	197.89	381.04	71.39	76.89
Solarban 570.30(2) solex	8.0	288.47	61.74	57.64	151.94	63.38	151.94	288.47	57.64	61.74	57.64	151.94	63.38	151.94	288.47	57.64	61.74
Solarban 570.20(2) solex	8.0	248.94	55.39	51.89	132.39	56.79	132.39	248.94	51.89	55.39	51.89	132.39	56.79	132.39	248.94	51.89	55.39
Solarban 560.20(2) solex	8.0	248.82	55.27	51.77	132.27	56.67	132.27	248.82	51.77	55.27	51.77	132.27	56.67	132.27	248.82	51.77	55.27
Solarban 560.14(2) solex	8.0	215.77	49.87	46.87	115.87	51.07	115.87	215.77	46.87	49.87	46.87	115.87	51.07	115.87	215.77	46.87	49.87
Solarban 560.8(2) solex	8.0	189.06	45.28	42.68	102.48	46.32	102.48	189.06	42.68	45.28	42.68	102.48	46.32	102.48	189.06	42.68	45.28