NBS BUILDING SCIENCE SERIES 112

Window Blinds as a Potential Energy Saver—A Case Study

U.S. DEPARTMENT OF COMMERCE NATIONAL BUREAU OF STANDARDS

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1. INTRODUCTION

The window has been a source of particular concern to energy researchers because of its potential for large heat gains and losses. As a result, many designers have explored ways of minimizing the detrimental energy-related characteristics of windows, while preserving their thermal, lighting and psychological benefits. Among the techniques suggested for improving window performance are the use of: (1) smaller windows, (2) window coatings to absorb or reflect energy, and (3) shading devices, both internal and external.

In conjunction with a research project monitoring energy use at the National Bureau of Standards (NBS) in Gaithersburg, Maryland, a study of the use of internal shading devices was undertaken. Although many suggestions for energy conservation in buildings require the occupant to participate actively in the process, little information is available on the degree or kind of participation currently practiced, even on a matter as simple as the use of shading devices at the window.

This study was designed with four goals in mind:

1) To determine a) whether the office occupants of the general purpose laboratories of NBS manipulate their window blinds; and b) if so, how frequently this occurs.

2) To test a number of external variables, identified by previous researchers as being important attributes of windows, to determine their relationship to window usage as measured by venetian blind position.

3) To determine the feasibility of energy saving operations dependent on the manipulation of venetian blinds by building occupants.

4) To develop and refine a methodology applicable to a variety of field investigations of building use by occupants.

Venetian blinds are a particularly versatile shading device, allowing selective control over window characteristics by means of adjusting blind height and the angle of the slats. Information about actual use is desirable because a number of proposed approaches for reducing energy losses are directly related to the use of venetian blinds. For example, one proposal involves positioning the slats to project beams of sunlight deep into the room (Rosenfeld and Selkowitz, 1976). Furthermore, venetian blinds are currently used to reduce direct solar heat gain through a window.

A field investigation of window blind usage and its relationship to energy conservation appears to have no precedent in the literature. Consequently, a major part of the effort was the development and application of appropriate methodologies for such an investigation. An equally important consideration was the desire to collect objective and quantifiable data based upon the actual behavior of people rather than upon their response to questions about their behavior.

2. BACKGROUND

Although only a limited number of systematic studies of window usage by building occupants have been conducted, and still fewer investigations are associated with the use of venetian blinds, background data do exist describing the physical performance of both windows and shading devices. A number of studies have also been conducted to assess the advantages and disadvantages of windows, from a thermal as well as a psychological standpoint.

2.1 HEAT TRANSFER AND WINDOWS

One variable that has an important influence upon window performance is the position of the sun within a day. Although the thermal performance of a window with a venetian blind is not equivalent to that of a wall, the blind when used properly can reduce undesirable heat gains and losses. For example, using a venetian blind to cover a south-facing window on a hot sunny day can cut the heat gain by at least one-half (Dix and Lavan, 1974). Calculations given in Table I indicate the effectiveness of venetian blinds in reducing heat gain upon a typical north- and south-facing window at NBS. (Heat loads were calculated using the appropriate formulas given in the ASHRAE Handbook of Fundamentals (1972).)

The amount of heat gain into the room is partially dependent upon the angle of the slats (Caemmerer, 1967). Slats set at a 45° angle can reduce the gain to about one-half, while fully closed slats can reduce it to almost one-quarter (Dix and Lavan, 1974). (Compare calculations for half-open blinds with those for closed blinds in Table I.) The reduction in heat loss is not as great during the winter months, although fully closed venetian blinds can reduce the heat transmission of a single-glazed window by about 10-15% (Dix and Lavan, 1974). Of course, during sunny winter days windows with good solar exposure should be opened to take advantage of the heat gain.

2.2 VIEW, LIGHTING AND WINDOWS

In addition to controlling thermal flow through a window, venetian blinds provide the occupant with a variable means of altering visual access to the outside. Blinds can be closed completely, eliminating view, daylight, and sunshine. They can be slanted, eliminating glare, and controlling daylight but allowing some view. They can be opened up completely, allowing full access to sunshine, daylight and view. They can shade room occupants from sky glare and aim direct solar radiation toward the ceiling, yet allow diffuse radiation to enter the room (Nicol, 1966). Stephenson and Mitalas (1967) comment that: "The particular feature of a horizontal slat-type shade that makes it so useful is that it can be adjusted so that its brightness in the direction of the ceiling is several times greater than that to the occupants of the room." Furthermore, the occupant has complete control over blinds so responses may be readily made to changes in the external world.

2.3 PSYCHOLOGICAL BENEFITS OF WINDOWS

Several studies of the psychological reactions associated with windows have dealt with buildings where occupants must spend extended periods of time. These investigations, primarily of office buildings, schools and hospitals, indicate that the major benefits attributed to windows are: light, sunshine, contact with the outside world, and a sense of spaciousness (Markus, 1967; Collins, 1975). These conclusions are drawn from attitude surveys of people in buildings with and without windows and from investigations employing simulation techniques such as photographs and

Table 1

Calculated Heat Loads (Btu/h)[1] for a Sunny Day upon a Typical NBS Window[2]

	No Blinds Direct Sun		Blinds Half Closed[3]		Blinds Closed	
	North	South	North	South	North	South
Oct. 7[4]						
9 AM	63.61	4962.65	-88.11	2606.36	-274.57	950.19
12 noon	1033.55	8735.49	594.83	4962.40	320.63	2305.89
4 PM	402.16	3253.84	221.19	1789.61	100.54	831.46
Feb. 10[5]						
9 AM	-1274.13	3880.84	-1142.50	1692.73	-1317.99	-29.25
12 noon	-320.64	7612.89	-461.02	3902.42	-724.25	1259.13
4 PM	-1039.04	2032.00	-905.23	783.84	-1014.91	-247.15
Jul. 21[6]						
9 AM	1339.56	2070.76	761.91	1164.07	410.93	593.73
12 noon	1854.32	4450.08	1060.24	2487.91	702.68	351.62
4 PM	1682.49	1755.61	948.00	988.22	759.35	777.63

[1]Calculations are derived from formulas given in the ASHRAE Handbook of Fundamentals (1972) for windows facing due north and south for 40°N latitude.

[2]Window dimensions are 7'8" (2.3 m) high and 4'6" (1.4 m) wide.

[3]45° slat angle

[4]Internal temperature assumed to be 72°F (22°C)

[5]Internal temperature assumed to be 68°F (20°C)

[6]Internal temperature assumed to be 74°F (23°C)

models. Consequently, the findings only report declared preferences, not the actual use of windows or shading devices.

Although the view to the outside constitutes a highly prized benefit of windows, it is sometimes desirable to limit visual communication with the outside world. This often occurs if the window is near the ground so that the occupants are frequently observed by people passing by. Markus (1967) identified three elements which affect the perception of visual privacy: 1) the nature of the personal relationship between the observer and observed; 2) the frequency or predictability of the interruption to privacy; 3) the nature of the observed activity.

Objectionable as intrusions upon privacy can be, the desire for a view to the outside may outweigh such objections. One solution that allows a view and a degree of visual privacy is to lower a venetian blind and adjust the slats to a semi-open position. Hill and Markus (1968) note that: "In window design, outward vision and visual privacy are both related to the minimum acceptable amount of visual information transmitted through the window aperture." Yet, the use of fixed mesh or slat shading devices can reduce view to a meaningless pattern (Hill and Markus, 1968). Unlike stationary louvers, the slat angle of a venetian blind can be varied to alter the amount of view out and incoming light.

Brierly (1971) comments that " . . . an increase in window size may lead to a potential loss of visual privacy, which will necessitate the use of privacy barriers or curtains even at the expense of a good view." If window size is reduced too far, then there may be too much visual privacy which "may result in both the potential isolation of the user from life passing by and a potential loss in the desirability of the view, and thus of less satisfaction with the environment."

Markus (1967) indicates the need for research to understand more fully the tradeoffs available to architects in window design:

> If the high capital and running costs of windows with their attendant control devices is to be economically justified then evidence is urgently needed on the psychological implications of windows for building occupants. These implications may be conveniently studied under these headings: sunshine awareness or desire; view-out, privacy (view-in). These three are related by protective blinds and screens -- the need for which is often due to sunshine penetration. It would seem therefore that a study of the visual properties of such screens is a good starting point; although without more fundamental studies based on occupants' preferences, judgements, and behavior, the results of this study cannot lead to design recommendations.

Markus' statements frame the experimental setting for the study to be reported here. As Markus points out, there is a great need to determine occupant preferences and behaviors with respect to windows and shading devices. In the present study, only occupant behavior was monitored to determine the effects of several external variables upon the use of a specific type of shading device -- venetian blinds. The study was undertaken to determine if the positioning of the venetian blinds could be explained in terms of such factors as orientation, view, or seasonal variables. In this way, the behavioral response to the environment created by the window and modulated by the venetian blind could be analyzed experimentally.

3. NBS WINDOW BLIND STUDY

The general purpose laboratory (GPL) buildings at the National Bureau of Standards present an opportunity to explore the use of shading devices and windows. There are 7 buildings, of which 6 were used for this study, each about 100 m long, with 3 floors above ground in each building. The buildings are oriented so that half the windows face due north and half face due south. (The shorter east and west walls do not have windows.) (Figures 1 and 2)

The investigation was focused on the windows of the office modules located along the exterior walls of these buildings. A typical office module is 10'9" (3.3 m) wide, 11' (3.4 m) high and 16' (4.9 m) deep. Most modules contain one window 7'8" (2.3 m) high and 4'6" (1.4 m) wide. The window

FIGURE 1. EAST FACADE OF A TYPICAL GPL BUILDING AT NBS GAITHERSBURG.

FIGURE 2. WEST FACADE OF A TYPICAL GPL BUILDING AT NBS GAITHERSBURG.

area is therefore approximately 29% of the window wall area and 20% of the floor area of each office module. The offices are typically occupied by two people, although occupancy by one or three individuals occurs as well. Figures 3 and 4 illustrate typical NBS offices studied.

Figure 5 indicates the layout of the buildings on the site. Inspection of this figure makes it evident that the windows in the six buildings present a variety of views to occupants. In several instances the view is relatively extensive -- providing a wide expanse of grass and trees stretching into the distance. In other cases, the view is restricted to that of another facade with only a grassy area or a driveway between the two buildings. These differences provide an opportunity to assess the varying contributions of facade orientation and view to venetian blind use. Many people have access to both open and restricted views, however, depending upon their location with respect to the window. Thus, the classification of windows by view type is only approximate. (Figures 6 and 7)

Before the formal investigation began, a casual inspection of the building facades indicated that the blinds on the windows were set in a wide variety of positions. (Figure 8 shows the many blind positions found on a typical facade at NBS.) These observations led to several questions? 1) Are the blind positions the result of a conscious decision on the part of office occupants to alter part of their visual environment -- i.e., the window? 2) Do the blind positions merely represent the effect of extraneous variables, such as changes by maintenance personnel? 3) Can something be learned about the relationship between window usage and energy conservation by examining window blind positions in a systematic fashion? 4) Can we identify and quantify design-related variables which influence the use of windows and blinds? Our next step was to design an experiment that would provide answers to these basic questions.

FIGURE 3. INTERIOR OF A SINGLE-OCCUPANT NBS OFFICE.

FIGURE 4. INTERIOR OF A DOUBLE-OCCUPANT NBS OFFICE.

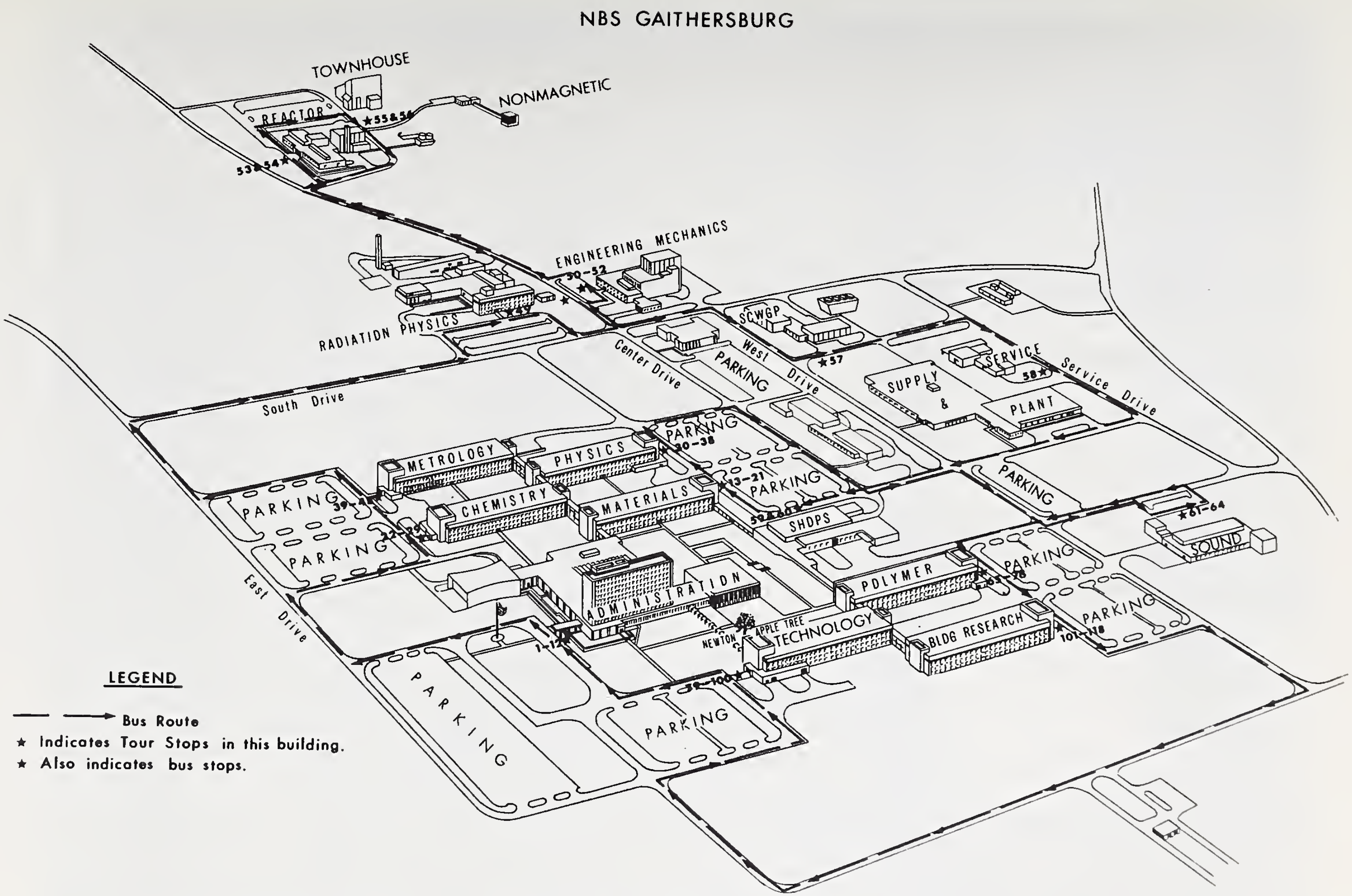


FIGURE 5. LAYOUT OF BUILDINGS AT NBS GAITHERSBURG.

FIGURE 6. OFFICE WITH ACCESS TO TWO VIEW TYPES. A. OPEN

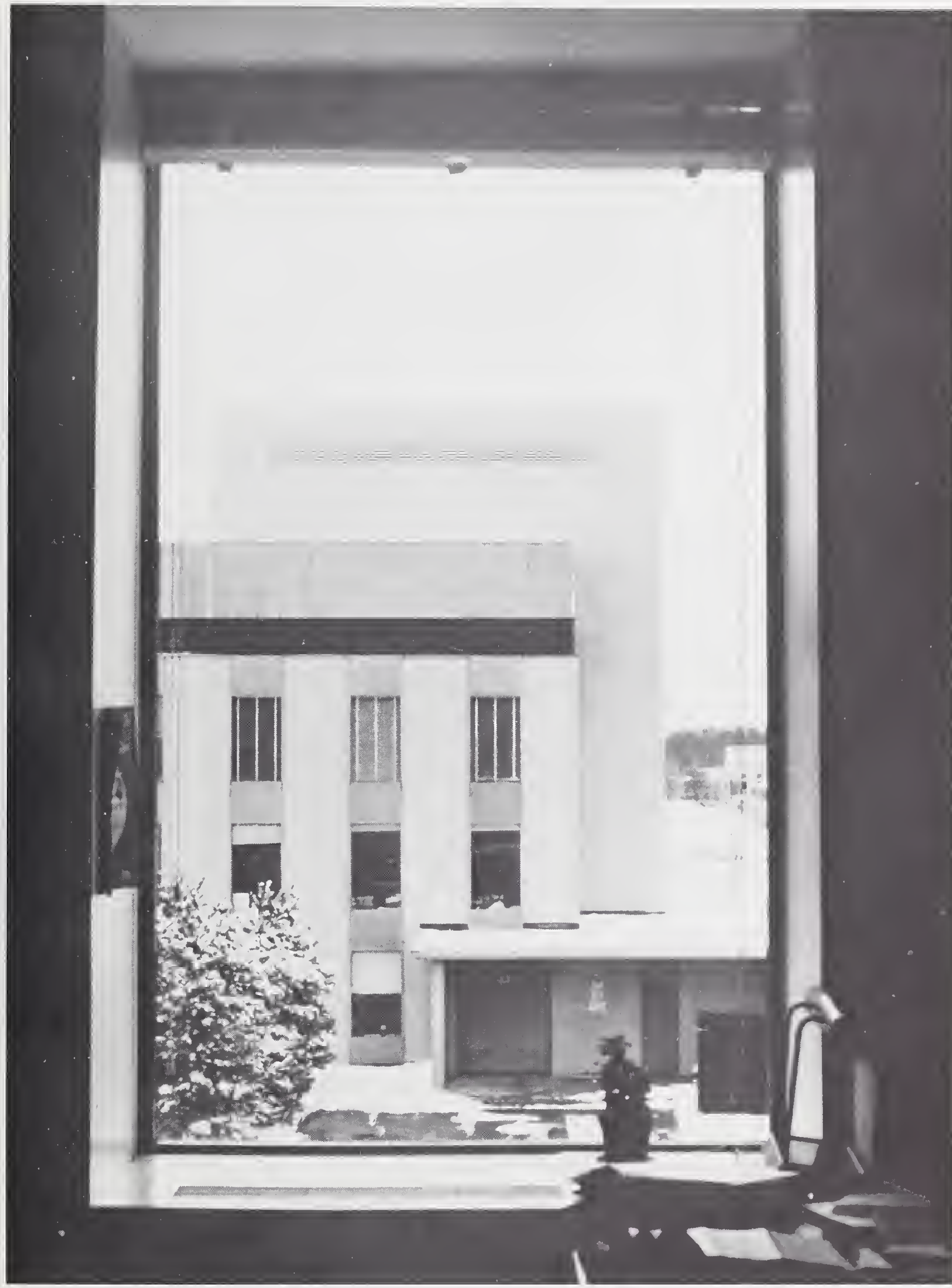


FIGURE 7. OFFICE WITH ACCESS TO TWO VIEW TYPES. B. RESTRICTED

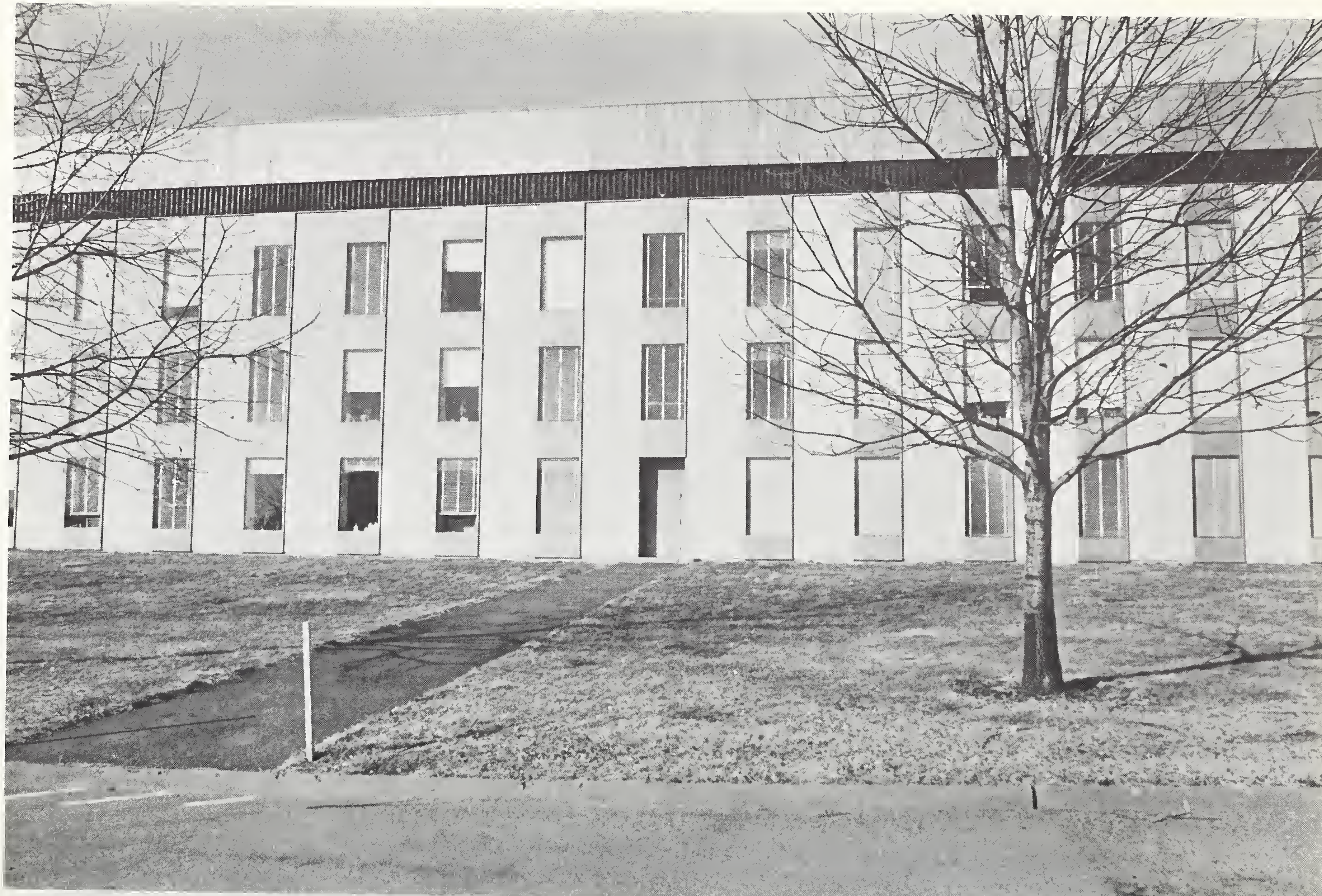


FIGURE 8. BLIND POSITIONS ON A TYPICAL NBS BUILDING FACADE.

4. EXPERIMENTAL DESIGN

4.1 RESEARCH APPROACH

Six general purpose laboratory (GPL) buildings of NBS were studied during the course of the investigation. As a means of maximizing the possibility that changes in blind positions could be attributed to office occupants, blinds were changed during the weekend by the researchers. Occupants would then come to work on Monday morning with the blinds in positions different from those on Friday. Two different "extreme" positions were employed as independent variables: (1) "up", raised to the top of the window (open), and (2) "down", lowered to the bottom of the window and closed (closed). The open and closed positions were used because they represent the extreme conditions of window usage, i.e., maximizing or minimizing their use. Since few blinds were open or closed before the study was initiated, these positions would be a sensitive indicator of changes made by occupants. In addition, the extreme blind positions served as a standard by which later changes could be compared.

Although each facade contains 90-99 windows (30-33 on each of three floors), the final sample size was reduced from 1100 to approximately 700 (Oct. - 746; Feb. - 774; July - 652). The seasonal variation in sample size was primarily a result of changes in foliage conditions. Windows in stairwells, restrooms, laboratories and other non-office space were excluded from the study. Furthermore, not even all of the office blinds could be positioned in accordance with the research plan. At times, books or plants blocked the window sill area. In other instances the blinds were immovable or malfunctioned. Table 2 presents a tabulation of the blinds changed by the researchers on the weekend, determined by analyzing photographs taken immediately after they were changed.

Among the major variables thought to affect window usage are compass orientation, view, and seasonal conditions. Fortunately, the layout of the laboratories permitted the study of compass orientation and view. The six buildings chosen for study have windows located only on the long north and south facades. As a result, the effects of two different orientations, north and south, could readily be studied for all six buildings. See Figure 1 for the physical layout.

The decision as to the type of view available to occupants from their windows was based upon the extent of openness in front of a facade. Two categories of view type were created: "open" and "restricted". Open views were considered to be those with an uninterrupted stretch of grass and trees with no nearby buildings. Restricted views were considered to be those in which only a small stretch of grass or asphalt (about 75-100 m) separated one building from another. The upper half of Figure 9 depicts an open view; the lower half shows a restricted view. The assignment to view-type group was only approximate because there are varying degrees of restriction upon the views from each facade depending, for example, on foliage on trees and placement of desks within modules.

Venetian blind usage was monitored by taking photographs of building facades before, during and after changes in blind positions. Each of the twelve facades was photographed at least four times during the week prior to the change in venetian blind position to provide baseline data on blind positioning.* The "before" photographs were taken in the morning and the afternoon (to account for sun position) on the Thursday and Friday preceding the weekend on which the change occurred. Then, over the weekend when the offices were unoccupied, the blinds in each facade were positioned and photographed to record the standard conditions. During the following week, all twelve facades were again photographed repeatedly (three times each day on three separate days) to determine the effect of the experimental treatment on changes in blind positions.

*See Section 4.3 for description of changes in procedure over time.

Table 2

Number of Venetian Blinds Experimentally Treated

1/0 Group			5/C Group		
Building Facade			Building Facade		
220S OPEN	Oct	65	221S Open	Oct	56
	Feb	61		Feb	61
	Jul	63		Jul	58
222S RESTRICTED	Oct	51	224S RESTRICTED	Oct	60
	Feb	49		Feb	68
	Jul	45		Jul	70
225N OPEN	Oct	67	224N RESTRICTED	Oct	36
	Feb	69		Feb	51
	Jul	69		Jul	52
221N RESTRICTED	Oct	64	223N OPEN	Oct	42
	Feb	66		Feb	57
	Jul	58		Jul	46

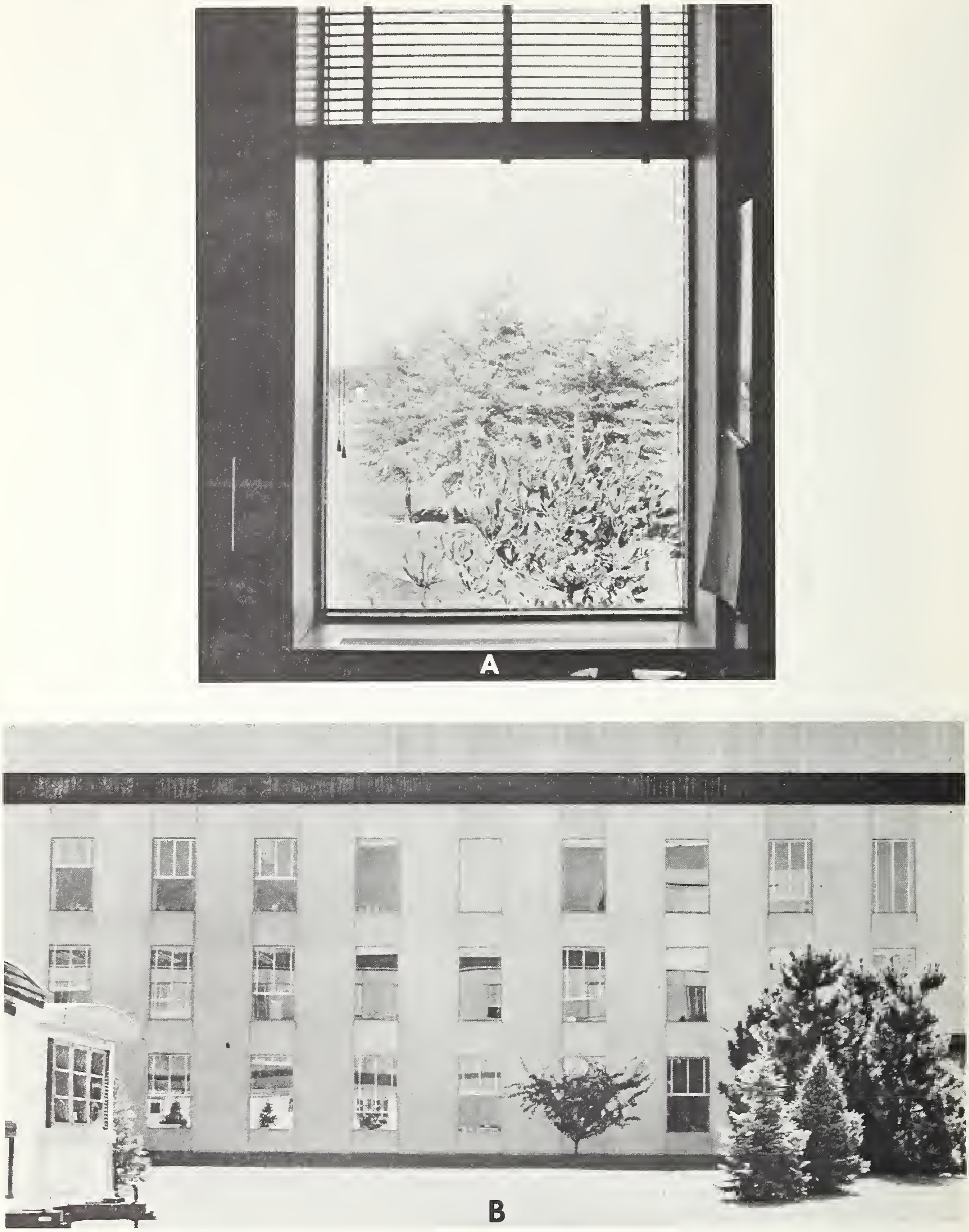


FIGURE 9. VIEW TYPES FROM OFFICES. A. OPEN B. RESTRICTED.

To determine the effects of seasonal change in weather and sun angle, the entire study was repeated twice after the initial October sequence. Thus, the procedure of photographing the twelve facades during the week before the experimental treatment, at the time of treatment, and during the week after treatment was observed for the following time periods: October 2-11, 1974; February 5-14, 1975; and July 17-28, 1975. The noon set of photographs was omitted during February because of the cold, cloudy conditions which made assessment of the effects of sun position a less important consideration. Rain on the final Friday of the study (July) caused the last 3 sets of photographs to be postponed to the next Monday. The table below presents selected weather conditions for seasonally typical days.

Table 3. Weather Conditions for a Typical Day

Month	Time	Temperature Range	Description
Oct.	9 AM	50 -60 F (10 to 15 C)	clear and sunny
	4 PM	60 -75 F (15 to 24 C)	clear and sunny
Feb.	9 AM	20 -35 F (-7 to 2 C)	cloudy and windy
	4 PM	30 -45 F (-1 to 7 C)	snow on ground
July	9 AM	70 -80 F (21 to 27 C)	hazy and humid
	4 PM	80 -90 F (27 to 32 C)	hazy and humid

Table 12 (Appendix D) contains detailed climatic conditions recorded during each phase of this study.

4.2 RESEARCH DESIGN

The experimental plan was a balanced factorial design, in which each of the twelve facades was assigned to one of three experimental treatment groups in which all possible combinations of orientation and view type were represented. Treatment group refers to the way in which the blinds were changed. Three conditions were chosen -- "up", "down" and "unchanged" or control. Table 4 depicts the assignment of facades to treatment groups. One of the three treatment groups was made a control group to determine whether the experimental positioning of blinds produced any systematic effects on later blind usage.

4.3 PROCEDURE

After the baseline photographs had been taken, the venetian blinds in eight of the experimental facades were changed to the appropriate treatment position. Blind positions were altered between 8 AM and 12 noon over the weekend when few of the professional staff were in the offices. Each of the altered facades was then photographed to provide a record of the blinds that had, in fact, been changed before the occupants came into their offices. This was necessary because blinds in the restrooms, stairways, labs, and restricted areas were not changed and were excluded from all data analyses.

Table 4

Assignment of Facades to Treatment Groups

EXPERIMENTAL GROUPS

I. "UP" - Treatment

Building*	Orientation	View Type
220	South	Open
222	South	Restricted
225	North	Open
221	North	Restricted

II. "DOWN" - Treatment

Building	Orientation	View Type
221	South	Open
224	South	Restricted
223	North	Open
224	North	Restricted

III. "CONTROL" - No Treatment

Building	Orientation	View Type
225	South	Open
223	South	Restricted
222	North	Open
220	North	Restricted

*Numbers refer to specific building designations. Six such buildings are used, each having two facades, one north and one south.

During the week following the experimental treatment, photographs were taken of all twelve facades on each of three days following the same procedure that had been established for the baseline photographs. Three sets of photographs were taken on each day, at 9 AM, noon, and 4 PM, to determine whether weather or sun conditions had any effect on behavior. This procedure was repeated one and four days later (Tuesday, Friday) to assess how often changes occurred and to account for offices which might be unoccupied on Monday.

Venetian blind positions were photographed with a 35 mm camera with a 28 mm wide-angle lens. Black and white film with an A.S.A. rating of 400 was used.

The record, taken at the same time as the photographs, consists of the following:

1) identification of the building being photographed

2) its orientation (N or S)

3) whether the Right (R), Middle (M) or Left (L) side of the building was being photographed.

4) date, time of photograph

5) roll number

6) approximate weather conditions

7) order in which photos were taken

Usually, three photographs were required to record an entire facade -- right, middle, and left. As a result of changing sun position, buildings were also photographed from different angles throughout the day. Approximately 36 photographs were taken each time blind positions were recorded.

After all the photographs had been taken in each season, each roll of black and white film was enlarged by a factor of two and printed on 11" x 14" (28 cm x 36 cm) contact sheets with six or seven facades on each sheet. This procedure made visual inspection easier, facilitated comparisons of facades, and minimized processing costs. At least two, and usually three, photographs of each facade were available. In order to facilitate analysis, the facade windows were numbered from right to left (as one faces the building or photo).

When the seasonal photographs had been developed, each window blind position was rated. A two-part alphanumeric code was used to rate blind positions. The first part (number) refers to the extent of the window covered by the venetian blind. Window coverage was rated by means of a five-category scheme (1-5) corresponding to 0%, 25%, 50%, 75% or 100% coverage. The second part of the score (letter designation) refers to the angle, or tilt, of the slats. Only two categories of angles, "open" (O) and "closed" (C) were employed. Initially, an attempt was made to identify a third category, "partially open". This category was rapidly abandoned because it was too difficult to make reliable identifications. The difficulty appeared to be due to the distance from the facade at which photographs were taken, combined with the limitations of resolution when they were greatly enlarged. See Table 5 below for details of the rating scheme.

Table 5. Detailed Rating Scheme

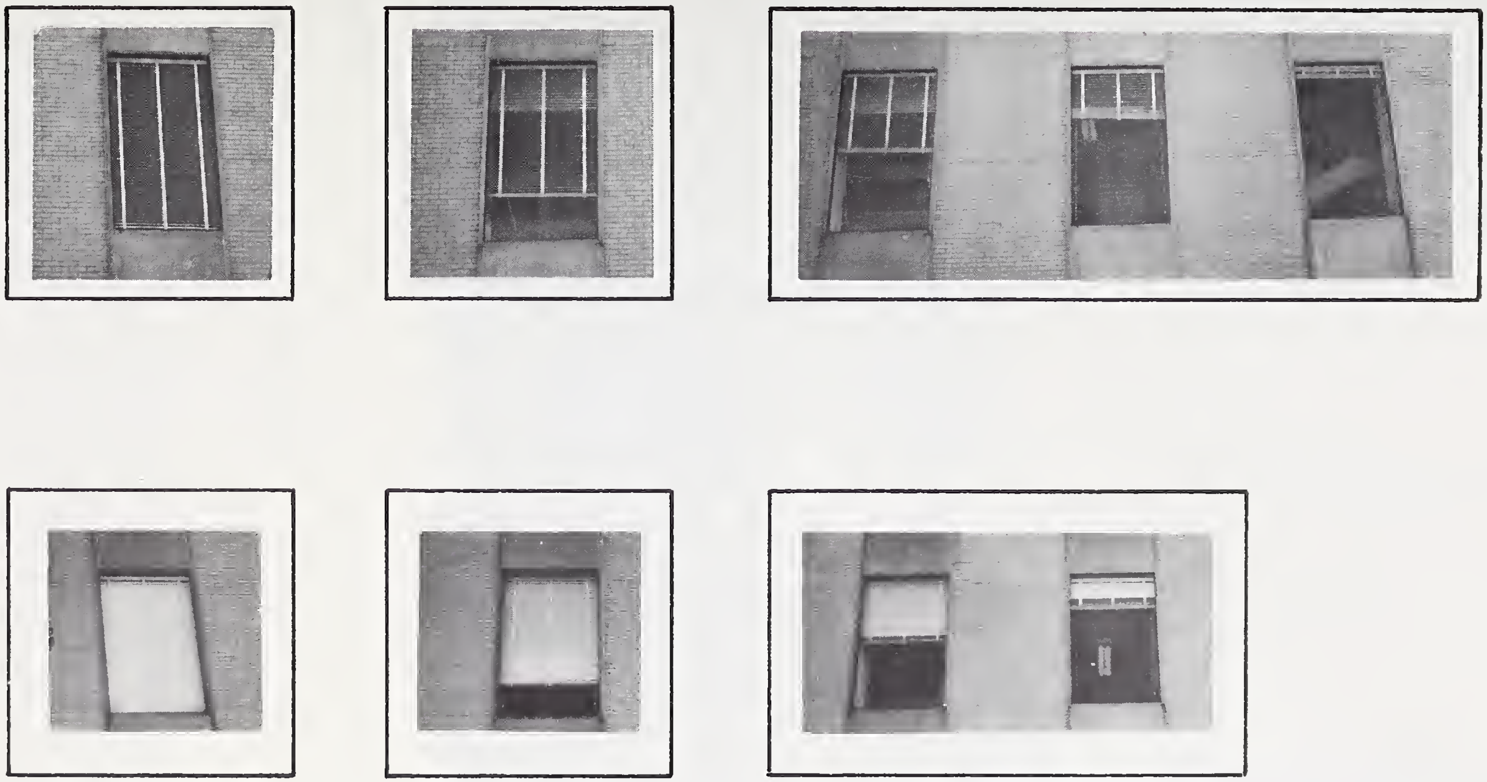
		Blind Position Ratings	
Percent Coverage	Number	Slat Angle "Open"	Slat Angle "Closed"
0%	1	1/0*	-
25%	2	2/0	2/C
50%	3	3/0	3/C
75%	4	4/0	4/C
100% ("down")	5	5/0	5/C*

The process of interpreting and scoring the photographic data thus involved assigning an alphanumeric rating for the two categories (coverage and slat angle) to each window. Figure 10 illustrates the categories employed. Ratings for all the data obtained during the week before treatment ["Before" data] were recorded separately from the data for the week after treatment ["After" data]. Thus, six separate sets of rating sheets, containing the before and after data for each of the three seasons, summarized the photographic data.

Two scorers with access to all photos independently rated all blind positions. After the ratings had been made for photographs in the "Before" and "After" sets, differences in the category ratings between the two scorers for a given week were reconciled by comparing all photographs of the window. Among the factors which contributed to difficulties in scoring blind positions were variations in: external lighting conditions, angle at which the photographs were taken, glare from the windows or the sun, shadows from other buildings (primarily from the eleven-story administration building), and early morning condensation upon the windows. Scoring errors and criteria differences were other contributing factors leading to discrepant scores between the two raters (which were resolved before a summary rating was made).

*Experimental treatment positions.

5/0 4/0 3/0 2/0 1/0



5/C 4/C 3/C 2/C

FIGURE 10. CATEGORIES USED IN RATING BLIND POSITIONS.

5. RESULTS

5.1 BLIND CHANGES MADE BY OCCUPANTS

5.1.1 Daily Change

Contrary to expectation, blind positions were not changed frequently during the course of a day, or from day to day. Of the approximately 700 blinds studied in each season, the photographic records showed that no more than 50 were changed at all during the week before experimental treatment or more than once during the following week. These 50 or fewer windows where blinds were frequently changed were excluded from subsequent analyses. It was therefore possible to use one summary rating to represent each blind position for the week preceding the experimental change. Similarly, a summary rating was given for each blind for the week after the experimental treatment. A summary rating was not included for windows that could not be rated more than one time (e.g., due to the presence of foliage obscuring the window).

5.1.2 Distribution of Blind Positions -- Before Treatment

What is the overall distribution of blind positions?

The overall distribution of blind positions can be assessed best by examining the data obtained before treatment first. Subsequent comparisons are made with the data obtained after treatment to observe the effects of the treatment itself.

Figure 11 indicates the total number of blinds for each of the 9 positions before experimental treatment. A brief inspection reveals that substantially more blinds were open than closed. A bimodal distribution is also apparent - with the greatest number of blinds being down and open (5/O position) or up (1/O). Few blinds were located at the bottom of the window with the slats closed (5/C position).

5.1.3 Effect of Experimental Factors

Did any of the external variables studied influence the placement of venetian blinds at NBS, and, if so, how? A Chi-square analysis of the distribution of positions before treatment was performed to test for any significant effect of the four experimental factors. This analysis demonstrated that orientation, view type, season, and assignment to experimental treatment group all significantly affected the distribution of blind positions. (X^2 figures for the Before data are presented in Table 9, Appendix A.)

5.1.3.1 Effect of window orientation: Figure 12 presents the effects of window orientation. The upper portion of the figure depicts those blinds facing north; the lower presents data for the south sides. Data are summed over the three seasons. The analysis of response by orientation unexpectedly revealed a highly significant effect of orientation (Table 9, Appendix A). Many more blinds were completely open (1/O position) on the north side than on the south side. Conversely, the number of blinds completely lowered with the slats open (5/O position) was greater on the south side than on the north side. These results are by far the most statistically significant ones obtained during the course of the study -- indicating the importance of building orientation to window blind usage.

5.1.3.2 Effect of view type and season: The other two experimental variables (view and season) were not as important in determining window blind usage as orientation or experimental treatment, although the effects of each were statistically significant (Table 9, Appendix A). Figure 13 presents a summary of blind positions for the two view types, open and

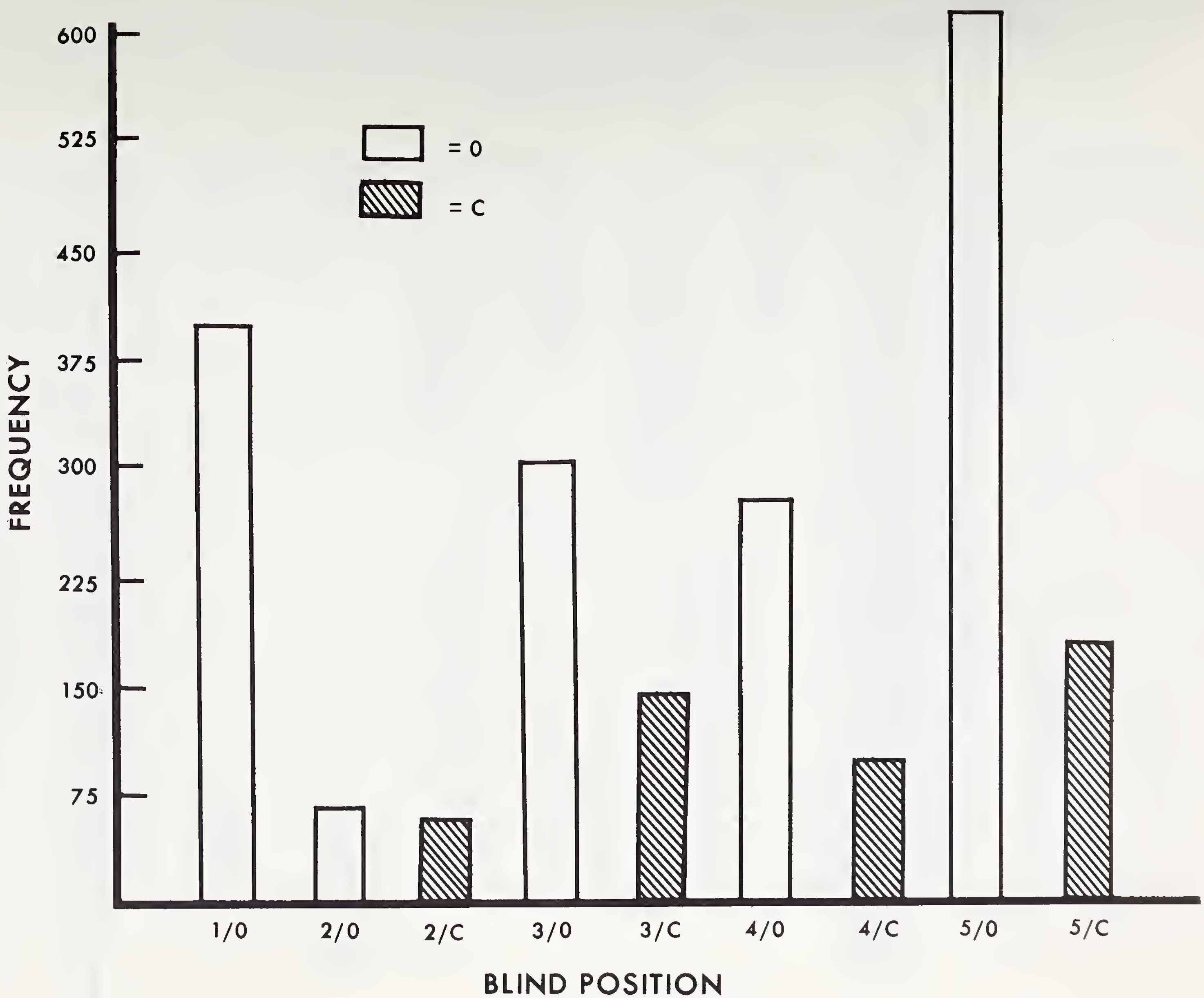


FIGURE 11. DISTRIBUTION OF BLIND POSITIONS BEFORE TREATMENT.

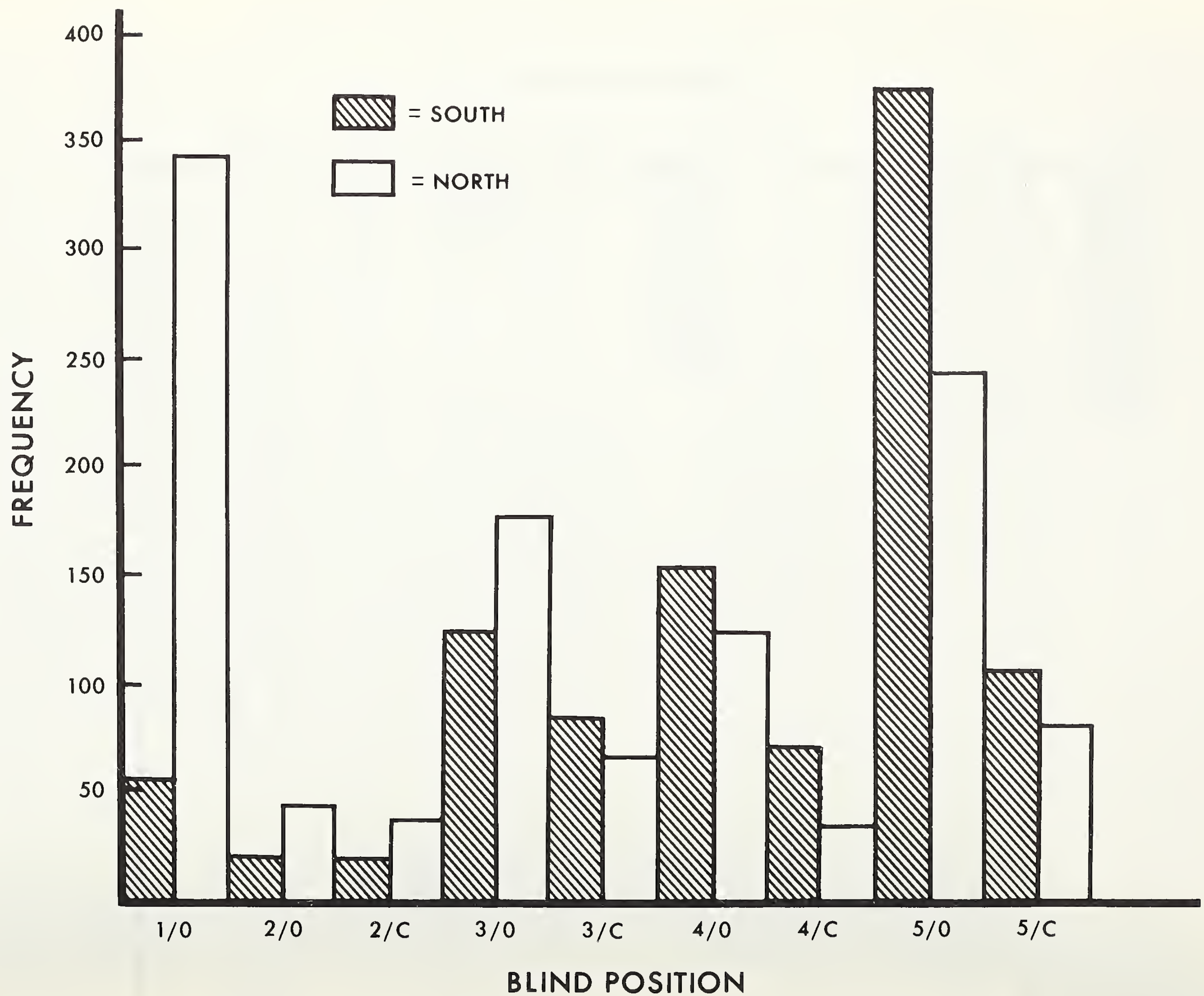


FIGURE 12. DISTRIBUTION OF BLIND POSITIONS BY ORIENTATION BEFORE TREATMENT.

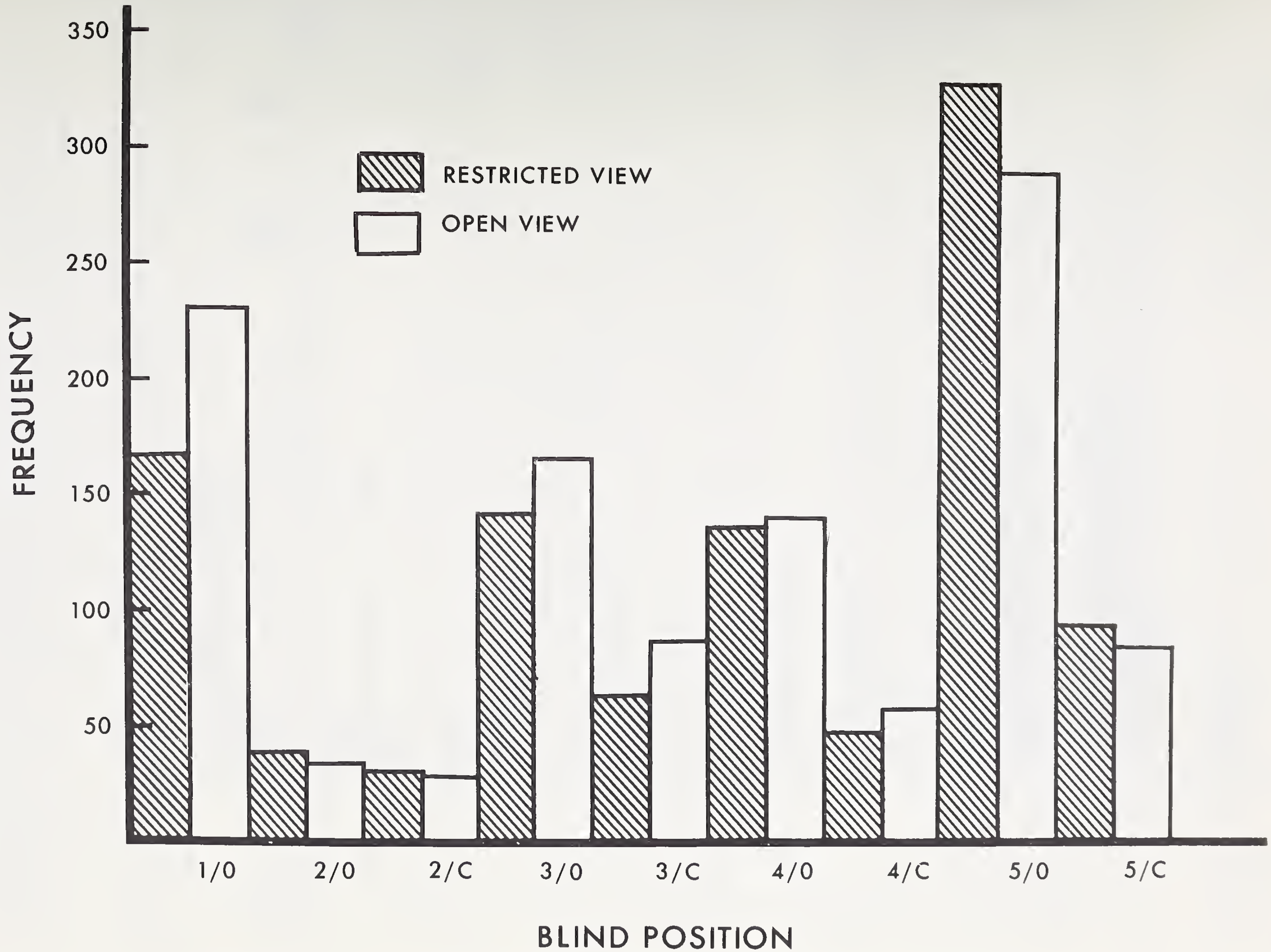


FIGURE 13. DISTRIBUTION OF BLIND POSITIONS BY VIEW BEFORE TREATMENT.

restricted. This shows more blinds at the top of the window (1/0 position) for open views than for restricted ones. For restricted views, more blinds were completely lowered (5/0 and 5/C positions).

Figure 14 presents a distribution of blind positions in each of the three seasons. The most noticeable difference among the seasons is an increase in the number of blinds at the bottom of the window with the slats open (in the 5/0 position) in February as compared with October and July. The distribution of responses is relatively stable for all other blind positions across seasons. The increase in blinds in the 5/0 position during February is accompanied by an overall increase in the number of blinds observed, because foliage no longer obscured many windows. Nevertheless, the February data appear to represent a genuine seasonal response, rather than a typical pattern among windows previously obscured by trees because only about 25% of the increase in blinds in the 5/0 position is due to windows covered by foliage in either October or July. In addition, because most of the February increase in the 5/0 position occurs for south-facing facades rather than for north-facing facades, it may be due to the lower position of the sun.

5.1.3.3 Effect of experimental treatment group assignment: The final analysis of the data before experimental treatment was concerned with the assignment of building facades to treatment groups, "Control", "Up", and "Down". This analysis demonstrated that a significant effect occurred before treatment. Blind usage was different for the facades assigned to different treatment conditions. Figure 15 presents the distribution of blind positions for each of the three treatment groups. An inspection of this figure reveals that many blinds which were to be placed in the "Up position (1/0) were there before changes were made. The "Control" and the "Down" groups were more closely matched in terms of blind usage.

The significant effect of treatment group assignment on blind positions indicates that windows were inadvertently assigned to treatment groups in a less than random fashion (see Table 9, Appendix A).

5.2 RESPONSE TO EXPERIMENTAL TREATMENT

Two aspects of the response to experimental treatment are considered: speed of response to treatment, and blind position after treatment. Data on this latter category will be examined in Section 5.3.

The response to experimental treatment was quite rapid. By 9 AM of the first day (Monday) after treatment, more than half of the blinds had been changed from the treatment position (56% in October, 61% in February, and 63% in July).

By 4 PM of the first day, a vast majority of the blinds had already been altered (80% in Oct., 82% in Feb., and 86% in July). Table 6 provides a breakdown of the blinds moved and the times that the changes were photographed. (Figure 16 illustrates the changes made over time.) The main body

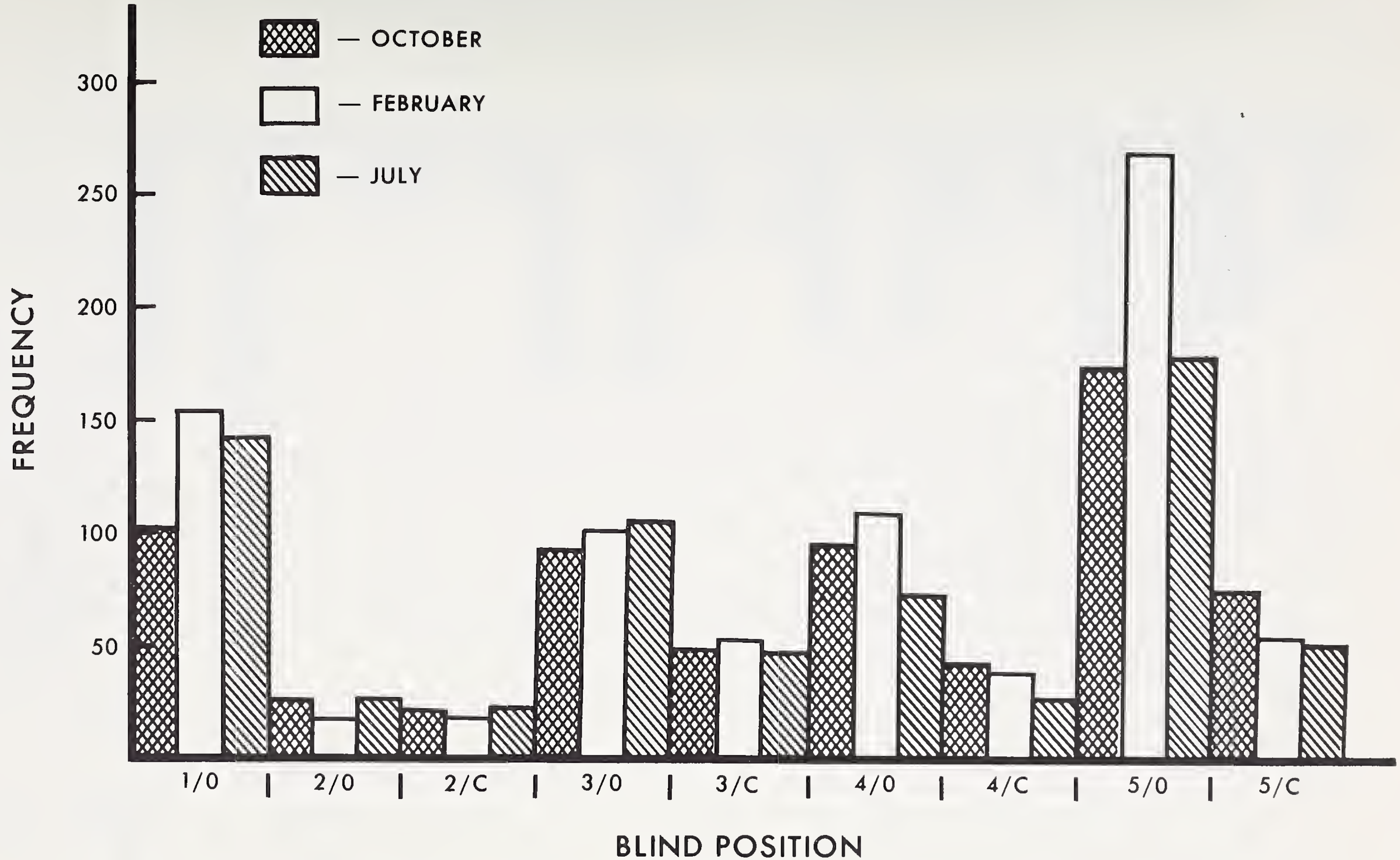


FIGURE 14. DISTRIBUTION OF BLIND POSITIONS BY SEASON BEFORE TREATMENT.

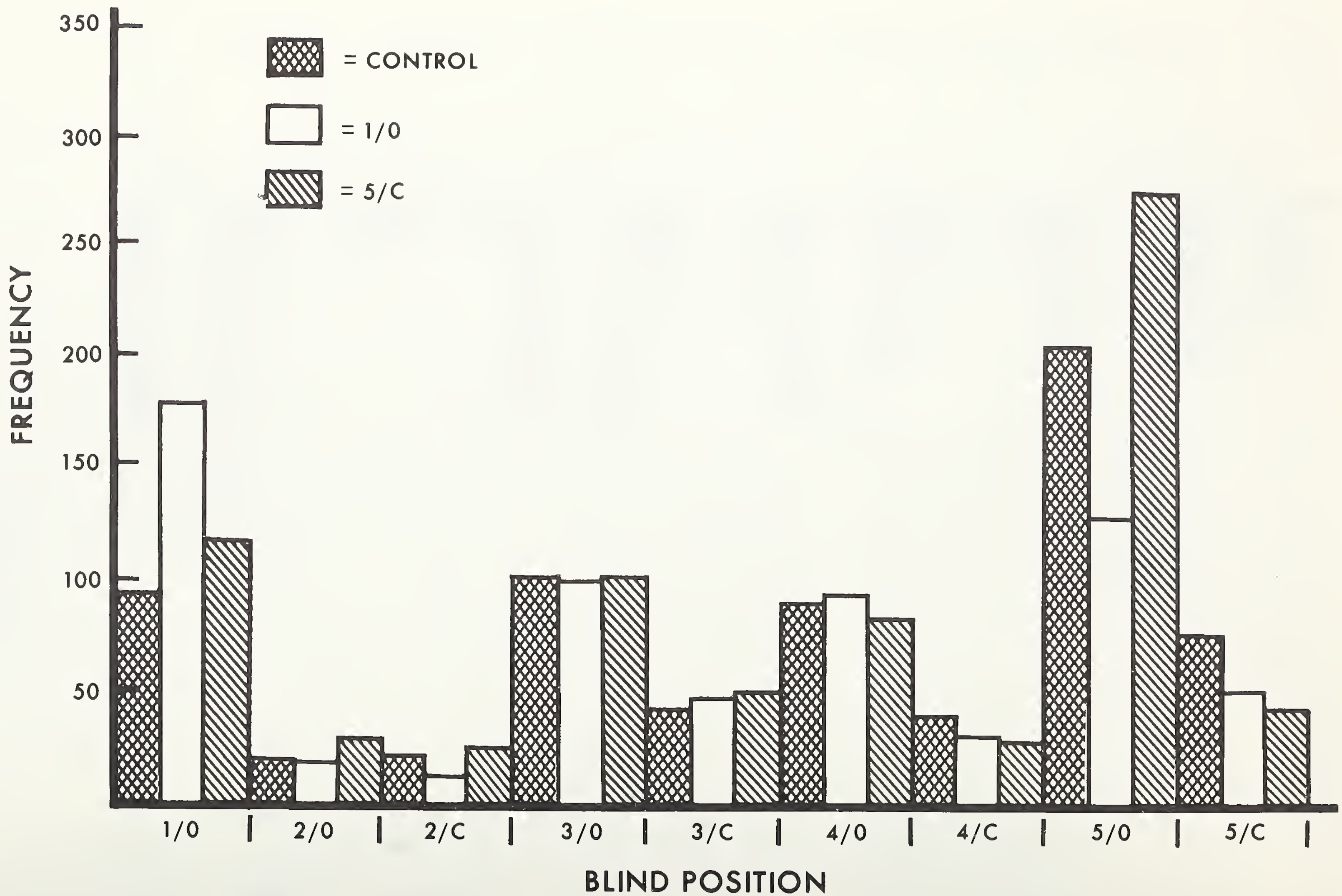


FIGURE 15. DISTRIBUTION OF BLIND POSITIONS BY TREATMENT GROUP BEFORE TREATMENT.

Table 6

After Treatment Blind Changes and Times Changes were Detected

		MONDAY			TUESDAY			FRIDAY				
		9 AM	Noon	4 PM	9 AM	Noon	4 PM	9 AM	Noon	4 PM	ΣN	"C"
1/0 Group												
220 S Open	Oct	16	6	5	0	2	4	4	1	2	40	8
	Feb	10		23	1		1	5		2	42	9
	July	12	2	4	1	3	1	2	0	0	25	8
222 S Restricted	Oct	12	6	2	8	2	0	5	0	0	35	5
	Feb	22		10	2		1	3		0	38	0
	July	12	3	3	0	0	2	1	1	0	22	4
225 N Open	Oct	10	5	0	2	0	2	1	0	0	20	2
	Feb	10		5	1		1	5		0	22	0
	July	5	0	2	1	1	0	1	0	0	10	3
221 N Restricted	Oct	11	5	2	0	0	0	2	0	0	20	0
	Feb	16		5	4		0	0		1	26	2
	July	6	2	3	0	0	1	2	2	0	16	2
1/0 Group												
SN	Oct	49	22	9	10	4	6	12	2		115	12
	Feb	58		43	8		3	13		3	128	11
	July	35	7	12	4	4	4	6	3	0	73	17
5/C Group												
221 S Open	Oct	25	8	0	0	1	1	0	2	0	37	7
	Feb	32		6	3		1	3		0	45	9
	July	27	8	1	1	1	0	0	1	0	39	8
224 S Restricted	Oct	36	13	1	1	0	4	1	0	1	57	4
	Feb	33		5	3		2	2		0	45	3
	July	41	7	0	2	1	0	1	0	0	52	11
224 N Restricted	Oct	22	4	3	1	1	1	3	0	0	35	0
	Feb	32		3	1		0	4		0	40	3
	July	19	3	0	1	0	0	1	0	0	24	8
223 N Open	Oct	23	6	1	0	1	0	2	0	0	33	1
	Feb	31		7	4		2	1		1	46	1
	July	24	7	6	0	0	0	4	1	0	42	6
5.C Group												
ΣN	Oct	106	31	5	2	3	6	6	2	1	162	15
	Feb	128		21	11		5	10		1	176	16
	July	111	25	7	4	2	0	6	2	0	157	33
TOTAL N	Oct	155	53	14	12	7	12	18	3	3	277	27
	Feb	186	0	64	19	0	8	23	0	4	304	27
	July	146	32	19	6	6	4	12	5	0	230	50

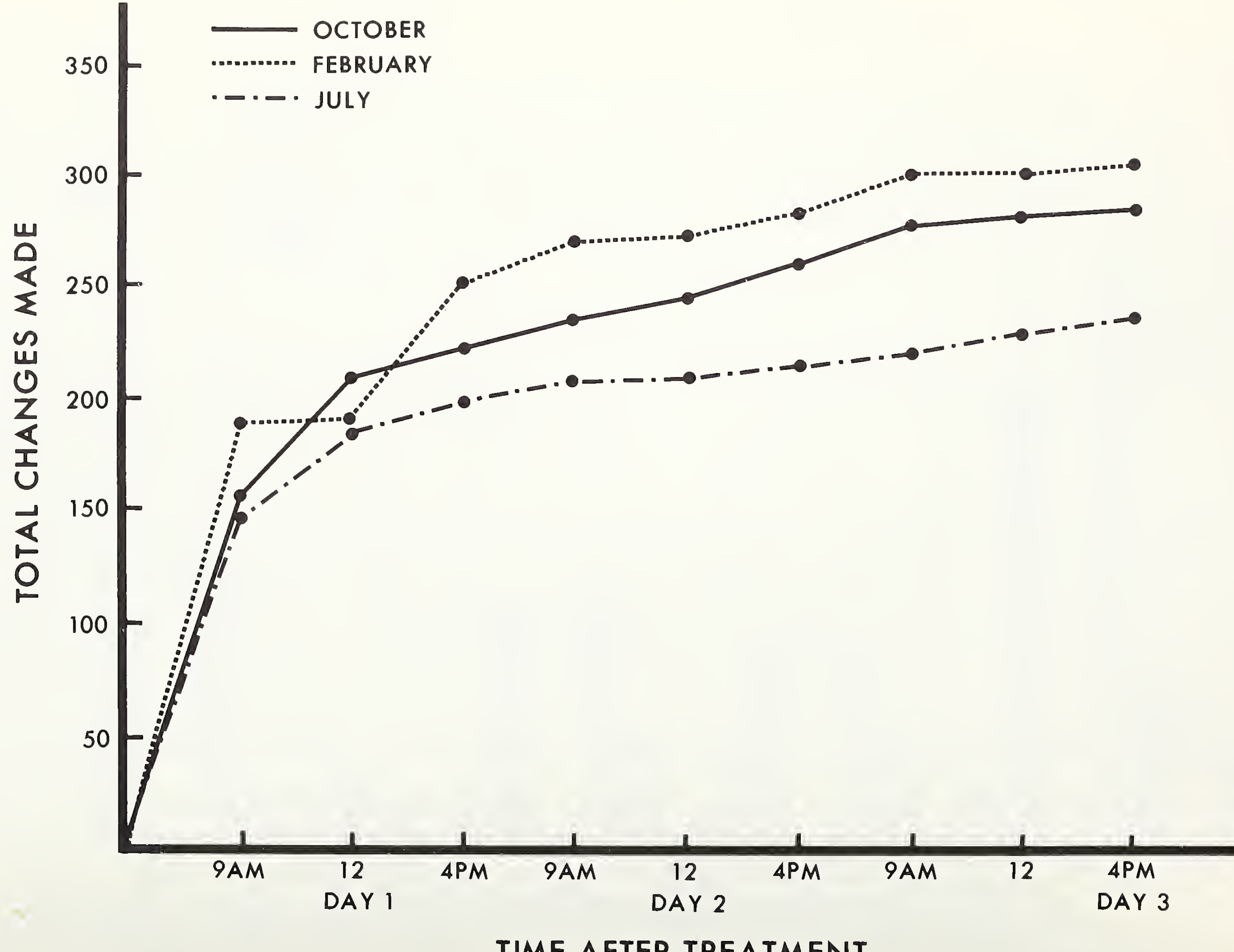


FIGURE 16. BLIND CHANGES AS A FUNCTION OF TIME AFTER TREATMENT.

of Table 6 describes the blinds that were moved only once after experimental treatment. The number of blinds moved more than once appears separately in the column labeled "c". Table 7 summarizes these findings, as well as those blinds not moved.

Of special interest is the fact that little change occurred from before to after treatment among the blinds assigned to the control group. This lack of change provides evidence that nothing occurred over the weekend which would encourage people to change blind positions -- other than the experimental treatment. See Table 7.

After the experimental treatment, most blind positions were changed only once during the week that observations were made (Table 7). Since the blinds which changed position more than once could not be readily assigned a rating, and since they were a small minority of the total sample, it was decided to eliminate them from the analysis. However, first we wanted to determine whether this approach would significantly bias our findings. See Figures 17 and 18. A Chi-square test was therefore performed between the total number of blind changes with and without blinds which were changed more than once. Table 8 indicates the results of this test. Since the differences were not statistically significant (or important for this study), later analyses were restricted to blinds changed only one time.

5.3 COMPARISONS OF BLIND POSITIONS -- BEFORE AND AFTER CHANGES

The first question to be answered is whether or not the experimental treatment altered the overall distribution of blind positions. In other words, did the treatment change the position of the blinds, and if so, how?

Figure 19 suggests that a typical response was to return the blinds to the before treatment position. In this graph, the percentage of blinds at each position before experimental treatment is correlated with the percentage of blinds at each position after treatment. The percentages are derived from data summed over all three seasons. Vertical deviation from the center diagonal indicates the degree of change in the percentage of blinds at a given position from before to after treatment. Inspection of Figure 19 reveals that most of the data points fall closely along the diagonal -- an indication that the experimental treatment did not, for the most part, change the distribution of blind positions. The major exception to this finding is the increased number of blinds completely opened (1/O position) after treatment. There was no comparable increase in the number of blinds in the down and closed position (5/C) which suggests that the experimental treatment "Down" influenced subsequent blind positioning much less than the fully open "Up" treatment. In other words, experimental treatment "Down" was not adopted by the people who were exposed to it as much as the "Up" treatment.

5.4 DIRECTION OF CHANGE AFTER EXPERIMENTAL TREATMENT

This analysis was directed toward determining the effect of the experimental treatment upon the subsequent distribution of blind positions.

Table 7

Summary of After Treatment Blind Response

	October	February	July
Total N	746	774	652
Control N	247	265	193
No Change	237	246	164
Control Changers (once or more)	10	19	29
Experimental N	499	509	459
No Change	195	178	179
Change Once	277	304	230
Experimental Changers (more than once)	27	27	50

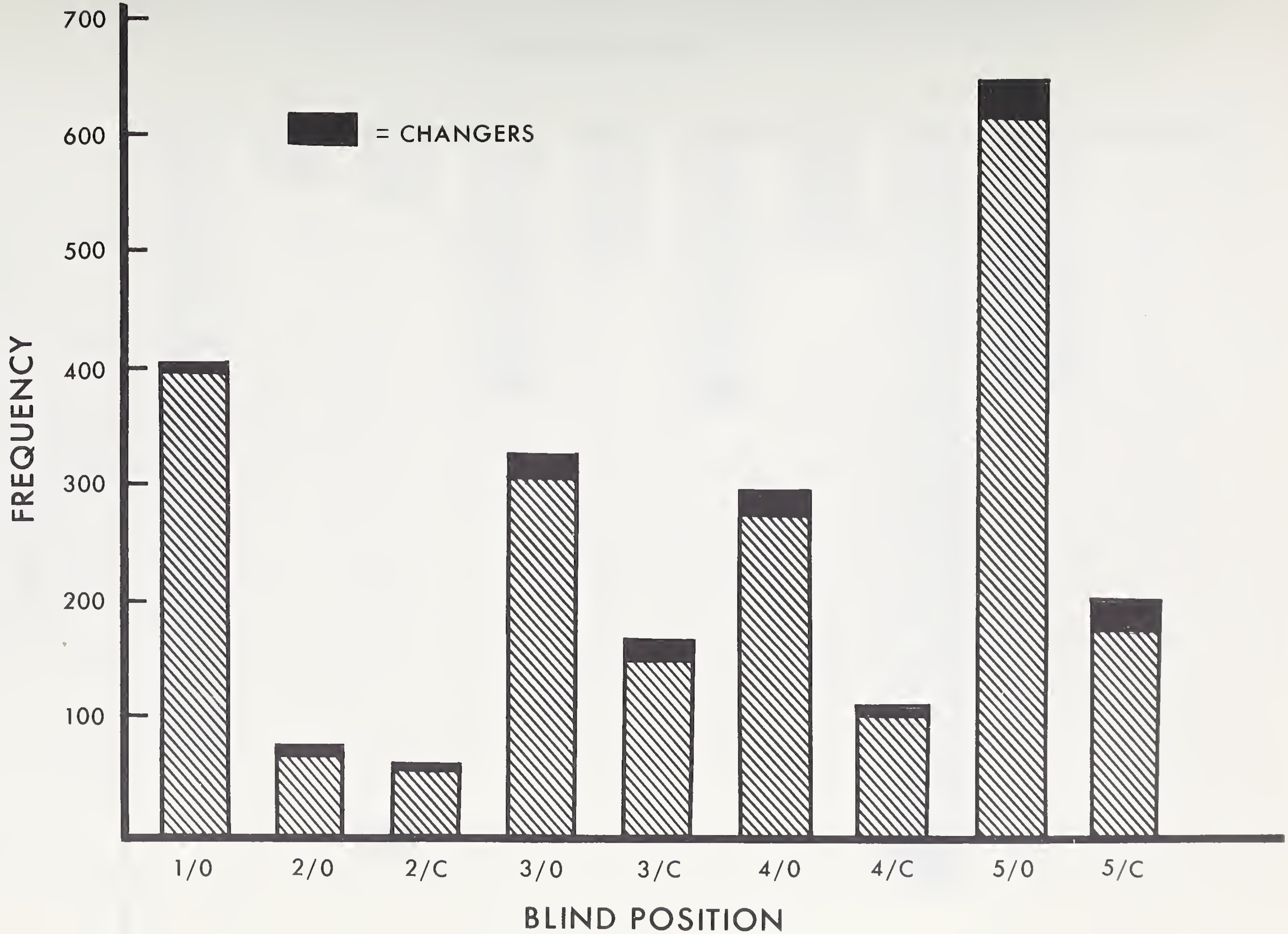


FIGURE 17. DISTRIBUTION OF BEFORE TREATMENT BLIND POSITIONS WITH CHANGERS ADDED.

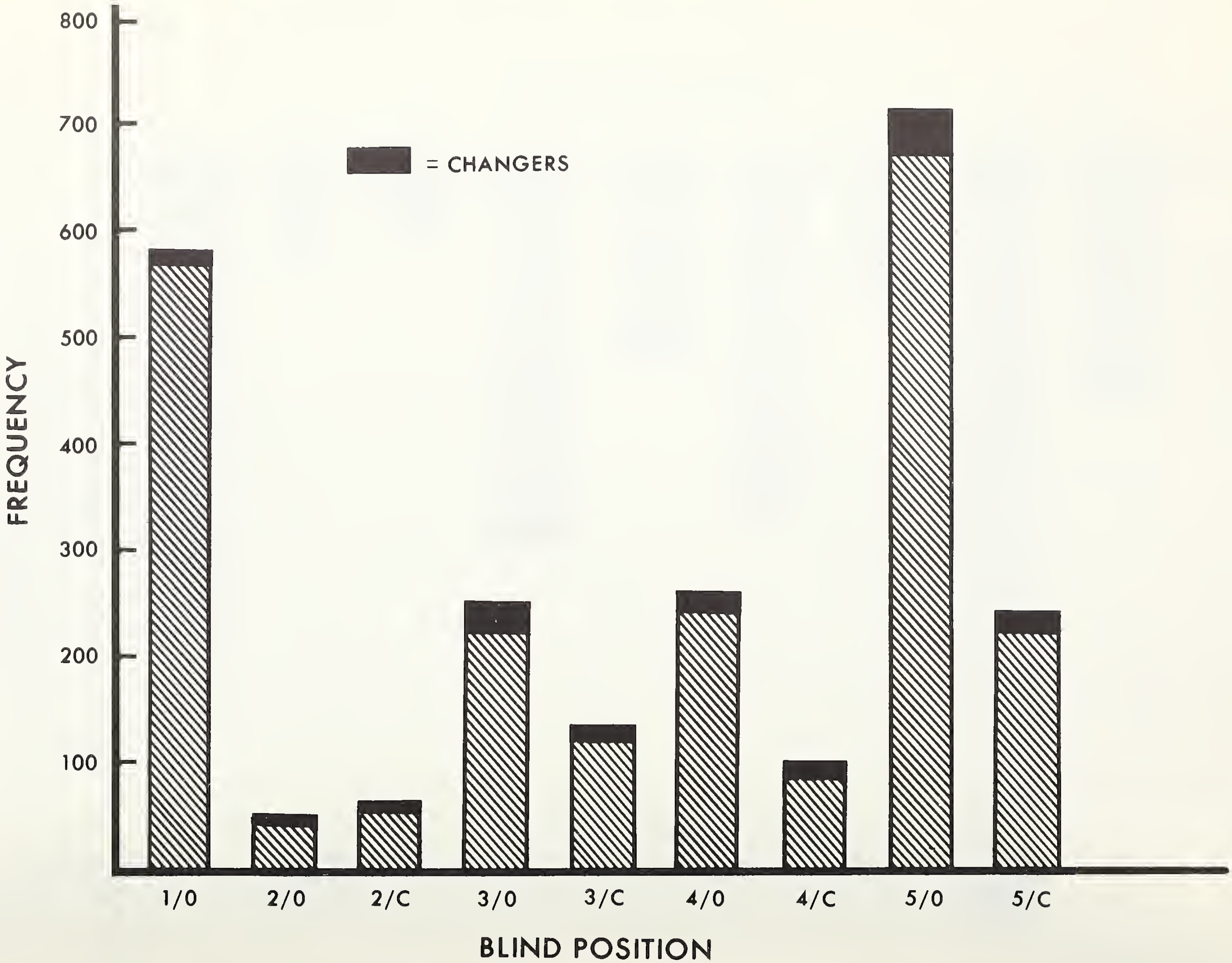


FIGURE 18. DISTRIBUTION OF AFTER TREATMENT BLIND POSITIONS WITH CHANGERS ADDED.

Table 8 - x^2 Analysis of Before Treatment Distribution With Changers Versus Without Changers

	Blind Position								
	1/0	2/0	2/C	3/0	3/C	4/0	4/C	5/0	5/C
With Changers (fo)	403	73	61	322	164	293	107	644	198
Without Changers (fe)	417.8	71.6	62.1	322.1	155.8	290.5	108.4	650.5	186.3

$x^2 = 1.7$, df = 8. No significant difference between the two distributions.

[1]Last position before treatment used in rating changer blind positions.

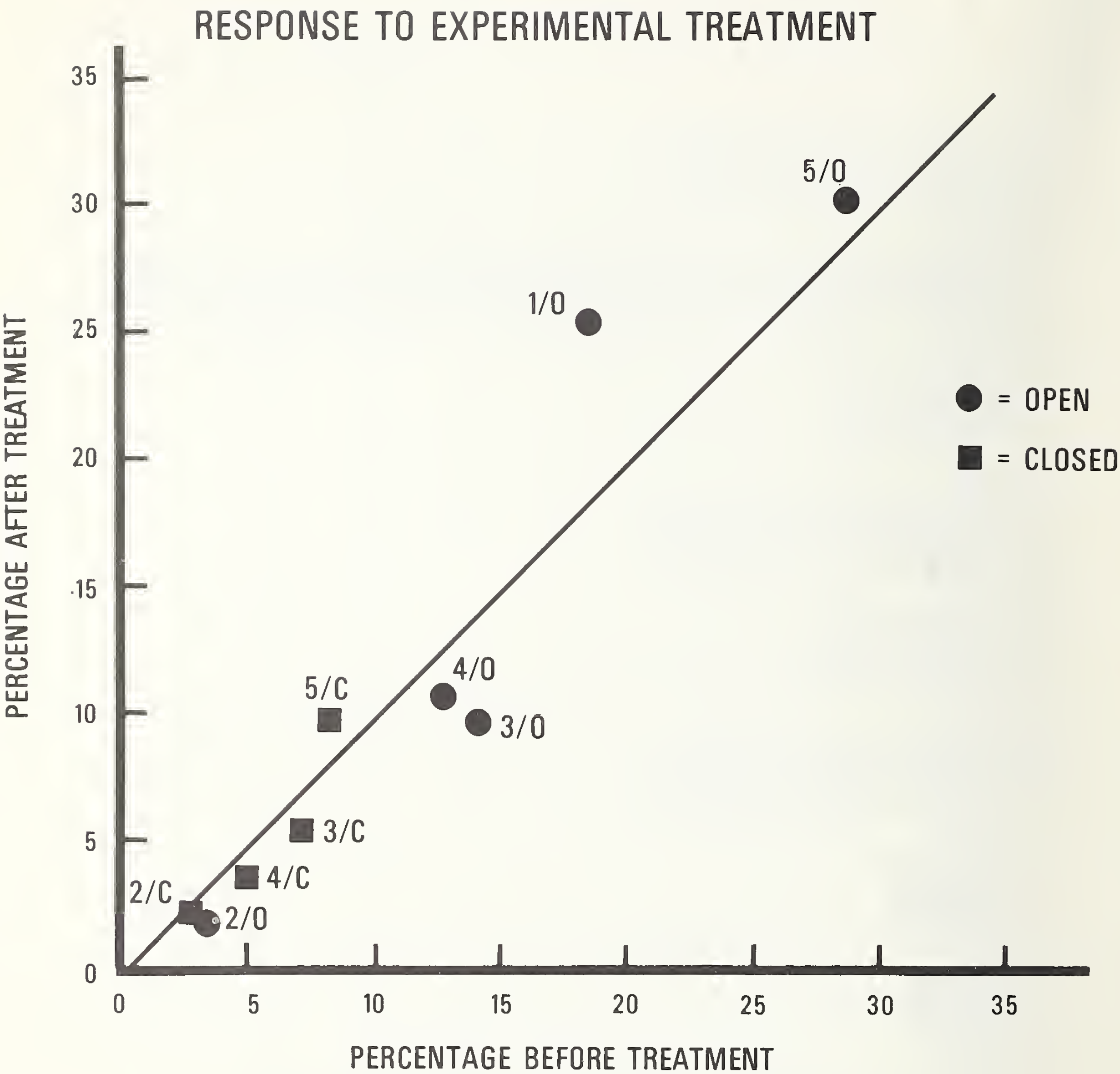


FIGURE 19. AFTER TREATMENT BLIND POSITIONS AS A FUNCTION OF BEFORE TREATMENT POSITIONS.

Although the previous analysis (Section 5.3) demonstrated little change after treatment, nevertheless the data in the 1/0, 3/0 and 5/0 position categories were somewhat altered.

The change in blind position after treatment was examined using two different approaches. The first was to note the variations in blind position for each of the twelve facades. (Summary data appear in Figures 20 and 21.) The bulk of the change occurred in the 1/0 and 5/C positions.

The second approach was to characterize the data by comparing statistical distributions of blind positions, before and after the experimental treatment was made. The data were summarized over facades and seasons in order to deal with general trends resulting from the experimental treatment. In this approach, individual blind positions after treatment were assigned to one of five categories as a function of position before treatment:

(1) Return - The blinds were returned after experimental treatment to the before treatment position.

(2) Higher - The blind was moved up the window after treatment with no slat angle change.

(3) Lower - The blind was moved down the window after experimental treatment with no slat angle change.

(4) Open to Closed - (O → C). The slat angle was changed from O (open) before treatment to C (closed) after treatment.

(5) Closed to Open - (C → O). The slat angle was changed from closed (C) to open (O) after experimental treatment.

A detailed breakdown of the number of blinds in each category is given in Appendix C.

The data summarized over the three seasons appear in Figure 20. The total number of blinds is plotted as a function of occurrence in each of the five categories. Each of the three experimental treatment groups, "Up," "Down," and "Control," is represented in the five categories.

Figure 22 demonstrates that the greatest number of blinds is concentrated in the "Return" category, indicating that the majority of blinds were returned to their original position after treatment. Fifty-five percent of the blinds in the "Up" group and 60% of the "Down" group, were returned to their previous position. Eighty-eight percent of the blinds in the control group were in the same position after blind positions were changed for the experimental groups. The next category, "higher," represents those blinds that were moved up the window after treatment. The largest number of blinds in this category were those that were moved "Up" -- about 30% of this treatment group. (Of this number, 84% were not changed from the experimental treatment position.) In the third category, "lower," the greatest number of blinds were those that were moved "Down" -- 16% of

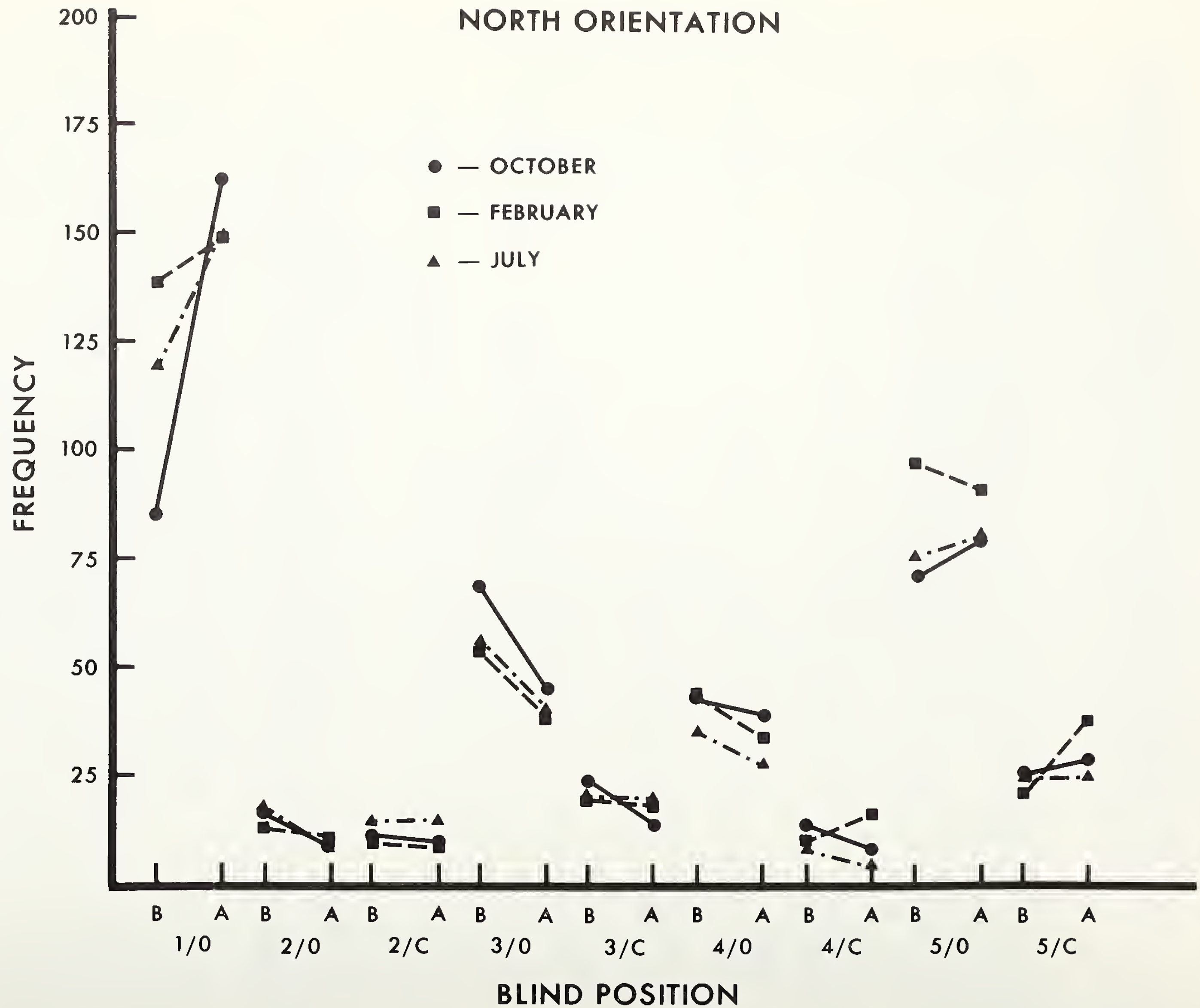


FIGURE 20. COMPARISON OF BEFORE AND AFTER TREATMENT BLIND POSITIONS BY ORIENTATION AND SEASON. A. NORTH ORIENTATION.

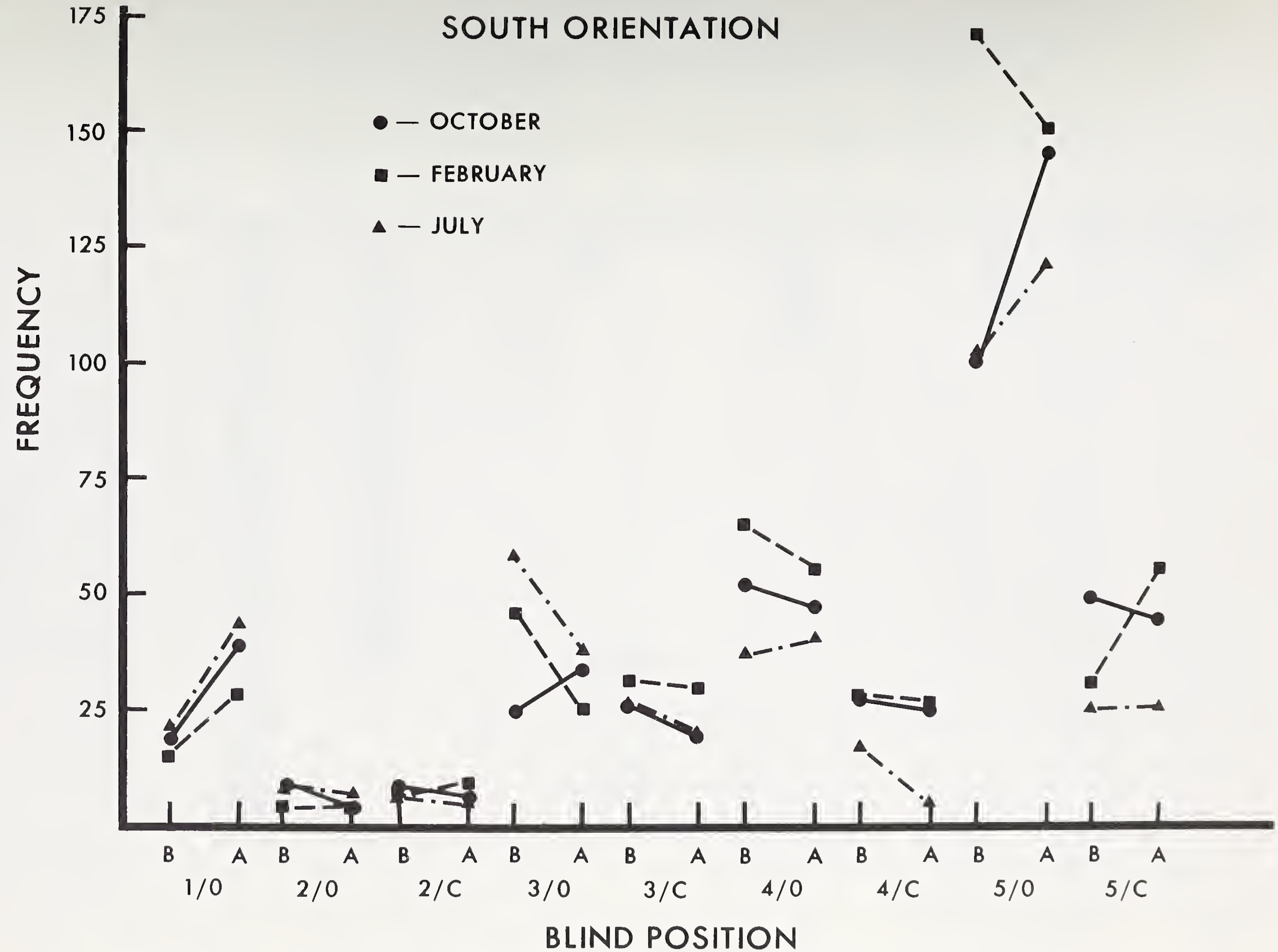


FIGURE 21. COMPARISON OF BEFORE AND AFTER TREATMENT BLIND POSITIONS BY ORIENTATION AND SEASON. B. SOUTH ORIENTATION.

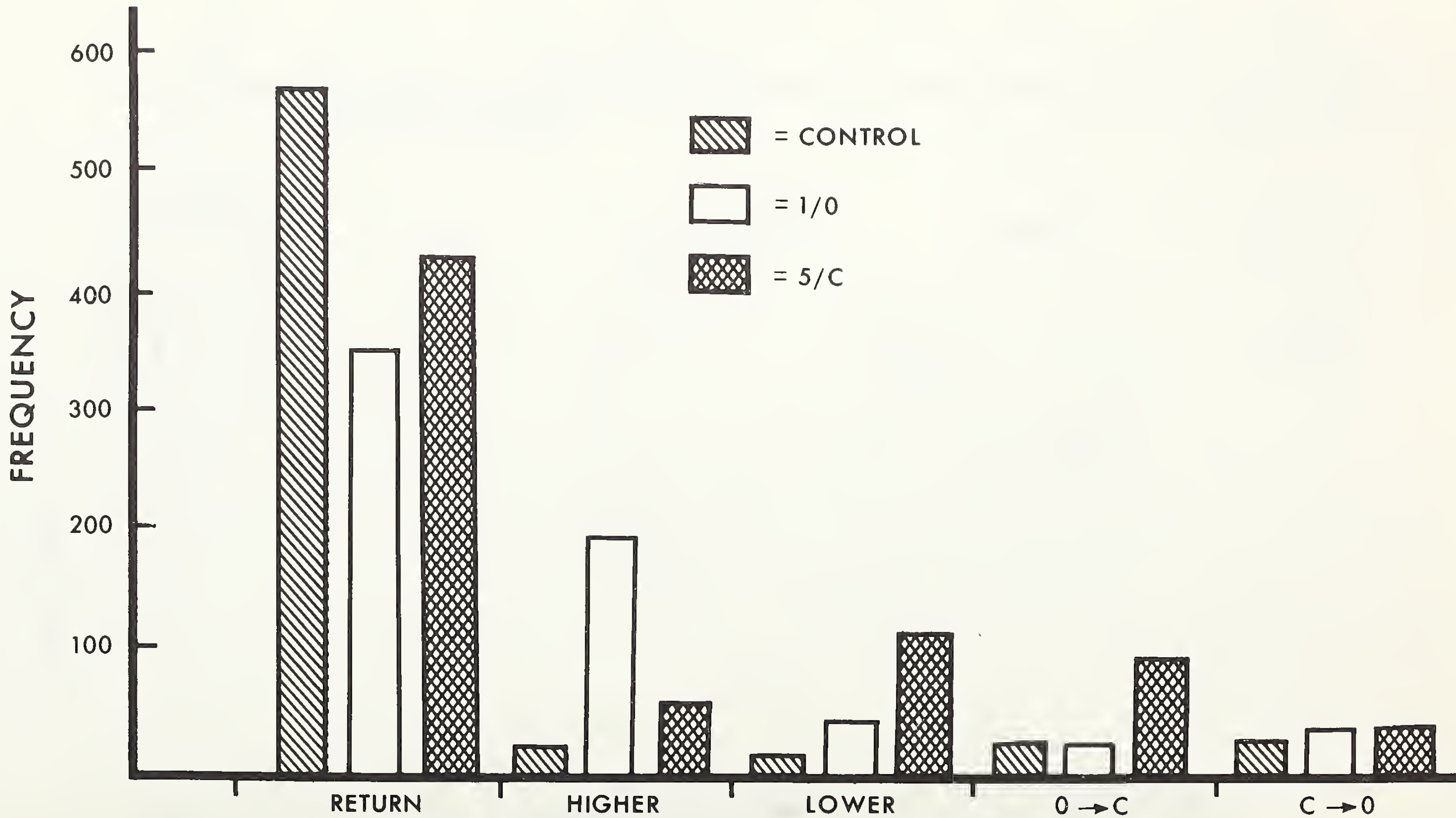


FIGURE 22. DIRECTION OF CHANGE IN BLIND POSITION FROM BEFORE TO AFTER TREATMENT.

this treatment group. (Of this latter number, 75% were not modified after the experimental change.) Blinds that were moved "Down" were also the most numerous in the fourth category "Open to closed," about 12% of this treatment group, as compared with 3% of the "Up" treatment group. Representation in the fifth group, "Closed to open" was split evenly among each of the three treatment groups, at about 5%.

To summarize, the major response to the experimental treatment was to return the blind to its pre-treatment position. When the blind was not returned, it tended to be put in a position that was similar to, or the same as, the experimental treatment position.

A X^2 analysis demonstrated that all four experimental factors, treatment, orientation, view, and season, exerted a significant effect upon the response. (Chi-square values for these factors are presented in Table 10, Appendix B.)

5.5 INFLUENCE OF EXPERIMENTAL FACTORS UPON AFTER TREATMENT DATA

As noted earlier, the distributions of responses obtained after treatment were significantly different from expected for all four experimental factors - treatment, orientation, view and season. How different, however, is the distribution of blind positions obtained after treatment from that obtained before?

Figures 23-27 present summary data obtained after treatment for each of the four factors, as well as for the overall distribution.

The first graph to be considered is that of the overall distribution of the data after treatment, Figure 23. When Figure 23 is compared with Figure 11 (Distribution of Blind Positions Before Treatment), it is apparent that the major difference is an increase in the number of blinds at the top of the window (1/0 position). A slight increase is also apparent in the number of blinds at the bottom of the window and open (5/0 position), while the number of blinds in other positions is correspondingly decreased. The changes in frequency of occurrence appear to be due to the experimental treatment, a premise borne out by the data depicted in Figure 24, Distribution of Blind Positions by Treatment Group After Treatment. The increase in the 1/0 position for the "Up" treatment group is particularly evident.

The increase in the number of blinds at the 1/0 position was apparent for the other major variables studied also: Orientation (Figure 25), View (Figure 26), and Season (Figure 27). In summary, although the dominant response to the experimental treatment was to return the blind to the pre-treatment position, the particular modifications made in blind position did influence later blind positions. This reaction is most noticeable for the "Up" treatment group as shown in Figure 24. Nevertheless, the effects of the other three experimental factors persist in a form similar to that obtained before treatment. Thus, Figure 25 demonstrates the marked differences between north- and south-facing buildings in a fashion very similar to Figure 12. Both the before and after treatment distributions of blind positions by orientation show much greater window

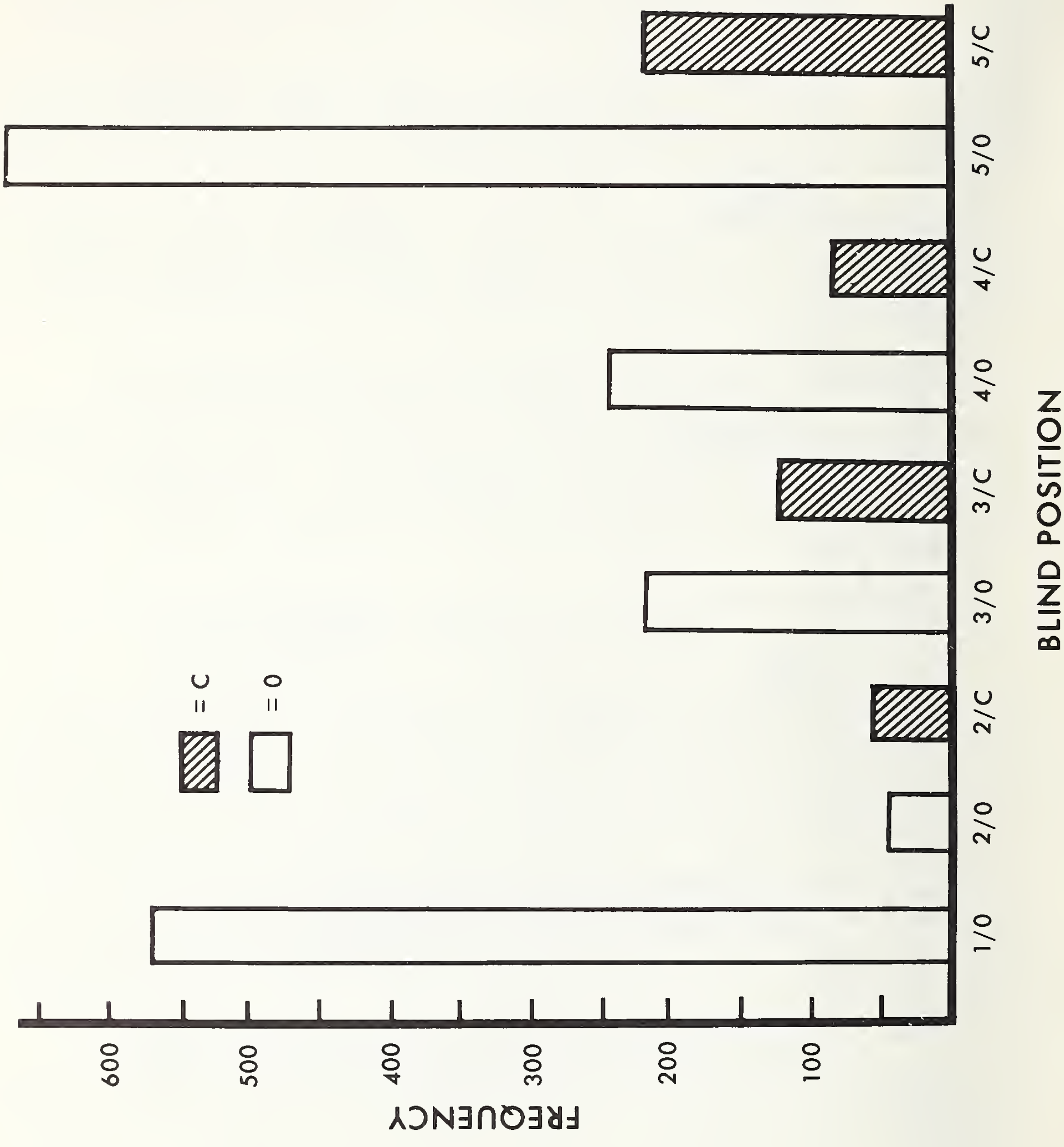


FIGURE 23. DISTRIBUTION OF BLIND POSITIONS AFTER TREATMENT.

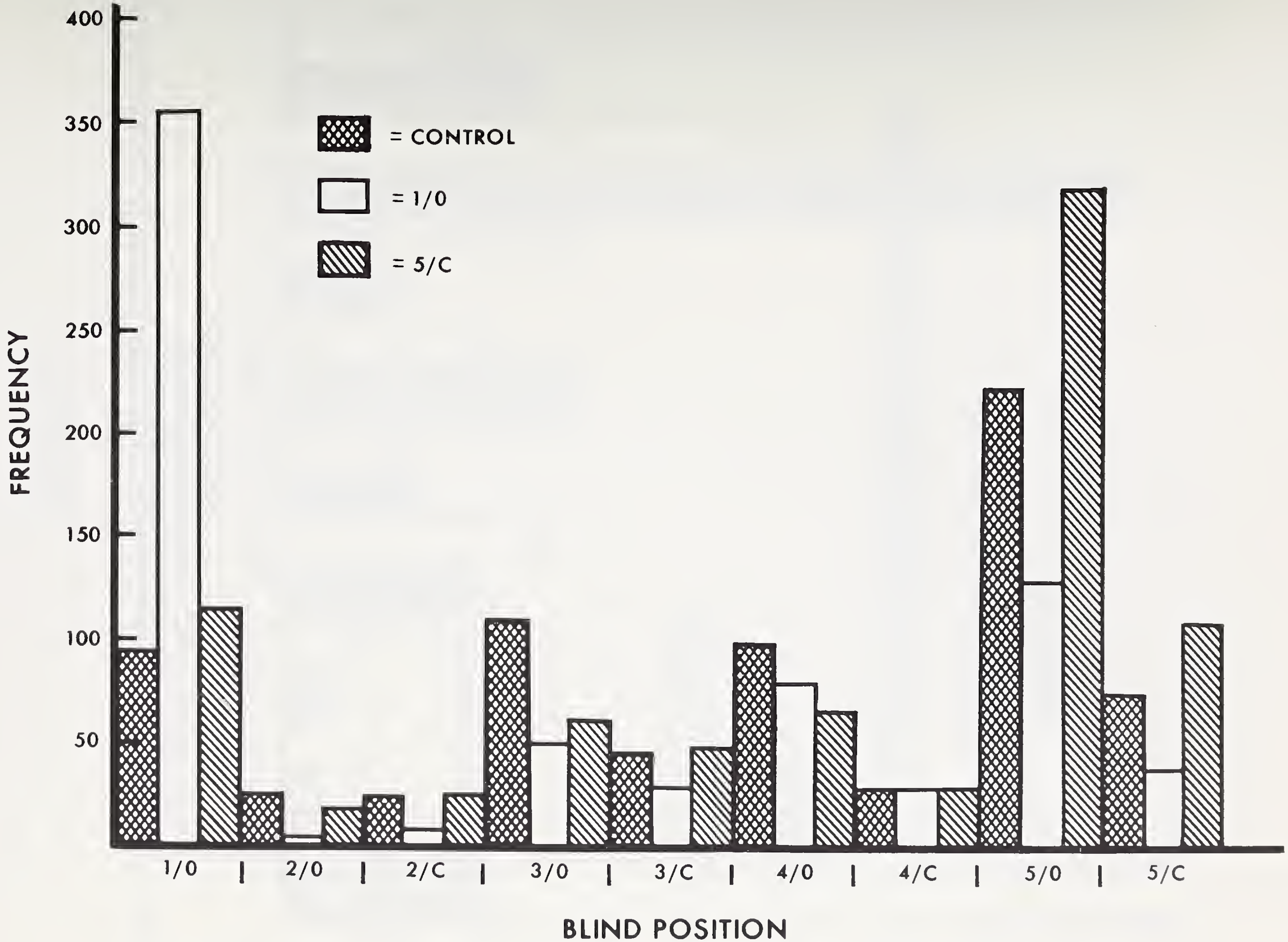


FIGURE 24. DISTRIBUTION OF BLIND POSITIONS BY TREATMENT GROUP AFTER TREATMENT.

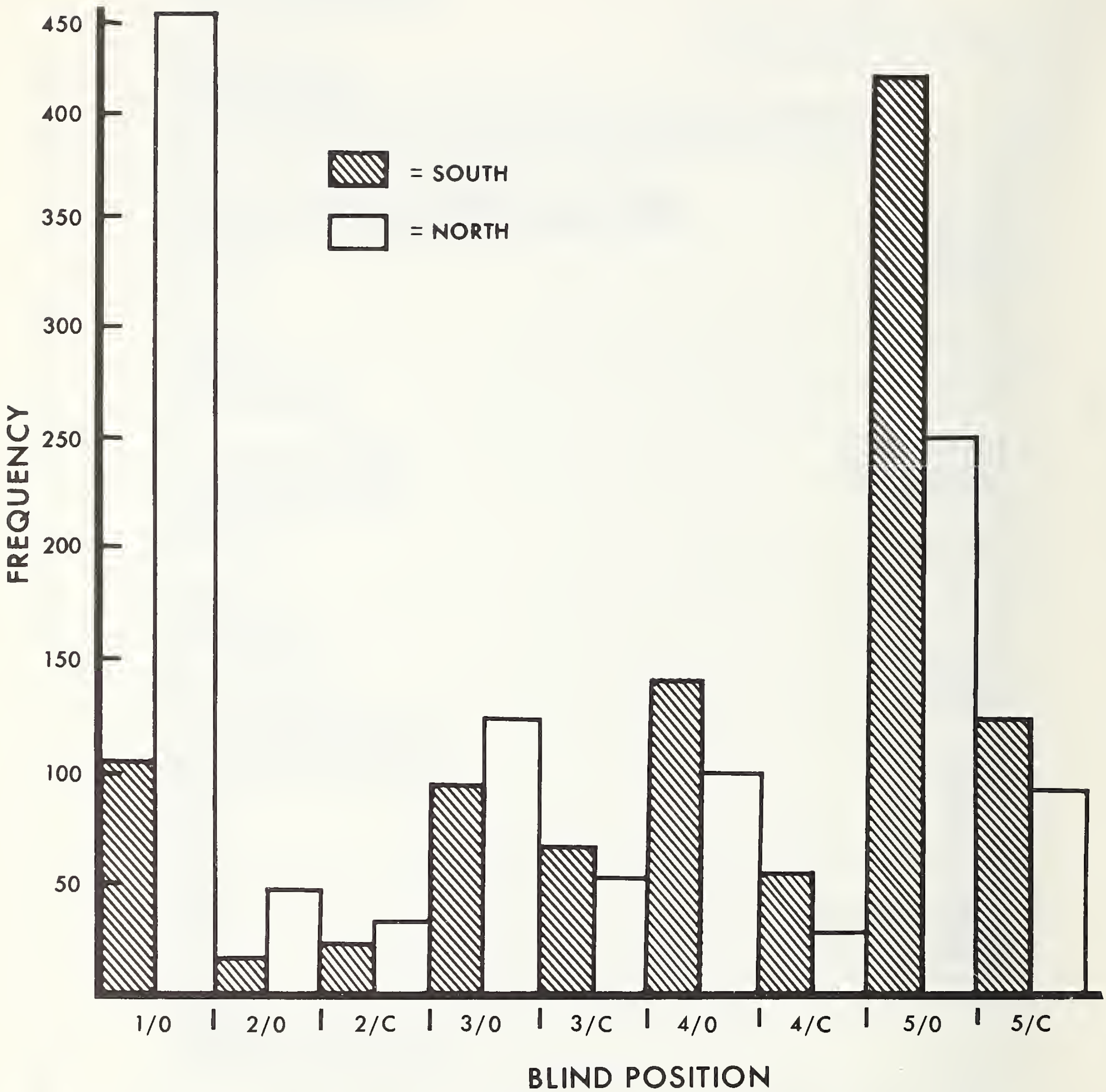


FIGURE 25. DISTRIBUTION OF BLIND POSITIONS BY ORIENTATION AFTER TREATMENT.

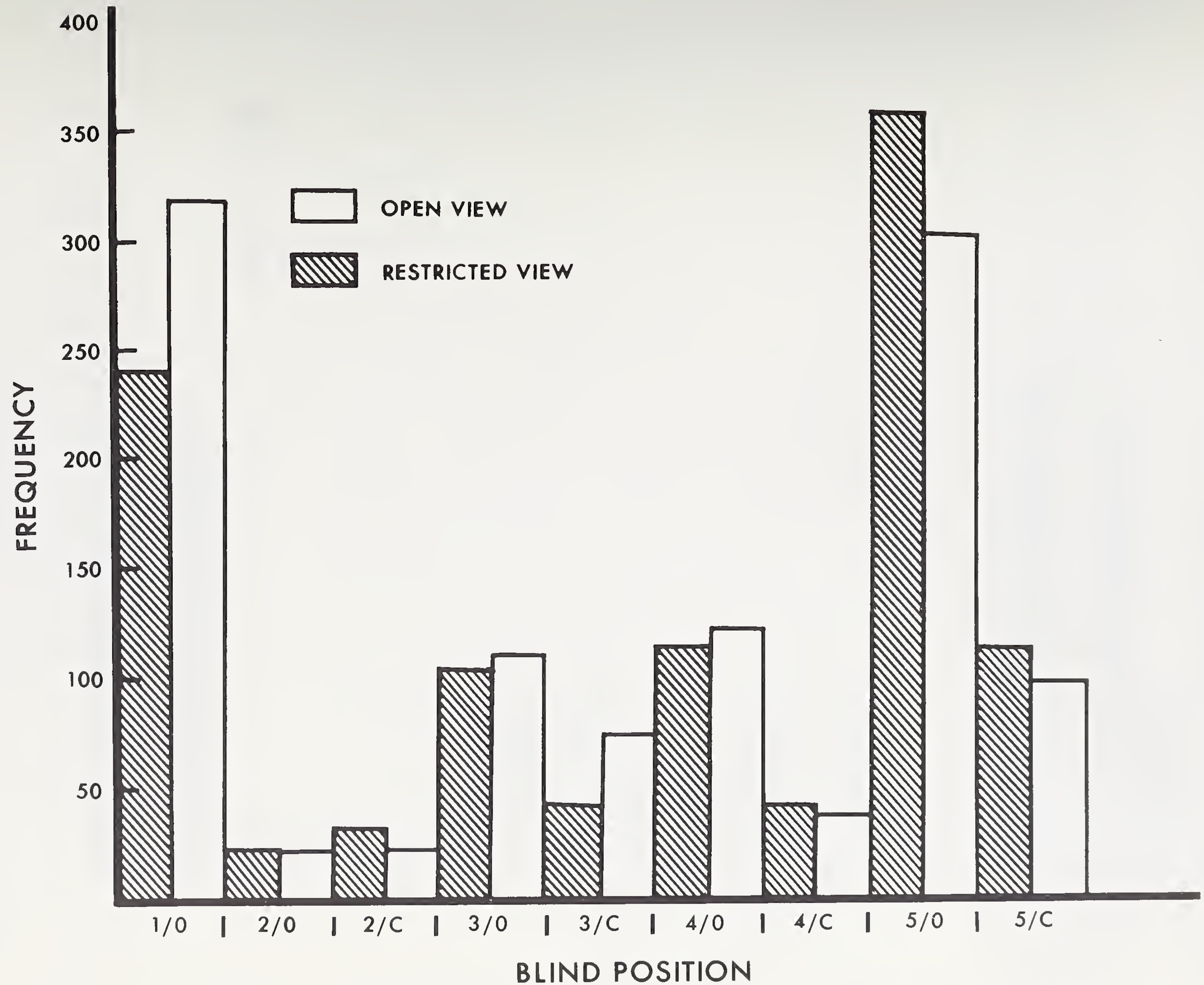


FIGURE 26. DISTRIBUTION OF BLIND POSITIONS BY VIEW AFTER TREATMENT.

exposure on the north side than on the south. Data presented in Figure 26 on the effects of view are quite similar to those for Figure 13 with more blinds at or near the bottom of a window for a restricted view, and more at the top of a window for an open view. These differences, however, are not particular marked either before or after treatment.

In Figure 27 (seasonal effects after treatment), rather interesting findings emerge. In February, the number of blinds in the 5/0 position decreased markedly from before to after treatment. In general, seasonal differences in the distribution of blind positions were less pronounced after treatment than they were before. Evidently the effects of the experimental treatment lessened the effects of seasonal change.

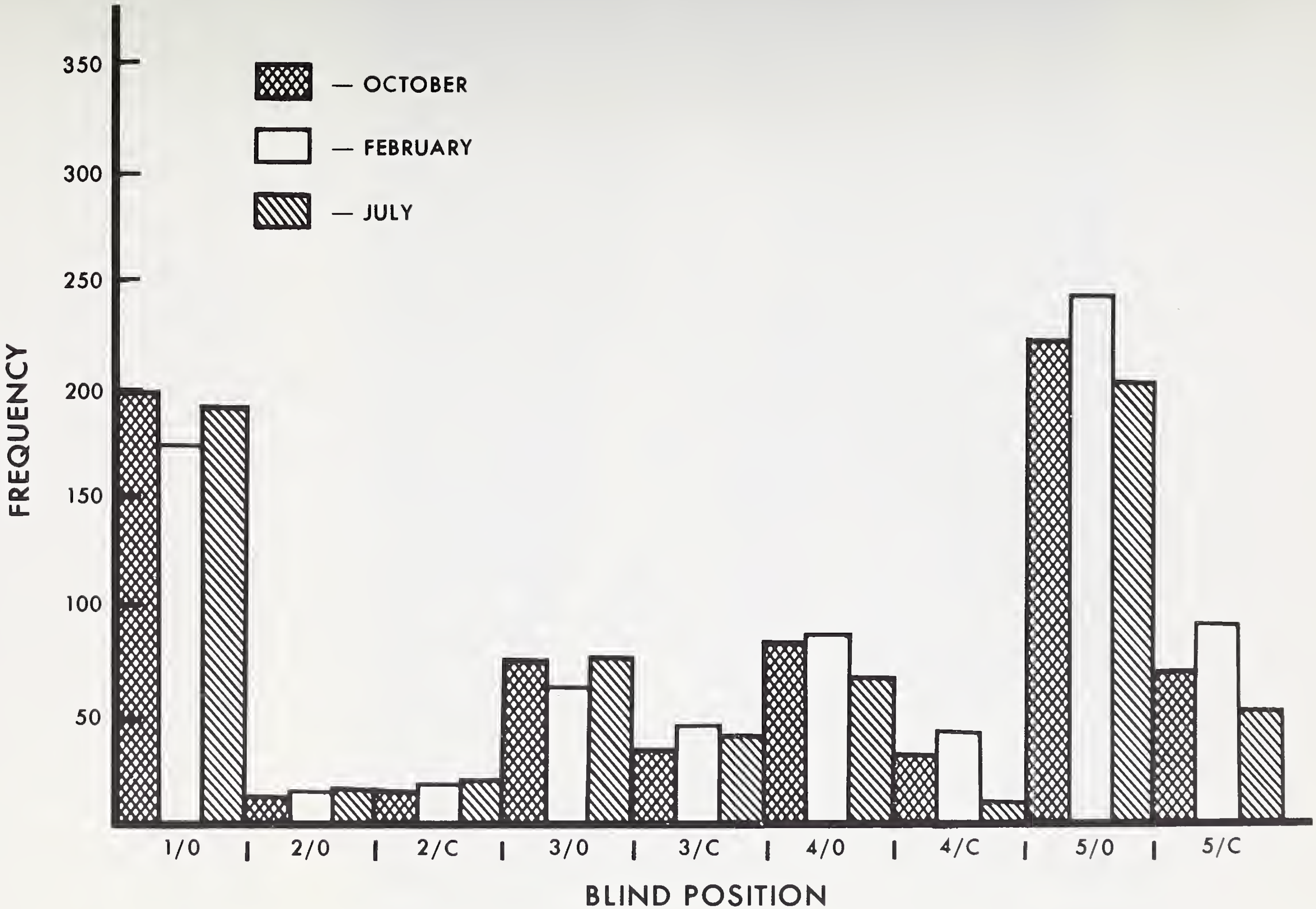


FIGURE 27. DISTRIBUTION OF BLIND POSITIONS BY SEASON AFTER TREATMENT.

6. DISCUSSION

The present study was performed to determine whether the window blind positions observed in the offices of the general purpose laboratories are indicative of occupant usage or attributable to other factors (e.g., maintenance). If window blinds were found to be altered by occupants, then we wanted to determine whether such changes were related in a systematic fashion to variables thought to affect window usage (e.g., view, geographic orientation, climate).

6.1 SETTING OF BLINDS -- "UP" AND "DOWN" TREATMENTS

As a means of determining whether the window blind positions viewed prior to the study represented preferred rather than randomly occurring acts, the blinds on eight building facades were systematically altered (with the other four building facades serving as controls). Our purpose in moving the blinds to preselected "extreme" positions ("Up," and "Down and Closed") was to test whether these seeming changes would be accepted by occupants or whether blind positions would be altered in accordance with individual preferences. The two experimental "treatments" of the blinds (upward in some instances, and downward for the others) were chosen because it was felt that these extreme changes would be most likely to affect later blind positions. Our findings indicated that this outcome did occur to some extent.

There was a significant tendency for blinds in the "Up" (1/O) treatment group to remain there, particularly on the north side of the buildings. Even in cases where the blinds did not remain completely up, more of the window was often left exposed. Blinds placed in the "down" (5/C) treatment group were not similarly affected -- they were not kept down. This difference may be attributable to a greater preference for total window exposure than for zero window exposure -- i.e., the positive functions of the window outweigh the negative ones. In fact, Figure 11 shows that 1/O positions were more than twice as common as 5/C positions before experimental treatment.

6.2 BUILDING ORIENTATION

For both treatment groups, building orientation influenced the response to treatment. Although all blinds in the "Up" group tended to be repositioned higher, the tendency was particularly pronounced on the north facades (see Table 11, Appendix C). The opposite effect was apparent in the "Down" treatment -- where occupants of the south-facing facades repositioned their blinds lower than did occupants occupying offices with northern exposures. These findings suggest a dominant response to window orientation when before-after comparisons are made of all windows whose blinds were altered.

The pronounced differences in distribution of blind positions between north and south facades indicate strongly that some external occurrence, most likely direct sunlight, influenced blind position settings. Yet, even though more blinds are in the lower half of the window on the south side, the majority have the slats open rather than closed. Thus, the blinds appear to be used primarily to control direct sunshine and glare, but not to eliminate the view or contact with the outside world.

6.3 VIEW TYPE

The differences in response to view, while statistically significant, are less easily explained than the response to orientation. Briefly, if a view is termed "open," the likelihood is greater that the blind will be in the upper half of the window. Yet, the differences in response to view type are not particularly large. Perhaps more important is the relatively small number of blinds in the completely closed (5/C) position (in which there is no view out) regardless of view type. This suggests that the blinds are not generally used to obscure the view out completely.

It is possible that the differences in response to view type would be greater if the views were more different -- or if the data were analyzed window by window after determining exactly what the view was for each occupant. It is also possible that the response is not really to view <u>out</u>, but to view <u>in</u>. Thus, in the views termed "restricted," the blinds may be positioned to minimize the "view-in" possibilities from nearby buildings. The differences in responses between open and restricted views may, in fact, not be attributable to differences in the quality of the view out, but rather to the ease with which other people can view <u>into</u> an office.

View type significantly affected the blind response to treatment, but the exact nature of the effect was not obvious. For instance, the significant difference between the restricted and open view types is mainly due to an increase in the number of 1/O blinds in the open category, and a decrease in the number of C T O blinds in the open group -- two apparently contradictory findings.

A possible explanation for the findings obtained concerns the type of views available in the offices studied. While some windows have only expansive views and others face facades of other buildings, in many instances the categorization of view type is not readily apparent. Moreover, the assumption was made that all windows on a given facade have a common view. This certainly was not the case, as demonstrated by Figures 1 and 2. Finally, the view from a window is importantly influenced by the viewing position within each office. The closer an office occupant is to the window, the greater the possibility to obtain different views with changes in viewing angle. (See Figures 6 and 7).

6.4 SEASONAL VARIATION

Although blinds offer considerable control for modifying the environment in response to seasonal variations, the data do not indicate that they were effectively used to conserve energy in the present study (Figures 20 and 21). These findings are not surprising since little evidence exists that office occupants are: (1) knowledgeable concerning effective window blind use to conserve energy (2) motivated sufficiently to change blind positions appropriately by season.

Appropriate window blind management in response to seasonal climatic differences therefore offers an opportunity for energy savings at NBS (and other buildings).

6.5 EXPLANATORY HYPOTHESIS (UNTESTED)

1. Windows have both positive effects (e.g., light in, view out) and negative effects (e.g., glare in, view in).

2. Each person arrives at a preferred blind position as a result of his individual weighing of the positive factors (open blinds) against the negative factors (closed blinds). For most people, the effects of the positive and negative variables are integrated over periods of time as long as weeks or months. Readjustments of blind positions at intervals of days or hours in response to short-term changes in the factors does not appear to be worth the effort for most people.

3. A substantial amount of direct sunlight (as in south windows) moves the positive-negative balance of factors toward the negative side (relative to north windows), presumably due to an increase of heat and glare.

4. Social factors may partially offset personal preference. Imposed changes in blind position may be ascribed to other office occupants or to organizational policy implemented by maintenance personnel.

5. Proximity of another building increases the negative factor of view in (weighted by number of potential observers), and, as with southern exposure, encourages blind settings more closed than open.

6.6 METHODOLOGICAL ISSUES

The present study demonstrated the general feasibility of photographing building facades to determine usage patterns of windows. While this investigation dealt with window blinds, the procedures employed should be equally, if not more useful, for windows with other shading devices, e.g., shades, draperies, curtains. Our intention of taking photographs of window blinds to determine usage patterns relating to major variables (orientation, season, etc.) met with partial success.

The major difficulty encountered was the limited resolution of the photographs that served as the basis for analysis. It was a rather easy task to determine the height of a given blind, and whether it was open or closed. Much more difficult (and frequently impossible) was a determination of the angle of the slats -- e.g., approximately 45° upward or downward. Obtaining information concerning slat angle -- if only two intermediate tilt positions -- is highly desirable as a means of determining the functions performed. For example, when the slats are tilted downward, little daylight or sunlight can penetrate the room, but the view near the building is relatively accessible (See Figure 28). On the other hand, when the slats are tilted upward, considerable daylight penetrates the room, but virtually no near view is available to occupants depending upon their position in the room (See Figure 29).

FIGURE 28. BLINDS WITH SLATS TILTING DOWNWARD.

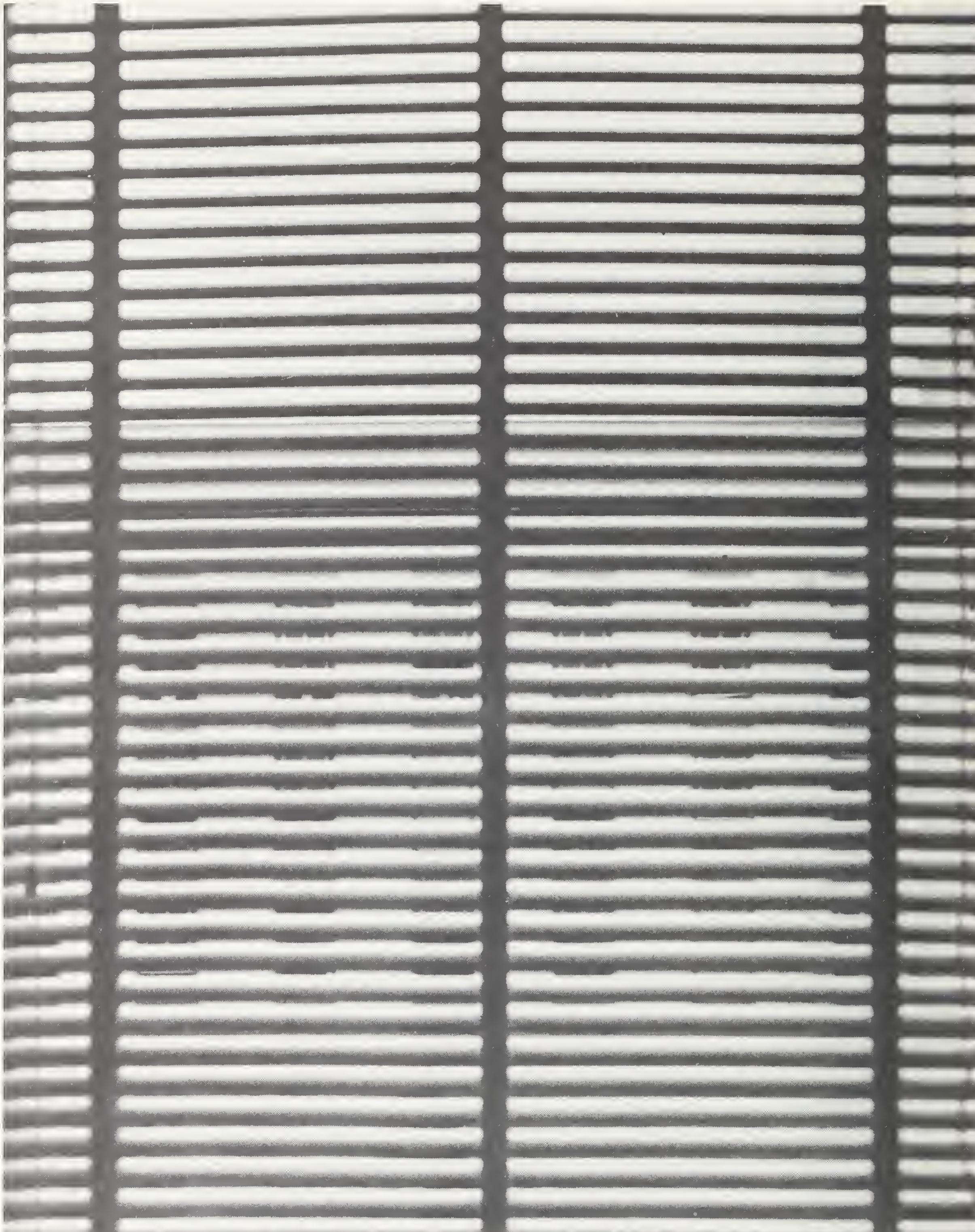


FIGURE 29. BLINDS WITH SLATS TILTING UPWARD.

In order to obtain information on slat angles by photographic means -- careful attention must be given to all factors which might influence the ultimate resolution of the photographs -- high resolution film, tripod, large format camera. Another necessary consideration is the determination of proper "line of sight," or angle, between camera and building facade.

Is experimental manipulation of blinds (or other shading devices) necessary?

The present experiment has demonstrated the usefulness of an experimental manipulation of an existing situation in forcing an occupant response. Thus, in situations where it is not known whether existing patterns of behavior reflect true occupant preferences, experimental changes of blinds appear to be worthwhile. Yet, because the main findings in this study indicate that people do position their blinds deliberately and do respond to external factors such as sunshine and view, the need for experimental intervention in future experiments may be somewhat lessened. Experimental "treatment" does provide greater confidence that the existing pattern of behavior is the one desired by the current occupants.

What form should the experimental treatment take?

In the present investigation, blinds were altered in one or two extreme ways ("up," and "down and closed"). These changes were likely to maximize the possibility of occupants noticing that modifications had occurred as well as the likelihood that they would not be kept at these "extreme" positions. If, instead of the window blind being adjusted to the totally open or totally obscured positions, intermediate settings were employed (e.g., half way up and closed), then desired window sizes might become more apparent. For example, the windows at NBS (2.3 m x 1.4 m) are quite large relative to many offices. If experimental settings obscured one quarter of the window area, our research findings might have been quite different, e.g., fewer people changing back to earlier settings, which might indicate an acceptance of window areas somewhat smaller than those in typical NBS offices.

6.7 ETHICAL CONCERNS

Researchers concerned with man/environment problems have been seeking approaches to collect objective behavioral information in a building's context for some time. Increasingly, photographic procedures have been employed to meet this need. The present study describes still another application of photography to understand better how people and the environment are mutually influential.

Our advocacy of data collection by photographic means is balanced by a concern to ensure that researchers are continuously sensitive to the need to maintain the privacy of any occupant whose "space" is photographed and plan and conduct their studies accordingly.

7. ENERGY CONSERVATION AND VENETIAN BLIND USAGE

The present study indicates that occupants of NBS offices did adjust their window blinds to control a major feature of their environment -- i.e., the functions of their windows. Study limitations did not permit us to determine <u>why</u> blinds were positioned as they were, but nonetheless, stable positions were apparent.

These findings suggest that under appropriate conditions, energy savings dependent on the activities of building occupants might be achieved. For example, instead of making major investments for automatic controls (e.g., light sensing devices), effective use of daylight is possible by manual control of light switches, in conjunction with appropriate positioning of venetian blinds.

The control of blinds by office occupants might provide considerable energy savings. However, we must first determine the feasibility of this approach. Will people expend the necessary time and effort to perform the proper functions?

This is a question that can be answered experimentally. One approach could be to provide the necessary technical information to office occupants -- together with reasons indicating the importance of behaving appropriately -- i.e., motivating factors. Then, we can monitor the behavior of occupants using an approach similar to that used in the reported study, to determine the effectiveness of the motivation employed (e.g., patriotic duty, tangible rewards, energy use, etc.)

An alternative way to achieve energy savings might be to have the maintenance staff close the blinds as part of their normal responsibilities each evening to reduce nighttime heat losses.

7.1 IMPROVEMENTS ON THE USE OF VENETIAN BLINDS

Among the methods which may be used to conserve energy by using blinds effectively are:

. During the summer season, lower the blind and close it during the hottest part of the day, especially on the south side of the buildings.

. During other seasons, leave the blind open (or raise the blind) to permit daylight to enter the office. Then, turn off overhead lights.

. During the winter season, lower the blinds and close the slats at night. Open them again during the daytime on all orientations.

7.2 INNOVATIVE IMPROVEMENTS IN BLIND DESIGN

A blind which permits two angles of slat angle (one from the top to the center of the window and the other from the center to the bottom) could be a very effective energy conserving design. Such a blind design could offer an expanded range of choices to occupants to optimize view, sunlight, daylight and other desirable attributes of windows and not expose large window areas when this practice wastes energy.

Use vari-colored blinds. Blinds covered with a highly reflective coating on one side will maximize daylight penetration. A highly absorbent coating on the other side will maximize heat absorption (Rosenfeld and Selkowitz, 1976). Slats should then be oriented so that incoming light strikes the reflective side during the summer months and the absorptive side during the winter months. Alternatively, the reflective side could be used to reflect solar radiation to the ceiling of the office. A careful examination should be made of the heat gains due to daylight and electric lighting and the subsequent loads upon the HVAC system, to determine the best energy-efficiency tradeoffs in any given room.

A padded insulating covering for each slat could be effective. If constructed properly, padded blinds would lock together to form an insulated panel to decrease the thermal transmission losses through the window on cold winter nights. Yet, the slats could be opened, and the blind raised during the day, to take full advantage of winter solar heat gain.

8. SUMMARY AND CONCLUSIONS

The investigation of window blind usage at the National Bureau of Standards led to a number of findings -- some anticipated, and others, unexpected.

Our hypothesis that observed blind positions are the result of actions by office occupants was largely supported. When blind positions were systematically altered, they did not remain in these positions. Rather, in the typical instance, the blind position was returned to the same placement where it had been prior to the experimental change.

With respect to how frequently blind positions were modified, we found that for the most part, when a preferred placement was established, the blind was not likely to be moved -- either from day to day, or within the course of a single day.

Of the experimental variables studied, the most significant influence on window blind position was found to be the compass orientation. The blinds on the windows with northern exposure were kept open to a significantly greater degree than those having southern exposure. On the other hand, blind placements could not be readily explained in terms of view quality or seasonal changes. The influence of these factors appears to be more subtle and requires further investigation.

The findings of the study suggest the feasibility of exploring energy savings procedures, based on the involvement of office users and the maintenance staff. That is, since office occupants <u>did</u> respond to seemingly arbitrary changes in blind positions by making modifications to suit their preferences, given appropriate motivation, they might be expected to perform energy conserving actions. This hypothesis can be tested by instituting a training (educational) program and determining its effects on influencing actions such as manipulating blinds in accordance with energy conserving practices. A variety of training techniques can be explored simultaneously to develop an optimum technique. Furthermore, it might be useful to explore the feasibility of a range of incentive schemes in conjunction with different training techniques as a means of developing an optimum system, based on user participation in energy conservation activities.

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BIBLIOGRAPHY

American Society of Heating, Refrigerating and Air-Conditioning Engineers, ASHRAE Handbook of Fundamentals, 1972 Edition, Chapter 20, New York.

Beckett, H. E., and Godfrey, J. A., Windows: Performance, Design and Installation, New York: Van Nostrand Reinhold, 1974.

Brierly, E. S., Sunshine, daylight, visual privacy and view in housing, Building, 1971, 11, pp. 119-123.

Button, D. A., Research into performance requirements for windows and window glass products, CIB - 6[70] Congress, 1974, 240-245.

Caemmerer, W., Testing of sunbreaks in Germany, Sunlight in Buildings, Proceedings, CIE Conference, Bouwcentrum, Rotterdam, 1967, pp. 211-216.

Chapman, W. P., Automatic controls can cut lighting costs, Architectural Record, May 1963, 192-193.

Collins, B. L., Windows and People: A Literature Survey, Psychological reactions to environments with and without windows, NBS BSS 70; 1975.

Dix, R. C. and Lavan, L., Window Shades and Energy Conservation, Illinois Institute of Technology, Dec. 1974.

Griffith, J. W., Conover, C. W., Arner, W. J., Daylighting design with adjustable horizontal louvers, Illuminating Engineering, Feb. 1957, p. 57-64.

Hill, A. R. and Markus, T. A., Some factors influencing vision through meshes, Human Factors, 1968, 10(5), p. 531-552.

Hollister, F. D., Greater London Council: A Report on the Problems of Windowless Environments, London: Hobbs, 1968, p. 121.

Hopkinson, R. G., The psychophysics of sunlighting, Sunlight in Buildings, Proceedings,CIE Conference, Bouwcentrum, Rotterdam, 1967, pp. 13-19.

Hopkinson, R. G., Glare from daylighting in buildings, Applied Ergonomics, 1972, 34, pp. 206-215.

Keighley, E. C., Visual requirements and reduced fenestration in offices -- a study of multiple apertures and window area, Journal of Building Science, 1973, 8, pp. 321-331.

Keighley, E. C., Visual requirements and reduced fenestration in office buildings -- a study of window shape, Journal of Building Science, 1973, 8, pp. 311-320.

Langdon, F. J., and Loudon, A. G., Discomfort in schools from overheating in summer, The Journal of the Institution of Heating and Ventilating Engineers, 1970, 37, pp. 265-274.

Loudon, A. G., Window design criteria to avoid overheating by excessive solar heat gains, Sunlight in Buildings, Proceedings, CIE Conference, Bouwcentrum, Rotterdam, 1967, pp. 95-102.

Markus, T. A., The function of windows -- a reappraisal, Building Science, 1967, 2, pp. 97-121.

Markus, T. A., and Gray, A., Windows in low rise, high density housing -- the psychological significance of sunshine, daylight, view and visual privacy, Windows and Their Function in Architectural Design, Proceedings, CIE Conference, Istanbul, 1973, Section 4.3.

Ne'eman, E., and Hopkinson, R. G., Critical minimum acceptable window size: a study of window design and provision of a view, Lighting Research and Technology, 1970, 2, 17-27.

Nicol, J. F., Radiation transmission characteristics of louver systems, Building Science, 1966, 1, pp. 167-182.

Petherbridge, P., Transmission characteristics of window glasses and sun controls, Sunlight in Buildings, Proceedings, CIE Conference, Bouwcentrum, Rotterdam, 1967, pp. 183-198.

Rosenfeld, A. H. and Selkowitz, S., Beam Daylighting, Chapter 5 of Report of 1975 Berkeley Summer Study on Efficient Use of Energy in Buildings, LBL 4411, 1976.

Stephenson, D. G., and Mitalas, G. P., An analog evaluation of methods for controlling solar heat gain through windows, ASHRAE Journal, Feb. 1962, 4(2), pp. 41-46.

Stephenson, D. G., and Mitalas, G. P., Solar transmission through windows with venetian blinds, Sunlight in Buildings, Proceedings, CIE Conference, Bouwcentrum, Rotterdam, 1967, pp. 151-166.

Appendix A

Table 9

X^2 Analysis of Before Treatment

Frequency of Occurrence of Blind Positions

Treatment by Response

Response	Observed	Expected	Treatment
1/0	96.00	128.58	Control
	181.00	127.28	1/0
	120.00	141.14	5/C
2/0	20.00	22.02	Control
	19.00	21.80	1/0
	29.00	24.17	5/C
2/C	21.00	18.14	Control
	10.00	17.95	1/0
	25.00	19.91	5/C
3/0	99.00	96.84	Control
	101.00	95.86	1/0
	99.00	106.30	5/C
3/C	42.00	46.96	Control
	50.00	49.49	1/0
	53.00	51.55	5/C
4/C	93.00	88.42	Control
	95.00	87.53	1/0
	85.00	97.06	5/C
4/0	39.00	35.95	Control
	42.00	35.59	1/0
	30.00	39.46	5/C
5/0	207.00	198.86	Control
	130.00	196.86	1/0
	277.00	218.28	5/C
5/C	79.00	60.24	Control
	61.00	59.63	1/0
	46.00	66.12	5/C

x^2 = 99.42   df = 16.00   significant @ .01 level

Table 9 (continued)

Orientation

Orientation	Observed	Expected	Response
North	342.00	212.04	1/O
South	55.00	184.96	
North	48.00	36.32	2/O
South	20.00	31.68	
North	36.00	29.91	2/C
South	20.00	26.09	
North	177.00	159.70	3/O
South	122.00	139.30	
North	64.00	77.45	3/C
South	81.00	67.55	
North	121.00	145.81	4/O
South	152.00	127.19	
North	32.00	54.58	4/C
South	70.00	47.52	
North	242.00	327.94	5/O
South	372.00	286.06	
North	81.00	99.34	5/C
South	105.00	86.66	

$x^2 = 275.308$ df = 8 significant beyond .01 level

Table 9 (continued)

View

Response	Restricted	Open	
1/0	167.00	230.00	
2/0	36.00	26.00	
2/C	29.00	27.00	
3/0	139.00	160.00	Observed
3/C	61.00	84.00	
4/0	136.00	137.00	
4/C	47.00	55.00	
5/0	328.00	286.00	
5/C	94.00	92.00	
1/0	192.92	204.08	
2/0	30.13	31.87	
2/C	27.21	28.79	
3/0	145.30	153.70	Expected
3/C	70.46	74.54	
4/0	132.66	140.34	
4/C	49.57	52.43	
5/0	298.37	315.63	
5/C	90.39	95.61	

$x^2 = 18.66$ df = 80 significant at .05 level

Response x Season

Response	October	February	July	
1/0	103.00	153.00	141.00	Observed
2/0	25.00	17.00	26.00	
2/C	20.00	14.00	22.00	
3/0	91.00	94.00	114.00	
3/C	49.00	49.00	47.00	
4/C	95.00	106.00	72.00	
4/C	41.00	36.00	25.00	
5/0	172.00	264.00	178.00	
5/C	83.00	53.00	50.00	
1/0	125.96	145.81	125.22	Expected
2/0	21.58	24.98	21.45	
2/C	17.77	20.57	17.66	
3/0	94.87	109.82	94.31	
3/C	46.01	53.26	45.74	
4/0	86.22	100.27	86.11	
4/C	32.36	37.46	32.17	
5/0	194.82	225.52	193.67	
5/C	59.02	68.32	58.67	

$x^2 = 53.52$ df = 16 significant at .01 level

APPENDIX B

Table 10

x^2 Analysis of Direction of Blind Change from Before Treatment to After Treatment

Treatment x Response

Response	Observed	Expected	Treatment
Return	673.00	438.98	Control
	341.00	423.42	1/0
	430.00	481.59	5/C
Up	22.00	87.53	Control
	193.00	84.43	1/0
	53.00	96.03	5/C
Down	11.00	52.91	Control
	38.00	51.04	1/0
	113.00	58.05	5/C
Open	24.00	29.72	Control
to	31.00	29.67	1/0
Closed	36.00	32.61	5/C
Closed	29.00	39.85	Control
to	23.00	38.44	1/0
Open	80.00	43.72	5/C

$x^2 = 407.848$ 8 df significant @ .01 level

Response x Season

Response	October	February	July	
Return	411.00	527.00	406.00	
Up	112.00	70.00	86.00	
Down	63.00	61.00	38.00	Observed
O→C	40.00	28.00	23.00	
C→O	19.00	78.00	25.00	
Return	436.28	516.77	390.96	
Up	86.99	103.04	77.96	
Down	52.59	62.29	47.12	Expected
O→C	29.54	34.99	26.47	
C→O	39.60	46.91	35.49	

$x^2 = 64.696$ 8df significant @ .01 level

Table 10 (continued)

Response x View

Response	Restricted	Open	
Return	670.00	674.00	
Up	111.00	157.00	
Down	71.00	91.00	Observed
O→C	47.00	44.00	
C→O	72.00	50.00	
Return	656.78	687.22	
Up	130.96	137.03	
Down	79.16	82.83	Expected
O→C	44.47	46.53	
C→O	59.62	62.38	

$x^2 = 13.430$ 4 df significant @ .01 level

Orientation x Response

Response	North	South	
Return	740.00	604.00	
Up	162.00	106.00	
Down	75.00	87.00	Observed
O→C	32.00	59.00	
C→O	58.00	64.00	
Return	721.72	622.28	
Up	143.91	124.90	
Down	86.99	75.01	Expected
O→C	48.87	42.13	
C→O	65.51	56.49	

$x^2 = 23.914$ 4 df significant @ .01 level

APPENDIX C

Table 11

Summary of Direction of Change in Blind Position from Before Treatment to After Treatment

Control		Return	Up*	Down*	O→C	C→O
225-S	Oct.	38	1	1	0	5
Open	Feb.	50	4	2	6	2
	July	32	5	1	0	1
223-S	Oct.	50	0	0	0	4
Restricted	Feb.	53	0	1	7	4
	July	25	1	0	0	4
222N	Oct.	65	1	0	0	0
Open	Feb.	60	0	2	3	0
	July	51	4	0	0	1
220N	Oct.	50	1	1	0	3
Restricted	Feb.	61	2	3	3	0
	July	38	3	0	0	0
1.0						
220S	Oct.	19	17	6	0	3
Open	Feb.	27	13	6	5	4
	July	22	22	5	0	4
222S	Oct.	20	8	4	2	2
Restricted	Feb.	32	11	2	2	5
	July	20	5	2	0	1
225N	Oct.	26	33	4	0	4
Open	Feb.	54	9	2	2	2
	July	43	19	1	0	4
221N	Oct.	17	27	2	1	1
Restricted	Feb.	44	12	3	7	1
	July	30	18	1	2	2
5.C						
221S	Oct.	23	3	16	5	4
Open	Feb.	34	5	10	8	2
	July	32	5	7	11	2
224S	Oct.	46	0	9	3	7
Restricted	Feb.	34	5	11	19	2
	July	47	1	4	3	3

*Excludes changes in slat angle.

Appendix D

Table 12

Weather Conditions During Blind Study

Date	Temperature	Clouds	Precipitation	Wind	Sunshine	Sun Altitude [1]	Sun Azimuth
October 1974							
9-30 - 4 PM	72°	scattered	none	12 mph	yes	22.5	69.6
10-1 - 9 AM	57°	none	none	12-17 mph	yes	32.8	57.3
10-1 - 12 Noon	62°	none	none	10-13 mph	yes	50.0	0.0
10-1 - 4 PM	64°	none	none	7 mph	yes	22.5	69.6
10-2 - 9 PM	51°	none	none	12-20 mph	yes	32.8	57.3
10-2 - 12 Noon	58°	scattered	none	14 mph	yes	50.0	0.0
10-2 - 4 PM	57°	scattered	none	17-30 mph	yes	22.5	69.6
10-7 - 9 AM	58°	none	none	5-8 mph	yes	24.5	49.8
12 Noon	75°	partial	none	14 mph	no	39.5	0.0
4 PM	72°	partial	none	14 mph	no	15.0	61.9
10-8 - 9 AM	50°	none	none	10-17 mph	yes	24.5	49.8
12 Noon	59°	none	none	9 mph	yes	39.5	0.0
4 PM	63°	none	none	10-13 mph	yes	15.0	61.9
10-11- 9 AM	56°	none	none	6 mph	yes	24.5	49.8
12 Noon	69°	none	none	7 mph	yes	39.5	0.0
4 PM	75°	none	none	3-7 mph	yes	15.0	61.9
February 1975							
2-5 - 4 PM	37°	total	none	9 mph	no	8.1	55.3
2-6 - 9 AM	39°	total	none	10 mph	no	16.8	44.0
4 PM	49°	partial	none	5 mph	no	8.1	55.3
2-7 - 9 AM	38°	partial	snow flurries	12-20 mph	no	16.8	44.0
4 PM	37°	none	none	16-28 mph	yes	8.1	55.3
2-10 - 9 AM	23°	none	none	9 mph	yes	24.3	49.7
4 PM	34°	partial	none	9 mph	some	14.8	61.6
2-11 - 9 AM	38°	partial	none	7 mph	some	24.3	49.7
4 PM	50°	total	none	5-10 mph	none	14.8	61.6
2-14 - 9 AM	29°	partial	none	9-12 mph	some	24.3	49.7
4 PM	41°	partial	none	10 mph	yes	14.8	61.6

Table 12 (continued)

Date	Temperature	Clouds	Precipitation	Wind	Sunshine	Sun Altitude	Sun Azimuth
July 1975							
7-17 - 9AM	76°	total	humid[2]	6 mph	no	47.2	76.7
4 PM	82°	total	humid	3-7 mph	no	35.8	87.8
7-18 - 9AM	76°	partial	humid	7 mph	yes	47.2	76.7
4 PM	86°	scattered	none	9 mph	yes	35.8	87.8
7-21 - 9 AM	78°	none	none	8 mph	yes	47.2	76.7
12 Noon	86°	scattered	none	3-6 mph	yes	70.6	0.0
4 PM	91°	scattered	none	6-10 mph	yes	35.8	87.8
7-22 - 9 AM	78°	scattered	none	12 mph	yes	47.2	76.7
12 Noon	84°	scattered	none	8-12 mph	yes	70.6	0.0
4 PM	87°	none	none	9-14 mph	yes	35.8	87.8
9-28 - 9 AM	78°	none	humid	7 mph	yes	47.2	76.7
12 Noon	86°	hazy	none	9 mph	yes	70.6	0.0
4 PM	90°	scattered	none	7 mph	yes	35.8	87.8

[1] Figures for sun altitude and azimuth are from the ASHRAE Handbook of Fundamentals - 1972 Ed., p. 390, for 40° N latitude (Gaithersburg approx. 39° N) for the 21st of the nearest month.

[2] Above 70 % relative humidity

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

Window usage at the National Bureau of Standards was studied by photographing venetian blind positions in offices at different times of the day and year. While blind positions were quite stable during the week of each study phase, they were quickly altered by the room occupants when deliberately set at extreme positions by the researchers. Significant differences were observed among blinds depending on compass orientation of the window, view type, season, and nature of experimental treatment. The greatest determinant of blind position was orientation, with blinds on north-facing windows being more open than on the south. The results suggest that energy conservation programs which rely on the activities of building occupants may be feasible. Suggestions are made for improvements in blind use and design.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Energy conservation; office buildings; orientation; photographic method; season; venetian blinds; view; window usage; windows.

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