COMFORT AND COOLING WITH BOX FANS

by

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INTRODUCTION

As the world supply of non-renewable hydrocarbon energy declines, the basis of the price of energy shifts from the cost of production to the cost of replacement of the energy source. Since the energy alternatives next in line are seen initially as less preferable, the price of energy to the consumer rises (Bupp, 1980). In the case of the United States, the consumer is an entire country. This country has chosen to regulate its energy use under the threat of an overly large imbalance of payments. One area of regulation is building temperature, which is strongly linked with thermal comfort. The portion of regulations in effect in the summer restrict the temperature in most buildings to 25.6 C (78 F) or above (Dept. of Energy, 1979). A jump of this lower temperature limit could very easily result in a heavy emphasis on fan-cooling to maintain the comfort level to which the population is accustomed. The strength of the desire to maintain a high comfort level is indicated by the fact that "About one third of the world's energy consumption is used to provide thermal comfort for man." (Fanger, 1977) Thus, knowledge of how to get the greatest benefit from the use of a fan might become critical. Moreover, the current ASHRAE Ceiling Wind Velocity of .8 m/s (158 ft/min) may be too low, particularly for persons performing manual labor. If this suspicion can be confirmed, a recommendation will be made to raise the ASHRAE Ceiling Wind Velocity.

LITERATURE REVIEW

Forced convection is physiologically effective in maintaining comfort

The earlier work with forced convection was concerned with gross behavioral and physiological reactions. Rohles (1965, 1970a) examined avoidance behavior of monkeys to wind. His work indicates that below 21 C (70 F) wind above 2.2 m/s (440 ft/min) does act as an aversive stimulus for monkeys. At 26.7 C (80 F), however, wind of 1.1 m/s (220 ft/min) and below produces avoidance behavior only 20% or less of the time in monkeys. While that doesn't necessarily mean that the wind was viewed by the monkeys as pleasant for 80% or more of the time, low velocity winds appear to be acceptable at appropriately warm temperatures.

A summary by Berdan et. al. (1970) claims that "...air currents with speeds up to 3 m/s [590 ft/min], temperatures up to 29 °C [84 F] and relative humidities not exceeding 60%..." are effective in extending the range of thermal comfort, defined in terms of physiological reactions and "...the sensation of heat." In addition, they found a drastic reduction in sweat rate "...as the airspeed increased at all air temperatures experimented with,..." including at 30 °C [86 F] and at 34 °C [93 F]. This showed that forced convection in the comfort condition is effective in promoting body heat loss as high as 34 C (93 F).

Van Hole (1971) contrasted forced convection with evaporative cooling. He dressed his subjects in 100% cotton knit long underwear

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and occupied them at a task having a work metabolism estimated by him at 116 Watts/m^2. Nevertheless, he found that an average air velocity of .66 m/s (130 ft/min) "...was sufficient to evaporate most of the sweat..." that his subjects secreted at 43 C (110 F) and 40% rh (p. 27). Neither of the two subjects voted that he was comfortable at these conditions while dressed in dry underwear after 45 minutes of heat stress. Wetting the underwear produced a vote of "comfortable" on a Thermal Sensation type ballot for only one of the subjects (pp. 21, 55). Thus, the temperature above which fan-aided cooling for dry clothing is ineffective is well below 40.2 CET* (43 C, 40% rh) (104.4 FET*).

Mitchell and Whillier (1971) have developed cooling power curves for people dressed in minimal dry clothing. They pointed out that in terms of specific cooling power, "The benefits of increasing wind speeds above 2 m/s are small." (Wyndham et. al. (1952) found little advantage in terms of physiological strain in increasing wind speed from 2 m/s to 4 m/s in hot environments.) However, Mitchell and Whillier build a strong case for the removal of metabolic heat and, hence, for the achievement of comfort, through the use of wind rather than through a decrease in the ambient temperature when low wind speeds will suffice:

> "In the region of low wind speed the cooling power of the environment increases rapidly with increasing wind speed, but only slowly with decreasing wet-bulb temperature. For example, ...the specific cooling power [of air] at 32 °C [90 F] wet-bulb and 0,1 m/s [20 ft/min] wind speed is about 40 W/m^2. In order to reach the same cooling power by decreasing wet-bulb temperature rather than by increasing wind speed, it is necessary to reduce the wet-bulb temperature to about 24 °C [75 F]."

Formulas discussed by Konz (1980) indicate that the total metabolism of a 70 kg assembler whose metabolic rate due to work is estimated to be .6 W/kg is 132 Watts:

Basal Metabolism	=	(1.28 W/kg)(70 kg)	=	89.6 W
Activity Metabolism	=	(0.6 W/kg)(70 kg)	=	42.0 W
Specific Dynamic Action 3 hours after eating			=	0. W
Total Metabolism of a 70 kg male			=	132. W

This figure, 132 W, is far below the figures for the estimated specific cooling power of air relevant to the present experiment (Table 1). Consequently, participants in the present experiment should have a favorable rate of heat exchange with the environment. (The smaller surface area for females is offset by the lower average body weight as well as by the lower basal metabolic rate of 1.16 W/kg.) Any discomfort felt by the participants in the present experiment therefore should not be attributed to heat buildup.

Kamon et. al. (1979) confirmed this point. His group found that wind velocities of .5, 1, 2, and 4 m/s (100, 200, 400, and 800 ft/min, respectively) produce identical physiological responses in clothed workers at wet bulb globe temperatures ranging from 27.2 C (81 F) to 34.4 C (94 F).

Forced convection is appropriate within a narrow temperature range

According to Fanger and Valbjorn (1979), "The classic work on discomfort from draughts was carried out by Houghten et. al.." Houghten et. al. (1938) determined that the perception of localized air movement as comfortable, at and below 21 C (70 F) both at the neck and at the ankles, increases consistently as the temperature is increased. Fanger and Valbjorn (1979) state that this work provides

TABLE 1

Estimated values for the specific cooling power of air based upon extrapolation of specific cooling power curves determined by Mitchell and Whillier (1971) down to the wet bulb temperatures indicated (still air minimum velocity = .20 m/s)

Temperature (C)	Temperature (F)	rh (%)	Psychrometric Wet Bulb Temperature (C)	Psychrometric Wet Bulb Temperature (F)	Wind Velocity (m/s)	Estimated Specific Cooling Power of Air, (W/m^2)	Cooling Power of Air for a Man of Surface Area = 2 m^2, (W)
25.6	(78)	40	16.7	(62.1)	.20	340	680
					.80	670	1340
					1.20	890	1780
27.8	(82)	40	18.4	(65.2)	.20	315	630
					.80	630	1260
					1.20	800	1600
30.0	(86)	40	20.2	(68.3)	.20	290	580
					.80	600	1200
					1.20	750	1500

"...the basis of most American recommendations on maximum permitted speeds."

The maximum permitted wind speed rises above 26 C (79 F). The ASHRAE provision for extension of the comfort zone above this temperature through the use of air movement implicitly recognizes that the shift in perception of air movement from unpleasant to pleasant is complete above 26 C (79 F).

The level of pleasantness of air movement may be quantified in terms of the temperature increase for which it will compensate. Nishi (1978) reports that an increase of .1 m/s in wind velocity at the baseline (v = 0.1 - 0.15 m/s (30 ft/min), T_a = MRT = 24 C (75 F), rh = 50%, clo = 0.6, M = 1.1 met) will effectively balance a change of 1.1 C (2 F) in ambient temperature. While the level of effectiveness is affected by the position of the fan, whether above the worker or directed at his torso, Nishi fails to mention the position of the fan.

Fanger et. al. (1974) have quantified the effect of wind in terms of preferred temperature. In their words, "On an average, the subjects preferred a temperature 2.3 deg C higher when exposed to a velocity of 0.8 m/s [160 ft/min] than in still air." This preference is the result of averaging the preferences determined for each of all five directions tested by Fanger et. al.. The subjects in this experiment wore 0.6 clo and were exposed to 50% rh. Their results agree within ± 0.2 C with those of Olesen et. al. (1972), with those of Rohles et. al. (1974), and with those predicted by Fanger's own comfort equation. Even then the deviations are all easily explained: the increment in preferred temperature due to velocity (0.8 vs ≤0.1 m/s) determined by Rohles et al, was high (2.4 C), consistent with the fact that his group used an overhead fan, which works against the convective upflow. The increment for Olesen et al. was low (2.0 C), consistent with their use of a uniform air flow. Fanger's comfort equation, too, was derived from results using uniform air flows. In fact, one of Fanger's (1974) own conclusions was that "Besides the mean velocity, the turbulence of the air flow seems to have an influence on man's comfort." Specifically, "...the subjects preferred a higher temperature when the turbulence was increased." Even then he noted that "In practice the air velocities to which man is exposed will seldom be as uniform as those in the experiment [1974]; normally, the air flow will be [even] more turbulent."

Olesen et. al. used a single 27 year old male to obtain an idea of the temperatures required to maintain the condition of comfort. While the "preferred temperature" at an air velocity of 0.8 m/s (158 ft/min) depended upon both the activity level and the amount of clothing worn (See Table 2), the air movement was not felt as a draft and caused no difficulty in creating the sensation of comfort. Table 2 shows that the "preferred temperature" was within the limits of the present experiment for the sedentary activity level. Since the turbulent air flow of the present experiment should be more effective than the laminar air flow employed by Olesen et. al., the least stressful conditions of the present experiment are expected to result in a vote of "neutral", if not "slightly cool".

TABLE 2

Mean preferred air temperatures at an air velocity of 0.8 m/s (158 ft/min) from Olesen et. al. (1972) in Centigrade degrees

Activity level:	Sedentary		Cycling	
Clo value	.1	.6	.1	.6
Air temp ≈ Radiant temp	28.6	26.4	23.8	20.8
Air temp 5 C > Radiant temp	29.8	26.6	25.4	20.0

Fanger (1975) contends that 30 C (86 F) is the ceiling air temperature above which wind is ineffective if the condition to be maintained is that of thermal comfort. Wind is ineffective in reducing the degree of warm discomfort above 35 C (95 F). At this temperature wind begins to increase the convective heat supply to the body, resulting in increased sweating. (According to Fanger (1977), while "cold discomfort is related to skin temperature, ...warm discomfort is more closely related to the wettedness of the skin...".)

Many considerations influence the perception of effectiveness of forced convection

Burton et. al. (1975) seated six male subjects at an office desk beneath an overhead fan. Temperatures studied ranged from 26.3 C (79.4 F) to 29.1 C (84.4 F) at 60% rh and a clo value of approximately 0.4. The subjects were allowed to occupy themselves with reading and writing for a period of three hours. This experiment brought up two significant points. First, while low velocity conditions do not elicit any age effect (Turnquist and Volmer, 1980), Burton et. al. found that age must be considered in any experiment using elevated temperatures and air velocities. As the temperature was increased within the range of the experiment, the older subjects preferred a smaller velocity increase than did the younger subjects. While the age range was only from 44 to 62, the lower basal metabolic rate of the older subjects may have resulted in a reduced need for cooling. Alternatively, older subjects may be more sensitive to wind or to the noise of a fan, as Burton et. al. suggested. The second significant point brought up by Burton et. al. is the possibility that the fan speeds chosen reflect annoyance as well as thermal factors.

While Burton et. al. (1975) made the implicit assumption that the preferred fan speed chosen produced what we now call thermal comfort, McIntyre made direct subjective assessments of "freshness", "pleasantness", and "annoyance", in addition to Thermal Sensation, in a very similar experiment. McIntyre (1978b) determined that there is an upper limit to acceptable air speeds used for cooling. This limit is determined by the interaction between the cooling effect, which increases as the square root of the air speed, and the perceived strength of the air flow, which increases as the square of the air speed. Conditions studied ranged from 22 C (72 F) to 30 C (86 F) at 50% rh using clo values of 0.4 (female) to 0.5 (male). Two inspection tasks were used "...to provide the subject with an activity that required concentration, and in which the disturbance from the fan might cause annoyance." While the experimental method is good enough to point out the interaction between the cooling effect and the perceived air strength, this experiment is of limited interest. McIntyre fails to mention either the negative interaction of the overhead fan with the convective upflow, forgotten by Burton et. al. as well, or the season in which the study was conducted. He mentions that "The fan speeds chosen were less than those necessary to maintain thermal neutrality; the subjects' skin temperatures and warmth votes increased with air temperature." This may be taken as an indication of the interaction between the cooling effect and annoyance with the pressure exerted by the air flow:

> "The disturbance of an air movement above 1 m/s in itself can cause annoyance, so that people given a free choice of air speed tend to under-compensate for a raised air temperature, and act to minimize the combined discomfort of warmth and air movement."(Cena and Clark, 1981)

Alternatively, the low fan speeds selected may be the result of a season or of a climate effect. McIntyre's results are consistent with those expected for a winter test since subjects prefer to be warmer in a cold climate (McIntyre, 1978c) or in the winter (Rohles, 1980).

The convective upflow neglected by Burton et. al. (1975) and by McIntyre (1978b) is generated by the differential between the worker's body temperature and the ambient air temperature. Cena and Clark (1981, p. 70) have contrasted forced convection with convective upflow:

> "When the body is exposed to a wind or is moving through the air, the natural convective boundary-layer flow is displaced and the body loses heat by forced convection. The variables that influence forced convection are the mean air velocity and the nature of the flow (i.e. whether it is laminar or turbulent), and the flow direction. The degree of turbulence and its scale can have a profound effect upon the heat loss."

Comparison of convective heat loss distributions around an oscillating leg versus around a thigh in a unidirectional wind "...equal to the mean velocity of the oscillating leg..." indicate that turbulence can approximately double the overall heat transfer coefficient. (Cena and Clark, 1981, p. 71)

The impact of turbulence on heat transfer is illustrated by work by McIntyre (1978a). He has mentioned that "...fluctuating draughts were found to be very much more disturbing than steady ones of the same average speed." While the term "draught" is applied to drafts of air cool enough to cause local discomfort, we may nevertheless discern from this that a fluctuating air speed should be much more effective in cooling than a wind of the same average speed. For this reason it is necessary "...to give a measure of the variability of the air speed, as well as its average value,..." as McIntyre suggested in his research on draughts.

Since the wind from a fan is turbulent, a box fan should provide more efficient cooling than the uniform air flows used in previous studies dealing with forced convection. Moreover, those studies employing downflowing air streams are of limited use since such air streams work against and even hinder the natural convective flow patterns (Cena and Clark, 1981, p. 73). Overhead fans are fine for tropical locale, where the ambient temperature often meets or exceeds skin temperature, resulting in zero convective upflow. But then the fans promote cooling through acceleration of sweat evaporation rather than through acceleration of convective cooling. Otherwise, these natural convective currents reach 0.5 m/s (100 ft/min) over the face when standing (Cena and Clark, 1981, p. 69): According to Fanger and Valbjorn (1979), the degree of detectability of air movement is temperature dependent. They say that "...a nude man in 15 ^{o}C [59 F] air generates a convective plume with speeds up to 0.5 m/s [100 ft/min]. In normal comfortable surroundings a speed over the head of up to 0.25 m/s [50 ft/min] may be found." If "still air" is characterized by the nonperception of local movement of air by 95% of the population, then 0.35 m/s [70 ft/min] is its maximum speed.

McIntyre(1978a) provides values for the natural convective upflow nearly the same as those of Fanger and Valbjorn (1979). According to McIntyre, the speed of the natural convective flow of air over the head lies in the range from 0.2 to 0.25 m/s and defines the border of the threshold of human detectability of air speed. This range is lower than that given by Cena and Clark (1981). But McIntyre's range of 0.01 to 0.05 m/s for "still" air is lower than that found elsewhere as well. So while we may take the range of 0.2 to 0.25 m/s as the lower limit of convective upflow and 0.5 m/s as the upper limit of convective upflow, the range of 0.25 m/s to 0.35 m/s appears to provide the best set of working values.

Cena and Clark (1981, p. 213) mention studies by McIntyre (1978) and by Houghten et. al. (1938) which, taken together, indicate the importance of penetrating the boundary layer composing the convective upflow if the worker is to be influenced. Extension of this information to the box fan indicates that a box fan must be situated to penetrate the boundary layer to be maximally effective. Even if penetration of the boundary layer is not achieved, the fan should at least supplement the natural convective flow pattern. Thus, its air stream must be directed along the horizontal or even from the floor along an upward slant.

The natural convective flow pattern is not the only factor that must be considered in determining fan placement. Temming and Hucho

(1979) point out that the maximum cooling sensation can be obtained from a limited volumetric air flow by directing it primarily at the head, chest, and abdominal regions, where it will reach the largest number of cold receptors and also produce the greatest heat dissipation. Their suggestion of directing the air flow at the torso is followed in the present study.

Rohles et. al. (1974) performed an experiment which clearly indicated the impact of convective upflow on comfort. Subjects (45 of each sex) dressed in 0.6 clo were exposed to a ceiling-to-floor uniform air flow for a period of three hours in groups of ten at 50% rh. As the dry bulb temperature was raised from 22.2 C (72 F) to 29.6 C (85.2 F), the mean affective responses decreased consistently when the air velocity was only 0.2 m/s (40 ft/min), but increased at the air velocities of 0.4 m/s (80 ft/min) and 0.8 m/s (160 ft/min). (See Figure 1.) At an ET^* of 29.4 C (85 F), the air velocity recommended to maintain thermal comfort was 1.6 m/s (310 ft/min). The present experiment uses a turbulent air flow that works with the convective upflow (at least 0.2 m/s), so the wind velocity required to maintain thermal comfort should be below 1.4 m/s (280 ft/min).

Preference of wind level is situation-dependent

Air movement has associated with it several beneficial aspects. The advantage of air movement in providing an "odor-free" environment and in reducing the concentration of micro-organisms on and near the body surface has been well recognized (Woods, 1978). The psychological aspects of air movement in combination with other outside factors are

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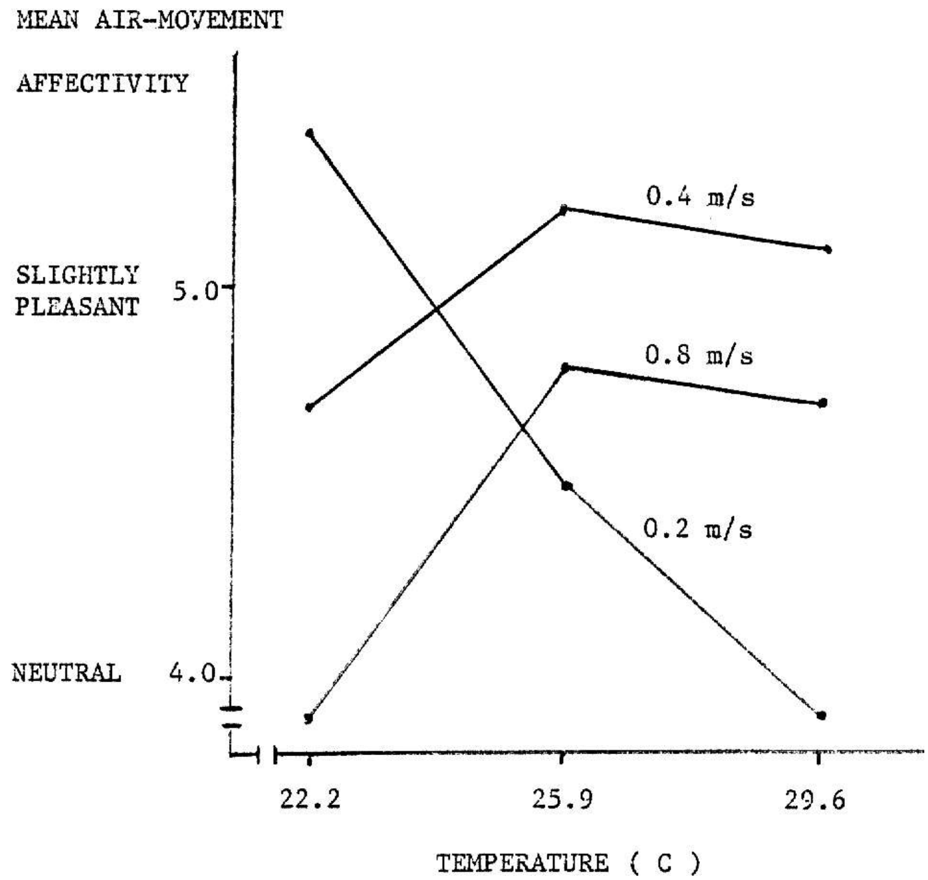

Figure 1. Mean affective responses of sedentary subjects exposed for 3 hours to 3 air movement levels under 3 temperature conditions after Rohles et. al. (1974). A ceiling-to-floor uniform air flow was used.

great enough to lead people to overexpose themselves to the environment, leading to hypothermia which in turn lowers resistance to infection, resulting in a cold or the flu. Thus, as Fanger and Valbjorn (1979) say, "There is no doubt that air movement can be pleasant. Unfortunately it seems to be impossible to choose an air speed and temperature that will be pleasant simultaneously to a large group of people."

The ASHRAE standards have tried to incorporate air speeds appropriate for a wide temperature range in order to satisfy as many people as practical. Berglund (1980) indicates that the proposed revision in ASHRAE standards for maximum mean air movement in the summer is 0.25 m/s (50 ft/min) within the comfort zone. Further, "As an energy conserving incentive for warm summer environments, the recent revision allows the temperature to be raised above the upper limit of 79 °F (26 °C) if the maximum average air movement is increased 30 fpm (0.275 m/s) for each degree F of increase to an absolute maximum air movement of 160 fpm (0.8 m/s) at 82.5 °F (28 °C). At 160 fpm loose paper may start to fly."

While the disturbance of loose paper may be annoying, 0.8 m/s (160 ft/min) is not a very high wind velocity in everyday terms. McIntyre (1978a) characterizes air speeds of 1.1 m/s to 2.0 m/s (220 ft/min to 400 ft/min) as a "light breeze". He remarks that while "Light papers blow from desk," this range is also a "Normal walking speed." Thus, the maximum speed of 2.0 m/s (320 ft/min) of the present study can hardly be characterized as extreme. Considering that air velocities of 18.8 m/s (3,700 ft/min) were common in the glass industry in 1968, it does not seem to be unreasonable to increase the formal ceiling on air velocity from 0.8 m/s (160 ft/min) to 1.2 m/s (240 ft/min).

The advantage of air cooling has been well recognized in some segments of the commercial world. According to Robertson (1976), vice president of an Australian commercial concern, "...progressive management is aware of the benefits of comfort conditions and the certainty of a return on investment in comfort cooling." He draws from the ASHRAE Guide and Data Book, saying, "Production declines in uncooled plants may range anywhere from 25 to 40 percent of normal on hot days." While his paper is concerned primarily with evaporative cooling, he brings up the point that "...the amount of 'target' air velocity determines the final level of comfort cooling." Further, says Robertson, "The concept of using target air velocity rather than avoiding it has to be accepted before effective industrial evaporative cooling projects can be designed." He goes on to recommend a maximum target velocity of 1.0 to 1.3 m/s (200 to 250 ft/min) for both sedentary work stations and light weight production. Thus, one industrial expert has committed himself to favoring a maximum target velocity above the ASHRAE limit of 0.8 m/s (160 ft/min). Further, Robertson is in favor of placing control in the hands of the worker: "The diffuser should be arranged so that the 'target' can adjust the air velocity and direction to suit his own needs." It is a very small step to apply all of these remarks directly to personal cooling using box fans. Box fans even overcome the final objection against evaporative cooling: while "...the initial cost advantage of evaporative cooling [over refrigerated air conditioning] fades away when the system becomes over designed,..." it is not possible to over design a cooling arrangement that uses box fans.

Hanjra (1978) performed an experiment in which he used air velocities above the current ASHRAE limit of 0.8 m/s (160 ft/min). He exposed two subjects to turbulent air flows at 32 C DBT, 55% rh, and a metabolic rate of 190 W. He found that "Both subjects preferred the highest air velocity 3.2 m/s [630 ft/min] as being 'pleasant' and 'cooler' on the air movement and thermal sensation voting scales." The lower relative humidity, lower temperatures, and the lower metabolic rate of about 132 W combine to offset the lower wind velocity in the present experiment. Thus, even the highest wind velocity of 2.0 m/s [320 ft/min] in the present experiment is expected to be perceived as "pleasant".

Directional preference must be considered. Fanger et. al. (1974) in an experiment referred to earlier found "No significant difference between the ambient temperatures the subjects preferred when they were exposed to air flows from different directions." The five directions for the wind source included the front, the right side, the back, below, and above the subject.

Hanjra (1978) found that "Subjects preferred air to be directed from the front or side, but not from the back." Rosen (1980) using 40 male subjects at 28 C (82 F) and 40% rh confirmed a population preference to have a turbulent flow averaging 0.7 m/s (140 ft/min) impinging on the front, particularly on the right front of the worker. Rosen found that no one orientation is disliked by everyone and, moreover, that every direction is preferred by someone.

TABLE 3

Thermal Sensation Votes (TSV) on 7-category scale expected at each hour for men and women dressed at 0.6 clo for those environments defined by Woods and Rohles (1972) which are relevant to the present experiment

Dry Bulb Temp	(F)	78	82	86
	(C)	25.6	27.8	30.0
Dew Point Temp	(F)	55.11	58.76	62.40
	(C)	12.84	14.87	16.89
Wet Bulb Temp	(F)	63.5	66.7	69.9
	(C)	17.5	19.3	21.1
rh	(%)	45.24	45.28	45.31
Old ET	(F)	71.81	74.74	77.62
	(C)	22.12	23.74	25.34
Gagge's ET*	(F)	77.78	81.62	85.41
	(C)	25.43	27.57	29.67
TSV	t = 1.0 hr	4.1	4.7	5.3
	t = 2.0 hr	4.1	4.7	5.3
	t = 3.0 hr	4.1	4.7	5.3

There is some ambiguity in the use of comfort votes

Table 3 displays the environmental parameters of the present study. The old effective temperature (Old ET) is given for convenience. It takes air movement into account, along with temperature and relative humidity. The combined effect of these three factors on human perception was expressed in terms of an arbitrary index based on still, saturated air. A chart of Old ET was first printed in ASHVE Transactions (31, 1925).

Expected values for the thermal sensation votes (TSV) on the 7-category scale for the present study are included in Table 3. These values were calculated from equations developed by Rohles and Nevins (1971).

More recently derived equations predict a change in TSV over time. Table 4 shows that the subjects should be expected to feel cooler the longer they stay in the environments indicated. The discussion section of the paper including the equations from which the TSV values are derived includes a comment by Fanger that those equations fit the data better than the earlier equations of Rohles and Nevins (1971), upon which the TSV values of Table 3 are based. Thus, the values for TSV given in Table 4 are more reliable as a check on the control condition of the present experiment, but are not expected to coincide with it since the clo value used to obtain the TSV values in Table 4 is too high.

The clothing ensemble for this experiment includes a light short sleeve shirt (0.14 clo), light trousers (0.26 clo), briefs for men or bra and panties for women (0.05 clo), ankle length socks (0.04 clo),

TABLE 4

Predicted Thermal Sensation Votes (TSV) on the 7-category scale (1=cold, 4=comfortable, 7=hot) in still air at 45% rh based on equations of Rohles et. al. (1975) for subjects dressed at .6 clo

DBT	(C)	25.6	27.8	30.0	SE
ET*	(C)	25.43	27.57	29.67	est.
Male	1.0 hrs	4.42	5.15	5.86	.83
	2.0 hrs	4.05	4.66	5.26	.78
	3.0 hrs	3.95	4.58	5.19	.82
Female	1.0 hrs	4.08	5.02	5.95	.89
	2.0 hrs	3.87	4.70	5.52	.92
	3.0 hrs	3.82	4.65	5.47	.90
Combined	1.0 hrs	4.28	5.16	6.01	.89
	2.0 hrs	3.98	4.71	5.43	.88
	3.0 hrs	3.84	4.54	5.22	.89

and shoes (0.04 clo). The clo value of the ensemble is 0.43;

$$I_{cl} = 0.82 * Sum = 0.82 * 0.53 = 0.43$$

The effective temperature at which the subjects should be closest to neutral on the TS scale is given by the equation presented by Rohles, Konz, and Munson (1980): $CET^* = 29.75 - 7.28 * I_{cl}$

$$CET^* = 26.6 \quad (= 80\ FET^*).$$

On this basis, subjects are expected to vote on the cool side of neutral when in the 25.6 C (78 F) DBT control condition. Subjects are expected to vote on the warm side of neutral when in the 27.8 C (82 F) and 30 C (86 F) DBT control conditions. (In fact, the subjects voted on the warm side of neutral in all three "still air" control conditions.)

The 9-category Thermal Sensation Scale used by Rohles and Wells (1977) should be used. In this way, direct comparison of changes in Thermal Comfort with changes in Thermal Sensation may be made. As Figure 2 shows, the center point of this scale is "neutral", rather than "comfortable". Consequently, confusion of the Thermal Sensation Scale with the Thermal Comfort Scale is eliminated.

It is important to recognize that these scales have meaning only in the narrow range of direct human thermal experience. The very manner in which these scales are laid out implies the existence of other categories irrelevant to the experiment at hand. This is borne out by the vote distributions heavily skewed to the extreme categories of the 7-category scale in Rohles' classic experiment (1970b) at the temperature extremes of the experiment, 15.6 C (60 F) and 36.7 C (98 F). The fact that the extreme categories of the 7-category scale are heavily preferred at such moderate temperatures indicates that the 7-category

7 Category Scale		9 Category Scale	
		1	very cold
cold	1	2	cold
cool	2	3	cool
slightly cool	3	4	slightly cool
comfortable	4	5	neutral
slightly warm	5	6	slightly warm
warm	6	7	warm
hot	7	8	hot
		9	very hot

Figure 2. Comparison of Thermal Sensation Scales.

scale has a very limited range. It is applicable only to mildly stressful conditions. Though Rohles and Wells (1977) provided a precedent for scale conversion followed to a limited extent by Rosen (1980), scale conversion by multiplication by 9/7 is improper on the Thermal Sensation Scale. The 7-category scale drops off before the 9-category scale, so has a more limited range of subjective assessment. It is true that voting in the neutral region of the scale may be more likely to diverge from neutral on the 9-category scale than on the 7-category scale. But this effect is counterbalanced by the impact of the nearly identical labeling on the subjective assessment of the environment in the range where the two scales overlap.

Ambiguity in subjective assessment is especially critical in the neutral condition. To quote Fanger (1977),

> "In agreement with ASHRAE's Standard 55-74..., thermal comfort for a person is here defined as 'that condition of mind which expressed satisfaction with the thermal environment.' This means that he feels thermally neutral for the body as a whole, i.e., he does not know whether he would prefer a higher or lower ambient temperature." (Underlining added)

The indecisiveness which is accepted by Fanger as characteristic of the condition of thermal comfort could lead people who are thermally comfortable to vote to have a higher or lower ambient temperature than they really want. This indecision could also lead people who are thermally comfortable to vote that they are more or less comfortable than they really are.

The indecision characteristic of the condition of thermal comfort complicates the subjective assessment of air movement. Madsen (1980) states...

> "A number of climatic chamber tests ...have shown that human beings will tolerate appriciably [sic] asymmetrical thermal fields. Nevertheless, it is common experience that people often complain of undesirable local cooling in everyday environments. This conflict probably arises because the human subjects are, as a rule, kept in overall thermal comfort during such climate chamber tests where they are exposed to asymmetrical thermal fields."

Similarly, people exposed to objectionable air movement in an otherwise uniform, comfortable environment may be predisposed to rate the environment highly and discount the nuisance of the wind.

The ideal vote analysis must allow for the uncertainty in the subjects' assessment of the environment. Two methods of vote analysis allow for these uncertainties. One method gaining broad acceptance is the determination of the Predicted Percent Dissatisfied (PPD) with the environment. The other method follows the philosophy of the one-tailed t-test and includes in the Predicted Percent Comfortable (PPC) all ballots opposite the direction of dissatisfaction. Thus, all votes of "comfortable" or cooler (less than or equal to 5 on the 9-category scale) in the warm environments of the present experiment are included in the PPC. Rohles' data (1970b) has been reduced to these forms to provide a useful check on the control conditions for each of the three temperatures used in the present experiment (See Table 5). The present experiment uses only 0.43 clo, rather than 0.6 clo, so the PPC should be higher and the PPD lower than the values indicated in Table 5.

TABLE 5

Votes of "comfortable" or cooler (≤4) and the corresponding Predicted Percent Comfortable (PPC) on the 7-category Thermal Sensation Scale in still air for 25 men and 25 women tested at rh≥45% at 0.6 clo. Predicted Percent Dissatisfied (PPD) is also shown.

Time	DBT	Men (25 S's total)				Women (25 S's total)				Total (50 S's total)				Expected Frequency for all 8 S's	
(hrs)	(C)	≤4	PPC	<3,>5	PPD	≤4	PPC	<3,>5	PPD	≤4	PPC	<3,>5	PPD	Votes ≤4	Votes <3,>5
1.0	25.6	12	48	3	12	14	56	5	20	26	52	8	16	4.2	1.3
	27.8	3	12	13	52	4	16	12	48	7	14	25	50	1.1	4.0
	30.0	2	8	16	64	0	0	17	68	2	4	33	66	0.3	5.3
1.5	25.6	13	52	1	4	15	60	3	12	28	56	4	8	4.5	0.6
	27.8	6	24	11	44	7	28	4	16	13	26	15	30	2.1	2.4
	30.0	1	4	14	56	1	4	16	64	2	4	30	60	0.3	4.8
2.0	25.6	18	72	2	8	20	80	6	24	38	76	8	16	6.1	1.3
	27.8	11	44	5	20	8	32	4	16	19	38	9	18	1.3	1.4
	30.0	3	12	9	36	0	0	14	56	3	6	23	46	0.5	3.7
2.5	25.6	18	72	3	12	15	60	1	4	33	66	4	8	5.3	0.6
	27.8	8	32	9	36	8	32	4	16	16	32	13	26	2.6	2.1
	30.0	5	20	6	24	1	4	14	56	6	12	20	40	1.0	3.2
3.0	25.6	19	76	1	4	17	68	2	8	36	72	3	6	5.8	0.5
	27.8	8	32	6	24	7	28	8	32	15	30	14	28	2.4	2.2
	30.0	8	32	8	32	3	12	10	40	11	22	18	36	1.8	2.9
Mean	25.6	16.0	64	2.0	8	16.2	65	3.4	14	32.2	64	5.4	11	5.1	0.9
	27.8	7.2	29	8.8	35	6.8	27	6.4	26	14.0	28	15.2	30	2.2	2.4
	30.0	3.8	15	10.6	42	1.0	4	14.2	57	4.8	10	24.8	50	0.8	4.0

A precedent for grouping Thermal Comfort Votes as well as Thermal Sensation Votes already exists. When Gagge used a 4-point comfort scale ("comfortable", "slightly uncomfortable", "uncomfortable", and "very uncomfortable"), "...the comfortable and slightly uncomfortable responses were lumped together to determine the percent comfortable of all responses." (Berglund, 1979)

Affective considerations are important in near-neutral thermal environments

Weather affects our outlook on the world. One study will be cited for the disbeliever. Helsing and Markush (1976) working in the Community Mental Health Epidemiology Program in Washington County, MD, found that hot weather had an adverse effect "...significant at the $p<.01$ level on the CES-Depression scale." Their "...data suggest that a late summer heat wave in a small eastern U. S. county had both physiological and psychological effects on the population." While a psychological effect this acute is unexpected in a short experiment, Howell and Kennedy (1979) have pointed out that "Even in laboratory settings it has been shown that comfort judgments reflect psychological as well as physical factors (Rohles, 1971)."

One experiment demonstrating the influence of psychological factors on comfort judgments was performed by Rohles and Wells (1977). Using a 9-category Thermal Sensation Scale at 23.3 CET* (74 FET*) in an air velocity of 0.20 m/s (40 ft/min) at 0.76 clo, they found "...that room decor could influence the thermal sensation." They determined, more specifically, that "...even if comfort is unaffected, the thermal sensation is definitely raised in the embellished environment." It is true that the insulating (clo) value of the "orange 'Swan' chairs (Arne Jacobsen)" used in the Modified Sherer Chamber may have been higher than that of the wooden tablet arm chairs used in the Standard Sherer Chamber in their experiment. In their judgment, however, "...the thermal sensation at least in the thermally neutral environment is a pure psychological reaction."

Before we limit our consideration of psychological reactions to thermally neutral environments, we must recall that the characteristics of a "thermally neutral environment" are themselves inconstant over time. Rohles (1980b) recently summarized the history of fluctuation of ASHVE recommendations for winter:

> "Many of the readers will recall that as long ago as 1924, ASHVE recommended 17.8 ^{o}C (64 ^{o}F) for a winter comfort condition. This was raised to 18.9 ^{o}C (66 ^{o}F) in 1925. By 1941, it was up to 20.0 ^{o}C (68 ^{o}F) and was 25.0 ^{o}C (77 ^{o}F) in 1960. The explanation offered for this upward trend is given in a paper by McNall, Ryan, and Jaax... who suggest that it is attributable to the widespread use of lighter clothing and [to] the increase in well-designed heating systems."

Berglund (1979) supports the opinion of McNall, Ryan, and Jaax when he observes that "The optimum temperature for office spaces is mainly a function of the occupant's clothing which is influenced by or chosen for the season and outside conditions." Nevertheless, the possibility of psychological adaptation must be considered. Just as Rohles' summary indicated that the process of psychological adaptation may alter the temperature range we prefer for comfort in winter, so may it operate in the summer as well.

Though psychological variables have been given little attention, Howell and Kennedy (1979) stated that they play a key role in determining thermal comfort... "Criteria relying exclusively on physical parameters are severely limited; 'psychological' factors can substantially extend the range of acceptable conditions." This fact has been recognized by Buskirk and Loomis (1977). They pointed out that "...there are important aspects of the thermal environment of consequence to workers and their employers other than comfort or thermal sensation considerations." To take the example of a basketball game, "The mental involvement with the contest overwhelms the comfort or thermal sensation evaluating mechanisms." They concluded that "The definition of 'too cool' and 'too warm' should be redetermined using tolerance/productivity criteria," where tolerance limits are defined "...as those extreme conditions which produce no significant degradation of performance within the allowable period of time. Thus the variable of mental involvement must be considered. In fact, Rohles working with Milliken, Skipton, and Krstic (1980) indicated that mental tasks should be incorporated into the procedure of future tests dealing with thermal comfort.

Howell and Kennedy (1979) have mentioned the possibility "...that some individuals would consider as most pleasant or 'comfortable' a condition that they rated cool or warm (categories which Fanger incorporates in his 'percent dissatisfied' index)." Berglund (1979) pointed to the same possibility in his remark that "A person feeling slightly cool or warm may not be dissatisfied or uncomfortable and the environment may still be thermally acceptable." This possibility was independently developed and proved by Rosen (1980). Rosen determined that in the summer people exposed to an environment of 28 C (82 F) at 40% rh dressed in 0.6 clo exposed to a wind velocity of 0.7 m/s (140 ft/min) tended to associate thermal comfort with a thermal sensation significantly shifted in the direction of "slightly cool". It is the opinion of this worker that the relationship between thermal comfort and thermal sensation is in the reverse direction in the winter. Howell and Kennedy have brought up the point that the findings of Griffiths and Boyce (1971) "...suggest that the highest comfort ratings occur at temperatures judged to be slightly cool rather than at the neutral point." Unfortunately, Griffiths and Boyce fail to mention the season in which their study was made.

McIntyre (1978c) contrasted experiments in Capenhurst in winter and in New Haven in the summer. He indicated that "In a cold climate people want to be 'warm'; they do not dream of a room somewhere which is thermally neutral. Conversely, in a hot climate 'cool' is seen as the desired state." He concluded, "It appears that the neutral temperature is higher than the preferred temperature in warm climates, and lower in cold climates." (Similarly, we should expect the analagous neutral fan velocity to be lower than the analagous preferred fan velocity in warm weather, and higher in cold weather.) Thus, the season in which a study is made can affect the associations we make with thermal comfort.

Rohles and Wallis (1979) found that "In tests conducted in the summer and the winter, the subjects tested in the winter exhibited a thermal sensation response that was higher than [that of] the subjects who were tested in the summer..." Specifically, "The average ratings for the 84 subjects tested in the winter (February, 1977) was approximately one-third of a rating warmer than the 84 subjects who were tested in the summer (August, 1976)..." These results led to a recommendation that tests evaluating automobile air conditioning systems be conducted in the summer. Since forced convection is most used in the summer, the summer is the best time to conduct tests involving subjective assessment of air movement of any sort.

In a later study Rohles (1980b) confirmed that "...the way in which an individual responds to warm or cool temperatures differs in the winter and in the summer." In this study we find the comment, "In short, the results of this single and somewhat limited study suggest that we like cool temperatures in the summer and warm temperatures in the winter." This study also reported that vote variability "...is highest around the temperature judged to be comfortable and serves as proof not only of the difficulty involved in thermal comfort measurement but /‾also of_/ the important role that is played by individual differences."

Rohles (1980a) found significant season by temperature interactions using both "...a 9 category Thermal Sensation ballot and a 7-pair semantic differential scale for measuring Thermal Comfort." His "... 31.7 C /‾89 F_/ environment was judged to be more comfortable in the winter than in the summer." The mean difference in perception of warmth in the winter was ((7.0-6.6)/9.0)*(100%) = 4.4% less than that in the summer, using the Thermal Sensation Scale. The mean increase in thermal comfort in the winter over that perceived during the summer of ((33.4-27.3)/63.0)*(100%) = 9.7% of the entire range on the Thermal Comfort Scale indicates that people are predisposed to accept a warm environment in the winter. (Rohles has thus provided the basis for an analytical explanation of spring fever.) Lest this conclusion be in doubt, Rohles' figures showed even more clearly that people are predisposed to accept a cool environment in the summer. Thus, the outside environment can affect a person's very perception of the inside environment. Conflicting work on this subject (McNall et. al., 1968) indicates, however, that the effect is small. Consequently, the results of the present experiment performed in the spring (1981) should be acceptable with respect to the time of year in which such a study should be performed.

Using data from Columbia, Missouri, Emanuel and Hulsey (1978) found that "...the maximum air temperature occurred on July 20, approximately 27 days after the longest day." So although the present experiment is conducted in the spring rather than in the summer, it is performed within two months of the most likely day for the maximum air temperature.

Activity seems to potentiate the influence of season on thermal sensitivity. McIntyre and Gonzalez (1976) found that season had a significant effect on thermal sensitivity when their subjects exercised on bicycle ergometers at a work rate of 44 watts. When their subjects were resting they could find no significant influence of season on thermal sensitivity ("seasons" = June and August). All of their work was done at 26.7 C (80 F) using a clo value of 1.1, but humidity was neither controlled nor reported. The clo value and the activity level are lower in the present experiment, while the temperature is within 3.3 C (6 F). Thus, it appears acceptable to conduct the present experiment in the spring.

A behavioral approach should minimize the effect of individual differences

Parsons (1979) has suggested that people's behavior may provide a more sensitive measure of the various nonquantifiable factors in the environment than what they say they feel. In his words, "Behavioral data may provide a superior index of human tolerance to temperature deviations and changes." A behavioral approach has been utilized effectively already by Fanger and McIntyre.

Fanger's (1975) concern with radiant or convective spot cooling resulted in the viewpoint that individual differences are important enough that the individual worker should be able to adjust his own level of personal cooling. This remark warrants consideration with respect to personal cooling with fans. Thus, the participant should be allowed to choose the distance from the fan that best suits him.

McIntyre (1975, 1978c) followed Fanger's example of directly determining the preferred condition in the determination of the so-called "preferred temperature." According to McIntyre (1978c),

> "The method of direct determination finds that individuals are very reliable, and that the preferred temperature of different groups of people is the same, whatever the general thermal experience of the group... With this method the subject sits by himself in an environmental chamber. He is asked at frequent intervals whether he would like any change in temperature, which is then provided by the experimenter. The subject thus brings the chamber temperature to his own preferred temperature, which is normally taken as the average temperature over the last 2 hr of a 3-hr experiment. The technique produces a single measure."

In a similar manner we may determine an analagous preferred velocity for each subject, defined as the average velocity over the last 2 hr of a 3-hr experiment. It is in his 1975 report that McIntyre mentions that his subjects were allowed to wear their own clothes, including trousers and long sleeved shirts. He found "...no reason to suppose that the standard deviation of 1.8 deg C in preferred temperature would have been reduced by employing standard clothing." Thus, the current experiment could allow the participants to wear their own clothing as well as to select their own preferred distance from the fan in order to control the wind speed.

Both Burton et. al. (1975) and McIntyre (1978b) attempted the direct determination of the preferred wind speed. While these experiments have already been criticized for their use of an overhead fan, they set the precedent of fixing the temperature for each run, allowing each subject to adjust the air velocity himself. As Burton et. al. explained, "The reason for this is that changes in air velocity can be made relatively quickly and independently of the room temperature." A similar approach has been adopted in the present experiment by allowing the subject to choose the best distance from the fan for the last half hour of each day's run. Although some day to day variability is expected for each subject, Fanger (1977) claims that "...the comfort conditions for the individual can be reproduced and will vary only slightly from day to day."

Van Hole (1971) controlled the air velocity at the work station by varying the distance of the fan from the work station. His placement of fans parallel to one another blowing in the same direction produced a turbulent flow when the distance was increased (p. 30). To avoid this interaction, the fans in the present experiment are aligned in opposite directions, as shown in Figure 3.

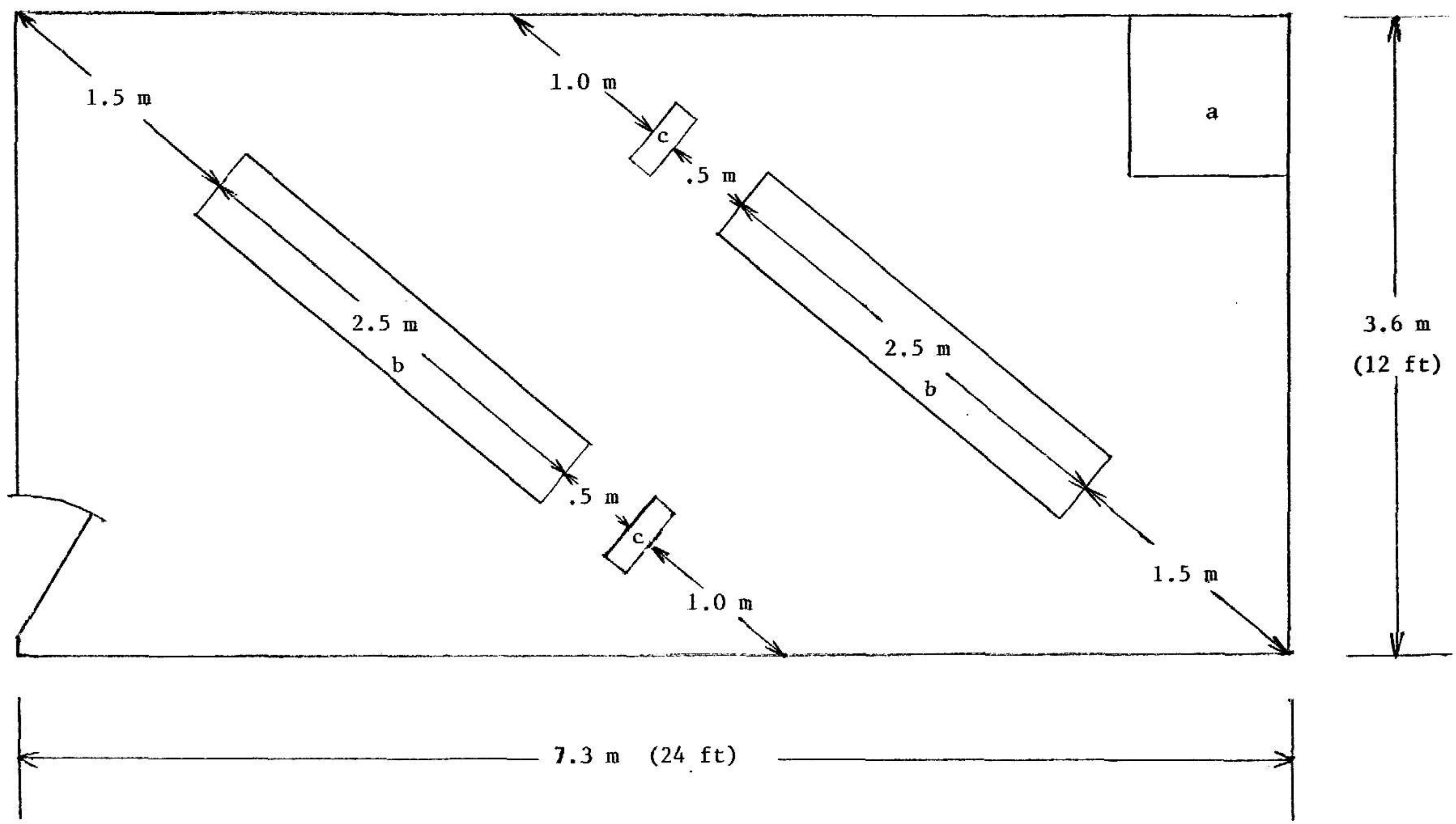

Figure 3. Diagram of test chamber. Key: (a)recorder's position, (b)range of subject positions, (c)fan position. Ceiling height 3.2 m (10.5 ft).

PROBLEM

Previous comfort studies have concerned themselves primarily with non-turbulent air flow, usually overhead, and have used sedentary subjects. Those studies which have dealt with non-sedentary situations have concentrated on physiological response, nearly neglecting subjective response. This study uses subjective measures to determine the best place to seat a worker with respect to a box fan. Considerations of sex and the type of task are included. Each subject in this study is actively engaged in different successive tasks, under several different environmental conditions.

METHOD

Task

Subjects sat in the KSU-ASHRAE chamber for three hours at a time. While in this room each subject alternately performed a pegboard task and a paperwork task 6 times each. The pegboard task involved moving each of 39 golf tees arranged in a square configuration one space counterclockwise. The arrangement is shown in Appendix A. The paperwork task is presented with its description in Appendix B. Each of the 6 task runs was allotted 10 minutes. After each task run 5 minutes were allotted to mark the two ballots shown in Appendix C. This combination of performing one task and casting one set of ballots is referred to as a "trial" as a matter of convenience. Subjects were asked to do all work at a rate which they felt they could maintain for an 8-hour workday, paid by the hour (Appendix D).

Subjects

Eight subjects participated, including four males and four females. Each subject reported residency within the continental United States for at least 60 days, as indicated in Appendix E. Each subject received $70 for his participation at the end of the experiment. One of the original subjects wore contact lenses. Her eyes dried up at any distance from the fan. For this reason she dropped out of the experiment. Thus, the subject population specifically excludes wearers of contact lenses.

Procedure and Experimental Design

Subject solicitation. Subjects were solicited through a classified ad in the Kansas State Collegian. This ad asked them to sign up at the Institute for Environmental Research (IER), where the sign up sheet shown in Appendix E was posted.

Subject intake and test chamber entry. Upon appearing at the IER, subjects who were not properly dressed were asked to change into the attire specified in Appendix E. Then the subjects entered the KSU-ASHRAE chamber. This room measures 3.6 m by 7.3 m (12 ft by 24 ft) and at the time of the study was carpeted but had white gypsum walls. Eight 1.2 m (4 ft) fluorescent fixtures behind 21.6 cm (8.5 in) valances along both sides of the 7.3 m (24 ft) walls provided a uniform lighting of 14 ft-candles, measured using a model 408 Simpson Illumination Level Meter.

Subjects were seated in front of a box fan set on "Off", as shown in Figure 4. Chairs had backs and cushions and were adjusted to provide a seat height 43 cm (17 in) or 41 cm (16 in) above the surface of the floor for men and women, respectively, following Bennett's figures for the medians. Release forms, shown in Appendix F, and personal data forms, shown in Appendix G, were filled out on the first day. Then each subject was given a copy of the detailed Subject's Instruction Sheet, shown in Appendix D, to read along with the experimenter reading aloud.

Daily runs. The experimental design for condition exposure on any given day is displayed in Appendix H. Subject codes were determined by the order of participation in the experiment. Names and phone numbers appeared only on the Personal Data Form and on a disbursement accounting form required by Kansas State University. The order of presentation of conditions was balanced, following the example set by McIntyre (1978b).

Experimental protocol. The first two "trials" of the first day were practice runs. On later days subjects were allowed to read or write during the corresponding first half-hour period. Following Rohles'

Figure 4. Experimental set-up: Subjects, engaged in the maze task, are seated 1.5 m from the fans, the experimenter in the corner. Tic marks on the rug are 0.5 m apart. Note the pegboard in the foreground.

experimental procedure, ballots in all "trials" were collected, so that no ballot could be referred to later on in the experiment. The two ballots shown in Appendix C were printed back-to-back to minimize cross-checking. Subjects faced the fan in all "trials". A measure of production during each 10-minute interval was provided by the number of triangles filled in as described in Appendix B for the paperwork task. The corresponding measure of production on the pegboard task was the number of times (number of pegs moved) around the pegboard. A daily log was constructed to record this information as well as to help the experimenter run the experiment (Appendix I). Subjects were allowed to talk with each other while engaged in these tasks. Subjects were allowed to drink as much water as they wanted in the period between tasks after casting their ballots.

Predetermined distance from fan. The fan was set on "Off" for each day's half-hour acclimation period. For the next 2 hours subjects were exposed to a predetermined condition. (Appendix H shows the experimental design for the predetermined conditions; Appendix K shows the alterations necessary to accomodate 3 makeup runs.) Subjects sat near to (1.5 m) the fan, set on "Off", for the control runs. For runs using the fan, subjects were asked to sit either near to (1.5 m) or far from (3.0 m) the fan, always set on "Low". An Alnor Series 6000 P velometer was used to take the air velocity measurements presented in Table 6. Air velocity measurements of 1.5 m/s and below were taken in conjunction with an Alnor Type 6050 P probe. Measurements of over 1.5 m/s were taken using a Type 6060 P pitot probe in combination with a Type 6030 CP velocity selector. The values for the time-weighted averages are presented in the context of the

TABLE 6

Air velocity measurements in m/s for two model 204001 Edison 20 in. box fans, types B and C, set on the lower of two available speed settings and raised 46 cm (18 in) above the surface of the floor

Distance from fan	Position	High (m/s) B	High (m/s) C	Low (m/s) B	Low (m/s) C	Time-Weighted Average (m/s) B	Time-Weighted Average (m/s) C	Fluctuation (%± of Avg) B	Fluctuation (%± of Avg) C
0.5 m	Center	2.3	2.2	0.4	1.7	1.2	2.0	90	10
(1' 8")	Right	0.9	2.3	0.0	0.6	0.4	1.3	120	80
	Left	0.1	1.7	neg	1.1	0.0	1.3	-	30
1.0 m	Center	2.5	1.7	1.4	0.6	2.0	1.4	30	60
(3' 3")	Right	1.4	3.2	0.2	1.6	0.7	2.4	100	30
	Left	0.7	1.7	0.1	1.0	0.4	1.4	80	30
1.5 m	Center	1.8	1.6	0.8	0.7	1.4	1.2	40	40
(4' 11")	Right	1.5	2.2	0.1	1.2	0.9	1.6	90	40
	Left	1.1	1.5	0.2	1.0	0.6	1.4	80	30
2.0 m	Center	1.6	1.2	0.7	0.6	1.4	0.9	50	30
(6' 7")	Right	1.4	1.5	0.1	0.6	0.9	1.0	90	50
	Left	1.5	1.5	0.6	0.2	1.0	0.8	50	90
2.5 m	Center	1.5	1.0	1.0	0.4	1.4	0.7	30	40
(8' 2")	Right	1.4	1.3	0.3	0.2	0.9	0.6	70	110
	Left	1.3	0.9	0.4	0.2	0.8	0.5	60	70
3.0 m	Center	1.5	0.7	0.7	0.1	1.3	0.4	40	75
(9' 10")	Right	1.3	0.5	0.3	0.1	0.9	0.3	70	70
	Left	1.2	0.7	0.2	0.1	0.7	0.4	70	75

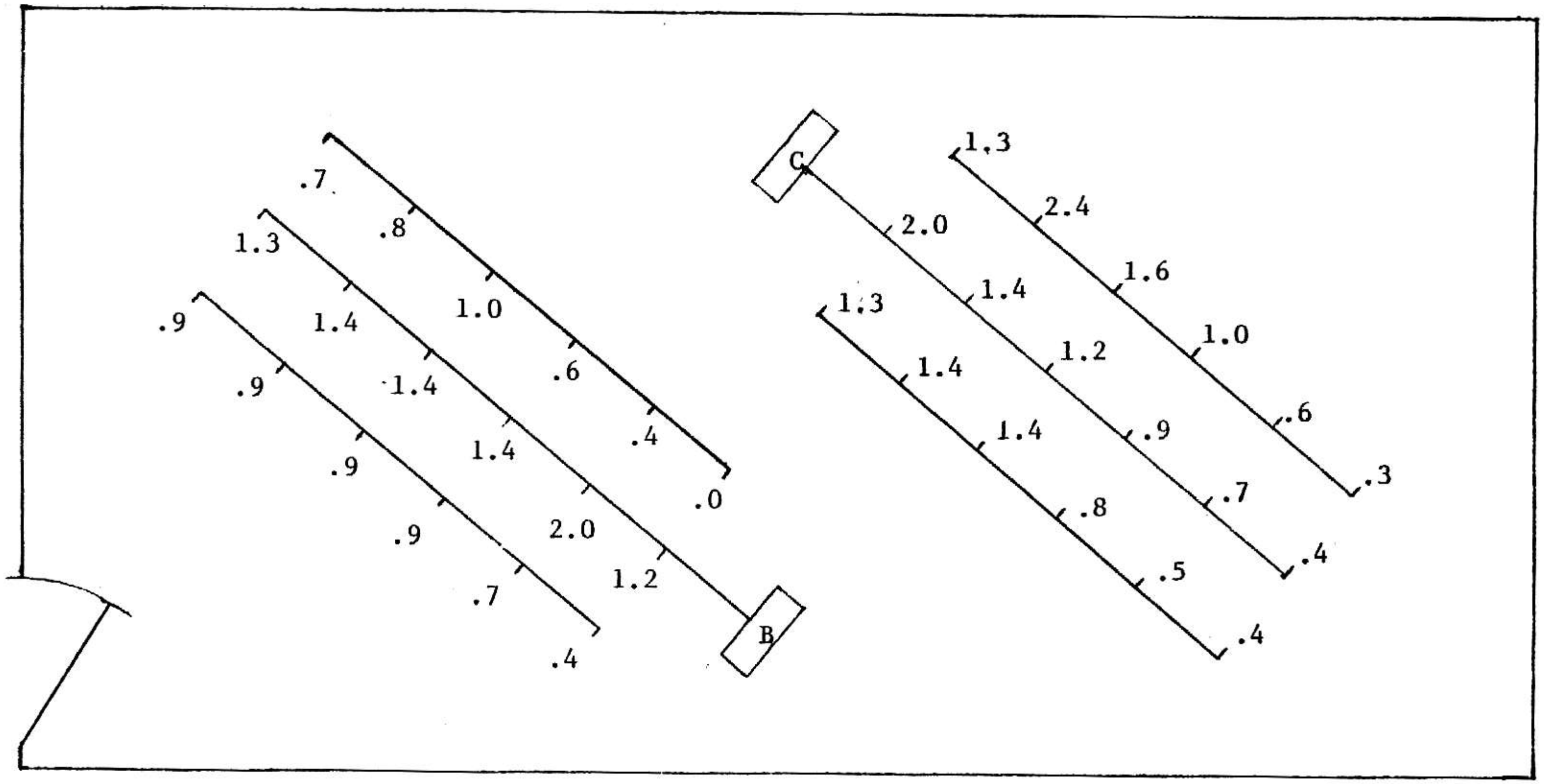

Figure 5. Velocity profile of model 204001 Edison 20 inch box fans, set on the lower of two available fan settings, viewed in the context of the enclosing room in the plane of the axis of the fans, 73 cm (29 in) above the surface of the floor. Values are time-weighted averages over fluctuations due to turbulence, taken at intervals of ½ m along the axis and ½ m to either side of the axis of each fan. Dimensions are m/s. Grille designs were wire (B) and flat (C).

enclosing room in the format of a fan profile in Figure 5 as well. The values for the type B fan presented in this profile are uniformly higher by a factor of 2 than the corresponding values determined for an earlier study using a Model 60 Anemotherm Air Meter with the very same fan in a smaller room (Rosen, 1980). While it is true that the Alnor velometer is a better instrument, giving more reliable readings, this contrast is also indicative of the effect of room size on the character of the air flow of a fan.

Comparison of the sound level measurements for the same fan in the two rooms also indicates that room size has an effect on the character of the air flow of a fan. The data is presented for comparison in Table 7. Data in both cases was collected with a Type 1565-A General Radio Company Sound Level Meter calibrated to ±1 dBA with a Type 1562-A General Radio Company Sound Level Calibrator.

Table 8 shows the sound levels to which subjects have been exposed in the present experiment. The additive effect of operating both fans simultaneously is apparent in contrast with the values shown in Table 9 for the individual fans. However, the sound levels encountered with the combined operation of both fans have already been shown to be acceptable in the pilot experiment (Rosen, 1980; Table 7, Low Speed Setting at 1.5 m). Thus, sound level was not expected to be a significant factor in the present experiment (this turned out to be the case).

Although sound level itself is not significant, the fluctuation in sound level at any one distance from the fan provides additional evidence of the turbulent nature of the air flow it produces. Even using the integrating scale implicit in the "dBA-slow" measurement, sound pressure

TABLE 7

Display of time-weighted average sound levels (dBA-slow) along the axis of the same fan in two different rooms (model 204001B Edison)

Speed Setting of Fan	Distance from Fan (m)	Room Dimensions 2.3 m by 3.4 m (Pilot Experiment)	 3.6 m by 7.3 m (Present Experiment)
Low	0.5	67	64
	1.0	64	61
	1.5	63	58
	2.0		56
	2.5		55
	3.0		54
High	0.5	74	74
	1.0	69	72
	1.5	68	68
	2.0		65
	2.5		65
	3.0		63
Room Background (dBA)		57	54

TABLE 8

Sound levels (dBA-slow) taken with a Type 1565-B General Radio Company Sound Level Meter along the axes of two model 204001 Edison 20 inch box fans, types B and C, for both fans operating simultaneously on the "Low" speed setting in the KSU-ASHRAE chamber, measuring 3.6 m by 7.3 m: these are the sound levels to which the subjects were actually exposed (Ambient = 54 dBA)

Distance from Fan (m)	Sound Level (dBA-slow)			
	Range in Operation		Time-Weighted Average	
	Type B	Type C	Type B	Type C
0.5	64 to 67	63 to 66	65	64
1.0	60 to 63+	60 to 64	61	62
1.5	58 to 61	57 to 59	59	58
2.0	57 to 60	57 to 58	58	58
2.5	56 to 58	57 to 58	57	58
3.0	56 to 58	57 to 58	57	58

TABLE 8a

Sound levels (dBA-slow) taken with a Type 1565-A General Radio Company Sound Level Meter along the axes of two model 204001 Edison 20 inch box fans, types B and C, independent of one another on the "Low" speed setting in the KSU-ASHRAE chamber, measuring 3.6 m by 7.3 m: these are the sound levels which characterize each fan in isolated operation (Ambient = 54 dBA)

Distance from Fan (m)	Sound Level (dBA-slow): Range in Operation, Type B	Range in Operation, Type C	Time-Weighted Average, Type B	Time-Weighted Average, Type C
0.5	62 to 67	63 to 66	64	64
1.0	58 to 63	57 to 59	61	58
1.5	56- to 59+	55 to 57	58	55
2.0	54+ to 57+	54 to 56	56	55
2.5	54 to 56	54 to 56	55	55
3.0	53+ to 55	54 to 56	54	55

fluctuations of 100% (3 dBA) are the norm (See Table 8a). When the meter was put in the "dBA-fast" mode, much greater fluctuation in sound level was registered. These fluctuations indicate the "impact" of the successive thrusts of air from the fan blades, despite the fact that the wind hit the microphone of the sound level meter on a tangent. Tables 8 and 8a together show that the noise levels for the 2 fans were about the same and that the experimental layout exposed the subjects to the sound output of both fans.

Final runs. At the end of 2½ hours in the chamber, subjects were allowed their choice of (1) moving closer to the fan, (2) moving further from the fan, or (3) having the fan turned off. Thus, each subject went through two "trials" in his own chosen condition, one using the paperwork task and the other the pegboard task. These choices were extended to the subjects during the last half hour of the control runs as well.

Subject discharge. The subject was asked to fill out a subject discharge sheet, shown in Appendix J, at the end of his participation in the experiment. Each subject was paid seventy dollars ($70) cash at this time for completing the experiment.

Measurements

The set of ballots used is shown in Appendix C. The first is a set of Thermal Comfort and Thermal Sensation ballots designed to measure the impression of the overall environment. The second is a set of semantic differential scales designed to determine the fan and task components of the overall environmental impression. All semantic differential scales have nine categories. A score of 9 applies to each of the analogs of the extreme favorable condition. A score of 1 applies to each of the analogs of the extreme unfavorable condition. A Standard Total Comfort Vote (STCV) was obtained by adding the scores for the seven analogs on the Thermal Comfort ballot excluding the warm...cool pair. A Loaded Total Comfort Vote (LTCV) was obtained by finding the sum of the products of the ratings with the loadings indicated in Appendix C. The Thermal Sensation ballot is scored as indicated on the ballot proper.

The loadings indicated in Appendix C were determined by Rohles, Bennett, and Milliken (1980, p. 26). Their experiment was done at two temperatures: 20 C (68 F) at 50% rh (20 CET^* = 68 FET^*) and at 25.6 C (78 F) at 50% rh (25.6 CET^* = 78 FET^*). This earlier experiment utilized various different aesthetic environments as well as a lower temperature range than the present experiment. Consequently, new factor loadings were derived from the new data of the present experiment for both variants of the Thermal Comfort scale. These variants were subjected to factor analysis both singly and combined.

The principal axis method was used to derive the initial factor pattern. Each pattern was then subjected to an orthogonal rotation using the VARIMAX procedure. Kaiser's Criterion for the retention of factors was used. This was all that was necessary for the variants of the Thermal Comfort scale, the results for which are presented in Tables 9 - 11. Tables 12, 14, and 16 show the results of this analysis as an intermediate stage for the Fan Votes, for the Task Votes, and for the Fan-Task Interaction Votes, respectively. The component variables of the resulting first factor for these last three voting scales were retained when the correlation with the factor was significant at the 0.01 level. These variables alone then were resubjected to the same

TABLE 9

Results of factor analysis of the Thermal Comfort Votes (Scales A & B combined) on the ballots cast in the first 2 ½ hours of the experiment including communality estimates along the principal axis (COM.EST.) and factor loadings (FACTOR I) by temperature (Similar values were found when votes through the entire time were used)

All Temperatures		25.6 C (78 F) Only		27.8 C (82 F) Only		30.0 C (86 F) Only		Environment Characterized
COM.EST.	FACTOR I	COM.EST.	FACTOR I	COM.EST.	FACTOR I	COM.EST.	FACTOR I	from High (9) to Low (1):
0.8681	0.9317	0.8087	0.8993	0.8274	0.9096	0.9143	0.9562	Comfortable Temp. to Uncomfortable Temp.
0.8710	0.9333	0.8608	0.9278	0.8738	0.9348	0.8612	0.9280	Satisfied to Dissatisfied
0.9056	0.9516	0.8580	0.9263	0.9155	0.9568	0.9215	0.9600	Comfortable to Uncomfortable
0.8840	0.9402	0.8531	0.9236	0.8453	0.9197	0.9131	0.9556	Good Temp. to Bad Temp.
0.5821	-0.7630	0.2866 xxxx	-0.5353	0.4345	-0.6591	0.8481	-0.9209	Warm to Cool
0.8834	0.9399	0.8044	0.8969	0.8728	0.9342	0.9248	0.9617	Pleasant to Unpleasant
0.5773	0.7598	0.5206	0.7216	0.5690	0.7543	0.6401	0.8000	Good Ventilation to Poor Ventilation
0.8459	0.9198	0.8508	0.9222	0.7539	0.8683	0.8865	0.9415	Acceptable to Unacceptable

Results of factor analysis of the Thermal Comfort Votes (A Scale alone) on the ballots cast in the first 2 ½ hours of the experiment including communality estimates along the principal axis (COM.EST.) and factor loadings (FACTOR I) by temperature (Use of all the ballots resulted in similar loadings; * = loading used to determine LAPC_A)

All Temperatures		25.6 C (78 F) Only		27.8 C (82 F) Only		30.0 C (86 F) Only		Environment Characterized
COM.EST.	FACTOR I	COM.EST.	FACTOR I	COM.EST.	FACTOR I	COM.EST.	FACTOR I	from High (9) to Low (1):
0.8836	0.9400*	0.8346	0.9316	0.8510	0.9225	0.9139	0.9560	Comfortable Temp. to Uncomfortable Temp.
0.8827	0.9395*	0.8794	0.9378	0.8749	0.9353	0.8701	0.9328	Satisfied to Dissatisfied
0.9121	0.9550*	0.8703	0.9329	0.9184	0.9583	0.9222	0.9603	Comfortable to Uncomfortable
0.8971	0.9472*	0.8688	0.9321	0.8616	0.9282	0.9169	0.9576	Good Temp. to Bad Temp.
Not Applicable		N/A		N/A		N/A		Warm to Cool
0.8837	0.9401*	0.8025	0.8958	0.8706	0.9330	0.9303	0.9645	Pleasant to Unpleasant
0.5574	0.7466*	0.4901	0.7001	0.5380	0.7335	0.6364	0.7978	Good Ventilation to Poor Ventilation
0.8608	0.9278*	0.8479	0.9208	0.7881	0.8878	0.8929	0.9449	Acceptable to Unacceptable

TABLE 11

Results of factor analysis of the Thermal Comfort Votes (B Scale alone) on the ballots cast in the first 2 ½ hours of the experiment including communality estimates along the principal axis (COM.EST.) and factor loadings (FACTOR I) by temperature (Use of all the ballots resulted in similar loadings; * = loading used to determine LAPC_B)

All Temperatures		25.6 C (78 F) Only		27.8 C (82 F) Only		30.0 C (86 F) Only		Environment Characterized
COM.EST.	FACTOR I	COM.EST.	FACTOR I	COM.EST.	FACTOR I	COM.EST.	FACTOR I	from High (9) to Low (1):
0.8838	0.9401*	0.8312	0.9117	0.8496	0.9217	0.9202	0.9593	Comfortable Temp. to Uncomfortable Temp.
0.8873	0.9420*	0.8819	0.9391	0.8885	0.9426	0.8799	0.9380	Satisfied to Dissatisfied
0.9180	0.9582*	0.8694	0.9324	0.9331	0.9660	0.9357	0.9673	Comfortable to Uncomfortable
0.8933	0.9452*	0.8677	0.9315	0.8503	0.9221	0.9220	0.9602	Good Temp. to Bad Temp.
0.5622	-0.7498*	0.2547 xxxx	-0.5047	0.4030	-0.6348	0.8419	-0.9175	Warm to Cool
0.8881	0.9424*	0.8153	0.9029	0.8744	0.9351	0.9255	0.9620	Pleasant to Unpleasant
Not Applicable		N/A		N/A		N/A		Good Ventilation to Poor Ventilation
0.8495	0.9217*	0.8498	0.9219	0.7699	0.8774	0.8811	0.9387	Acceptable to Unacceptable

TABLE 12

Results of factor analysis of the Fan Votes on the ballots cast in the first 2 ½ hours of the experiment including communality estimates along the principal axis (C.E.) and rotated factor loadings (FACT.I, FACT.II) by temperature (Factor analysis of ballots cast over the entire 3 hour period resulted in similar loadings; the asterisks denote variables selected as components of the LAPFV, subjected to a second factor analysis shown in Table 13)

All Temperatures			25.6 C (78 F) Only			27.8 C (82 F) Only			30.0 C (86 F) Only			Fan Characterized	
C.E.	FACT.I	FACT.II	C.E.	FACT.I	FACT.II	C.E.	FACT.I	FACT.II	C.E.	FACT.I	FACT.II	High(9) to Low(1):	
0.4392	0.0963	0.6557	0.1554 xxxx	0.3942	N/A	0.5306	0.0589	0.7260	0.4981	0.7001	0.0894	Smooth to Buffeting	
0.6480	0.6432	0.4840	0.6993	0.8362	N/A	0.7342	0.6625	0.5434	0.4843	0.6104	0.3341	Pleasant to Unpleasant	**
0.6571	0.1919	0.7875	0.3106 xxxx	0.5573	N/A	0.6591	0.0364	0.8110	0.7774	0.8426	0.2597	Cheerful to Gloomy	
0.5839	0.0124	0.7640	0.2817 xxxx	0.5308	N/A	0.6676	-0.1826	0.7964	0.5222	0.7140	-0.1113	Quiet to Noisy	
0.7758	0.8808	-0.0078	0.7251	0.8515	N/A	0.6682	0.7775	-0.2523	0.8070	0.1350	0.8881	Useful to Useless	**
0.8492	0.9213	0.0200	0.7887	0.8881	N/A	0.8905	0.9372	-0.1102	0.7780	0.0175	0.8818	Convenient to Inconvenient	**
0.8472	0.8650	0.3147	0.8632	0.9291	N/A	0.8658	0.9110	0.1894	0.8123	0.6174	0.6565	Like to Dislike	**

TABLE 13

Results of factor analysis of subset of the Fan Votes on the ballots cast in the first 2 ½ hours of the experiment including communality estimates along the principal axis (C.E.) and the accompanying factor loadings (FACT.I) by temperature (Asterisks denote loadings used to determine LAPFV)

LAPFV = 3.6604*(0.7578*PleasFan + 0.8480*UseflFan + 0.8947*ConvnFan + 0.9144*LikeFan) - 12.5

All Temperatures			25.6 C (78 F) Only			27.8 C (82 F) Only			30.0 C (86 F) Only			Fan Characterized
C.E.	FACT.I	FACT.II	C.E.	FACT.I	FACT.II	C.E.	FACT.I	FACT.II	C.E.	FACT.I	FACT.II	High(9) to Low(1):
												Smooth to Buffeting
0.5742	0.7578*		0.6912	0.8314		0.5141	0.7170		0.3805	0.6169		Pleasant to Unpleasant
												Cheerful to Gloomy
												Quiet to Noisy
0.7191	0.8480*		0.8080	0.8989		0.5596	0.7481		0.7544	0.8686		Useful to Useless
0.8004	0.8947*		0.8460	0.9198		0.8453	0.9194		0.6066	0.7788		Convenient to Inconvenient
0.8360	0.9144*		0.9090	0.9534		0.8621	0.9285		0.7259	0.8520		Like to Dislike

TABLE 14

Results of factor analysis of the Task Votes on the ballots cast in the first 2 ½ hours of the experiment including communality estimates along the principal axis (C.E.) and rotated factor loadings (FACT.I, FACT.II) by temperature (Factor analysis of ballots cast over the entire 3 hour period resulted in similar loadings; the asterisks denote variables selected as components of the LAPTV, subjected to a second factor analysis shown in Table 15)

All Temperatures			25.6 C (78 F) Only			27.8 C (82 F) Only			30.0 C (86 F) Only			Task Characterized	
C.E.	FACT.I	FACT.II	C.E.	FACT.I	FACT.II	C.E.	FACT.I	FACT.II	C.E.	FACT.I	FACT.II	High(9) to Low(1):	
0.7233	0.7482	0.4044	0.7684	0.7659	-0.4263	0.6542	0.7238	0.3610	0.7758	0.7903	0.3889	Relaxing to Tense	* *
0.7902	0.8865	-0.0655	0.8507	0.9168	0.1013	0.7183	0.8457	0.0554	0.7765	0.8721	-0.1265	Pleasant to Unpleasant	* *
0.7495	0.8385	-0.2155	0.8046	0.8540	0.2742	0.6897	0.8139	-0.1650	0.7229	0.8212	-0.2204	Cheerful to Gloomy	* *
0.6884	0.1045	0.8231	0.5741	0.0111	-0.7576	0.7205	0.2308	0.8169	0.7309	0.1195	0.8465	Easy to Hard	
0.3965	0.2695	-0.5690	0.3854	0.2244	0.5788	0.4085	0.2404	-0.5922	0.4647	0.3143	-0.6049	Consuming to Boring	
0.7966	0.8893	-0.0758	0.8287	0.8901	0.1909	0.7439	0.8617	0.0359	0.8070	0.8964	-0.0599	Agreeable to Disagreeable	* *
0.8074	0.8889	-0.1310	0.8361	0.9001	0.1610	0.7264	0.8339	-0.1759	0.8543	0.9187	-0.1011	Like to Dislike	* *

TABLE 15

Results of factor analysis of subset of the Task Votes on the ballots cast in the first 2 ½ hours of the experiment including communality estimates along the principal axis (C.E.) and the accompanying factor loadings (FACT.I) by temperature (Asterisks denote loadings used to determine LAPTV)

LAPTV = 2.9331*(0.7295*RelxTask + 0.8929*PleaTask + 0.8502*CheeTask + 0.8953*AgreTask + 0.8938*LikeTask) - 12.5

All Temperatures			25.6 C (78 F) Only			27.8 C (82 F) Only			30.0 C (86 F) Only			Task Characterized
C.E.	FACT.I	FACT.II	C.E.	FACT.I	FACT.II	C.E.	FACT.I	FACT.II	C.E.	FACT.I	FACT.II	High(9) to Low(1):
0.5322	0.7295*		0.5146	0.7174		0.5264	0.7255		0.5959	0.7720		Relaxing to Tense
0.7972	0.8929*		0.8580	0.9263		0.7266	0.8524		0.7726	0.8790		Pleasant to Unpleasant
0.7227	0.8502*		0.7648	0.8745		0.6721	0.8198		0.7089	0.8420		Cheerful to Gloomy
												Easy to Hard
												Consuming to Boring
0.8016	0.8953*		0.8271	0.9095		0.7414	0.8610		0.8127	0.9015		Agreeable to Disagreeable
0.7989	0.8938*		0.8325	0.9124		0.6998	0.8365		0.8437	0.9185		Like to Dislike

TABLE 16

Results of factor analysis of the Fan-Task Interaction Votes on the ballots cast in the first 2 ½ hours of the test including communality estimates along the principal axis (C.E.) and rotated factor loadings (FACT.I, FACT.II) by temperature (Similar values resulted when ballots were analyzed by task or when combined over the entire 3 hours; the asterisks denote components of the LAPIV, subjected to a second factor analysis shown in Table 17)

All Temperatures			25.6 C (78 F) Only			27.8 C (82 F) Only			30.0 C (86 F) Only			Fan Makes Task
C.E.	FACT.I	FACT.II	C.E.	FACT.I	FACT.II	C.E.	FACT.I	FACT.II	C.E.	FACT.I	FACT.II	High(9) to Low(1):
0.6788	0.8239	N/A	0.7145	0.8453	N/A	0.7907	0.8454	0.2757	0.5854	0.7562	0.1166	Soothing to Disturbing **
0.7016	0.8376	N/A	0.7514	0.8869	N/A	0.7252	0.8488	0.0686	0.6982	0.5182	0.6555	Easier to Harder **
0.6115	0.7820	N/A	0.6519	0.8074	N/A	0.6993	0.8344	-0.0564	0.5169	0.2116	0.6871	More Agreeable to Less Agreeable **
0.5196	0.7208	N/A	0.5885	0.7671	N/A	0.6259	0.7765	-0.1514	0.6878	-0.0544	0.8276	Less Frustrating to More Frustrating **
0.6852	0.8278	N/A	0.7206	0.8489	N/A	0.6574	0.7960	0.1544	0.7194	0.8265	0.1903	Orderly to Chaotic **
0.1810 xxxx	0.4254	N/A	0.3648 xxxx	0.6040	N/A	0.9533	0.0356	0.9757	0.2991 xxxx	0.5469	-0.0023	Cheerful to Gloomy
0.7096	0.8424	N/A	0.7351	0.8574	N/A	0.7032	0.8378	0.0350	0.7716	0.8102	0.3395	Efficient to Inefficient **

TABLE 17

Results of factor analysis of subset of the Fan-Task Interaction Votes on the ballots cast in the first 2 ½ hours of the test including communality estimates along the principal axis (C.E.) and the accompanying factor loadings (FACT.I, FACT.II) by temperature (Asterisks denote loadings used to determine LAPIV)

LAPIV = 2.5723*(0.8152*Sooth + 0.8505*Eas + 0.7954*MAgree + 0.7328*LFrustr + 0.8276*Ord + 0.8380*Effi) - 12.5

All Temperatures			25.6 C (78 F) Only			27.8 C (82 F) Only			30.0 C (86 F) Only			Fan Makes Task
C.E.	FACT.I	FACT.II	C.E.	FACT.I	FACT.II	C.E.	FACT.I	FACT.II	C.E.	FACT.I	FACT.II	High(9) to Low(1):
0.6646	0.8152*		0.6881	0.8295		0.7473	0.8644		0.6187	0.7849	0.0510	Soothing to Disturbing
0.7233	0.8505*		0.7935	0.8908		0.7249	0.8514		0.7053	0.5938	0.5939	Easier to Harder
0.6326	0.7954*		0.6828	0.8263		0.6833	0.8266		0.5135	0.2601	0.6677	More Agreeable to Less Agreeable
0.5370	0.7328*		0.6095	0.7807		0.5800	0.7616		0.7304	-0.0334	0.8540	Less Frustrating to More Frustrating
0.6848	0.8276*		0.7129	0.8443		0.6523	0.8077		0.7939	0.8850	0.1036	Orderly to Chaotic
												Cheerful to Gloomy
0.7023	0.8380*		0.7320	0.8556		0.7018	0.8378		0.7457	0.8078	0.3052	Efficient to Inefficient

factor analysis procedure in order to derive factor loadings uncontaminated by the presence of the irrelevant variables. The resulting factor loadings are shown in Tables 13, 15, and 17 for the Loaded Average Percent Fan Vote (LAPFV), for the Loaded Average Percent Task Vote (LAPTV), and for the Loaded Average Percent fan-task Interaction Vote (LAPIV). (Average Percent refers to the Average of all the Percent values of the components of any one given scale.)

The signs of the factor loadings must be incorporated into the Loaded Average Percent Vote (LAPV). Fortunately, the general case for the LAPV reduces to a simple expression:

With n = Number of Components of Scale,
Fc = Factor for Component c of Scale,
Vc = Vote on Component c of Scale,
RV = Range of Possible Values for Scale,

$$\text{Maximum Total Vote} = \left[5n + \left(4 * \sum_{c=1}^{n} |Fc|\right)\right] \text{ for a 9-category scale and}$$

$$\text{Minimum Total Vote} = \sum_{c=1}^{n} |Fc|$$

$$= \left[5n - \left(4 * \sum_{c=1}^{n} |Fc|\right)\right] \text{ for a 9-category scale.}$$

$$\text{Now, LAPV} = \frac{100\%}{RV} * \sum_{c=1}^{n} \left[(4*Fc) + Fc(Vc - 5)\right]$$

$$= \frac{100\%}{RV} * \sum_{c=1}^{n} \left[Fc(Vc - 1)\right]$$

$$= \frac{100\%}{RV} * \left[\sum_{c=1}^{n} Fc(Vc) - \sum_{c=1}^{n} Fc\right]$$

$$= \frac{100\%}{RV} * \left[\sum_{c=1}^{n} Fc(Vc)\right] - \frac{100\%}{RV} * \left[\sum_{c=1}^{n} Fc\right]$$

Since RV = Maximum Total Vote − Minimum Total Vote,

$$RV = 8 * \sum_{c=1}^{n} |Fc| \text{ for a 9-category scale, so}$$

$$\text{LAPV} = \frac{100\%}{8 * \sum_{c=1}^{n} |Fc|} * \sum_{c=1}^{n} Fc(Vc) - \frac{100\%}{8 * \sum_{c=1}^{n} |Fc|} * \sum_{c=1}^{n} Fc$$

$$\text{Thus, LAPV} = 12.5\% * \frac{\sum_{c=1}^{n} Fc(Vc)}{\sum_{c=1}^{n} |Fc|} - 12.5\% * \frac{\sum_{c=1}^{n} Fc}{\sum_{c=1}^{n} |Fc|}$$

for the general case for a 9-category scale.

This formula shows that the signs of the factor loadings must be incorporated into the LAPV. But when the signs are all positive, $\sum_{c=1}^{n} Fc = \sum_{c=1}^{n} |Fc|$ and for a 9-category scale

$$\text{LAPV} = 12.5\% * \frac{\sum_{c=1}^{n} Fc(Vc)}{\sum_{c=1}^{n} |Fc|} - 12.5\% .$$

So while the (Standard) Total Comfort Vote (STCV) is simply the sum of the raw scores for its scale components (Appendix C),

LAPC_R is the Loaded Average Percent Comfortable derived using the factor loadings reported by Rohles, Bennett, and Milliken (1980), using the adjective pair warm - cool in place of the adjective pair good ventilation - poor ventilation,

LAPC_A is the Loaded Average Percent Comfortable derived using the same scale components as the STCV but loadings determined from the data for this experiment, and

LAPC_B is the Loaded Average Percent Comfortable derived using the adjective pair warm - cool in place of the adjective pair good ventilation - poor ventilation and loadings determined from the data for this experiment.

Non-thermal Factors

The lighting, previously mentioned, was supplied by eight 1.2 m (4 ft) 40 W cool-white Westinghouse fluorescent fixtures hidden behind valances as described by Rohles, Bennett, and Milliken (1980). The combination of this low-level lighting and white walls resulted in a soft, uniform illuminance of 12 - 14 ft-candles. While walnut paneling might have been preferable, Rohles, Bennett, and Milliken (1980) failed to find an effect on Thermal Comfort (LAPC_R) for either luminaire or wall treatment in a thermally neutral (25.6 C DBT (78 F DBT), 50% rh) environment with an air velocity of 0.2 m/s (40 ft/min).

RESULTS AND DISCUSSION

Influence of Independent Variables on Subject Behavior

The two positions explicitly selected by each subject on each day were combined to give a mean explicitly selected position for the day. Next, the velocities corresponding to these mean positions were read from Figure 5. This data is shown in Appendix K. An ANOVA analysis of this data (Appendix L) showed that the chamber temperature, the group number, the chamber temperature x group number interaction, and the sex x group number interaction were all significant at or below the 0.05 significance level. The mean fan velocities explicitly selected after 2.5 hours in the chamber were 1.2 m/s at 30.0 C (86 F), 1.0 m/s at 27.8 C (82 F), and 0.7 m/s at 25.6 C (78 F), all at 45% rh. These mean explicitly selected fan velocities were all significantly different from one another at an alpha level of 0.05 (MS=0.09). In contrast, the fan condition over the previous 2 hours had no significant effect on the mean explicitly selected fan velocity, according to the ANOVA analysis. Sex was not significant at an alpha level of 0.05.

The lack of a significant sex difference may be the result of an influence of position choice by the other subject in the chamber, always of the opposite sex. In a few instances, in fact, the two subjects of a group appeared to be finding a position that would be mutually satisfying. While group number and its interactions may owe their significance to the wide variation in outside conditions encountered during the month of the experiment (Appendix M), the influence of individual (group) differences seems much more likely.

The order in which all the subjects were exposed to the different conditions did not have an effect on the explicitly selected fan velocity significant at the 0.05 level. However, when the daily subject responses were grouped according to the condition combination (temperature x fan condition) of the day, the effect was highly significant ($P = 0.0009$), as shown in Appendix L. Close examination of the Duncan's multiple range test results shows that this is due to differences in chamber temperature rather than to differences in fan velocity.

Subject Characteristics Not Important

Of 10 general linear models for each of 8 dependent variables, only a total of 4 out of 80 showed a subject characteristic to have an effect on one of the dependent ballot variables significant at the 0.10 level. Only 1 of the 80 was significant at the 0.05 level. But 0.1 x 80 = 8 and 0.05 x 80 = 4 effects are expected to have $P = 0.1$ and 0.05 respectively. Furthermore, none of the effects was consistent with respect to either independent variable (subject characteristic) or dependent variable (ballot scores). Thus, experimental differences cannot be attributed to the physical characteristics of the subjects. While physical characteristics may affect thermal comfort, the subject size ($N = 8$) was not large enough to show a significant effect in this experiment.

Validity of Subject Preferences

The votes of the subjects just prior to discharge (Appendix J) indicate that the experiment is valid from the subjects' point of view. Overall, the subjects voted (mean ($N = 8$) vote/points on scale) that

1) their votes more than adequately represented their feelings (6.9/9.0, S.E. = 0.4),

2) the weeks of the experiment had gone slightly better than average (5.8/9.0, S.E. = 0.4),

3) where the period had been out of the ordinary, the voting in the experiment was not influenced by the day's events (5.0/9.0, S.E. = 0.0), and

4) the experiment did not ask for too much (4.9/9.0, S.E. = 0.4).

Fan noise levels during the predetermined fan conditions using the fan were marked midway between "quiet" and "noisy" (5.3/9.0, S.E. = 0.10, S.D. = 1.4 with N = 192 for 3.0 m from the fan; 4.9/9.0, S.E. = 0.11, S.D. = 1.5 with N = 192 for 1.5 m from the fan).

Before the subjects were informed of the actual chamber conditions at the end of the experiment, they were asked if they had a "favorite temperature" (See Appendix J). All the subjects were able to indicate a "favorite temperature" from general experience. The mean value was 73.2 F, S.E. = 0.7 F, S.D. = 2.1 F, with all 8 values in the range from 71 to 77 F (21.7 to 25.0 C). Since these values are derived from an average of all the environments encountered in the daily lives of the subjects, an estimated rh of 40% should apply.

Influence of Fan Velocity on Temperature Estimated by Subjects

The last question on the Comfort-Sensation Ballot (Appendix C) asks subjects to estimate the temperature. The mean responses to this question are summarized in Table 18 by temperature - fan condition. While the effect of the fans on the Temperature Estimate of the subjects (TE) in any one fan condition was expected to decrease as the actual temperature was raised, the actual differences between the three temperatures were smaller than the S.E.'s. Moreover, 3 of these 4 differences were opposite the direction expected. Thus, it appears to be permissible to combine these results, ignoring temperature, to obtain values more representative of the effect of the fans on the TE within the temperature range studied. Thus, Table 18 shows the derivation of the two single values for the average effect of the fan on the perceived temperature of the environment for the temperature range from 25.6 C DBT (78 F DBT) to 30.0 C DBT (86 F DBT): An average velocity of 0.8 m/s resulted in a perceived temperature which was 2.5 C (4.5 F) lower than in the "still air" ($v \leq 0.35$ m/s) control condition. (Actual air velocity at chest height in the "still air" condition out of the convective updraft was measured at 0.1+ m/s using a non-directional probe supplied with a model 1650 tsi Air Velocity Meter; Rohles and Wells (1977) reported an air velocity of 0.20 m/s (40 ft/min) for "still air" for both chambers at the IER at 23.2 CET* (74 FET*).) An average velocity of 1.3 m/s resulted in a perceived temperature 3.5 C (6.3 F) lower than in the "still air" control condition.

Figure 6 provides graphic evidence of the effect of fan use on the perceived temperature (TE). The tendency to underestimate the actual

TABLE 18

Influence of fan velocity on Fahrenheit Temperature Estimated by the subjects (TE) using mean values derived from daily mean values by subject code - temperature - fan condition in order to obtain correct values for standard error (S.E.)

Description	Fan Condition (Average Fan Velocity in m/s)	Actual Temperature (S.E. with n=8) 78 F DBT 77.8 FET* (25.4 CET*) (25.6 C DBT)	 82 F DBT 81.6 FET* (27.6 CET*) (27.8 C DBT)	 86 F DBT 85.4 FET* (29.7 CET*) (30.0 C DBT)
TE (F) for	"Off" (≤0.35)	76.1 (1.8)	79.6 (1.1)	82.5 (2.2)
	"Far" (=0.8)	72.0 (1.4)	75.1 (1.6)	77.6 (1.3)
	"Near" (=1.3)	70.3 (1.9)	72.1 (2.1)	76.9 (2.0)
Difference between TE (F) and Actual FET* for	"Off" (≤0.35)	-1.7	-2.0	-2.9
	"Far" (=0.8)	-5.8	-6.5	-7.8
	"Near" (=1.3)	-7.5	-9.5	-8.5
Difference between TE (F) and Actual FET* corrected for tendency displayed in control ("Off") condition to underestimate actual temperature				
for	"Far" (=0.8)	-4.1	-4.5	-4.9
for	"Near" (=1.3)	-5.8	-7.5	-5.6
Average influence of fan use on Fahrenheit Temperature Estimated by the subjects				
for	"Far" (=0.8)	....	-4.5	....
for	"Near" (=1.3)	....	-6.3	....

RELATIONSHIP OF MEAN OVER 2.5 HRS OF EXPOSURE FOR DEP VAR SHOWN TO TEMP FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S), F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

PLOT OF MESTTM*CTEMP   SYMBOL IS VALUE OF FANCOND

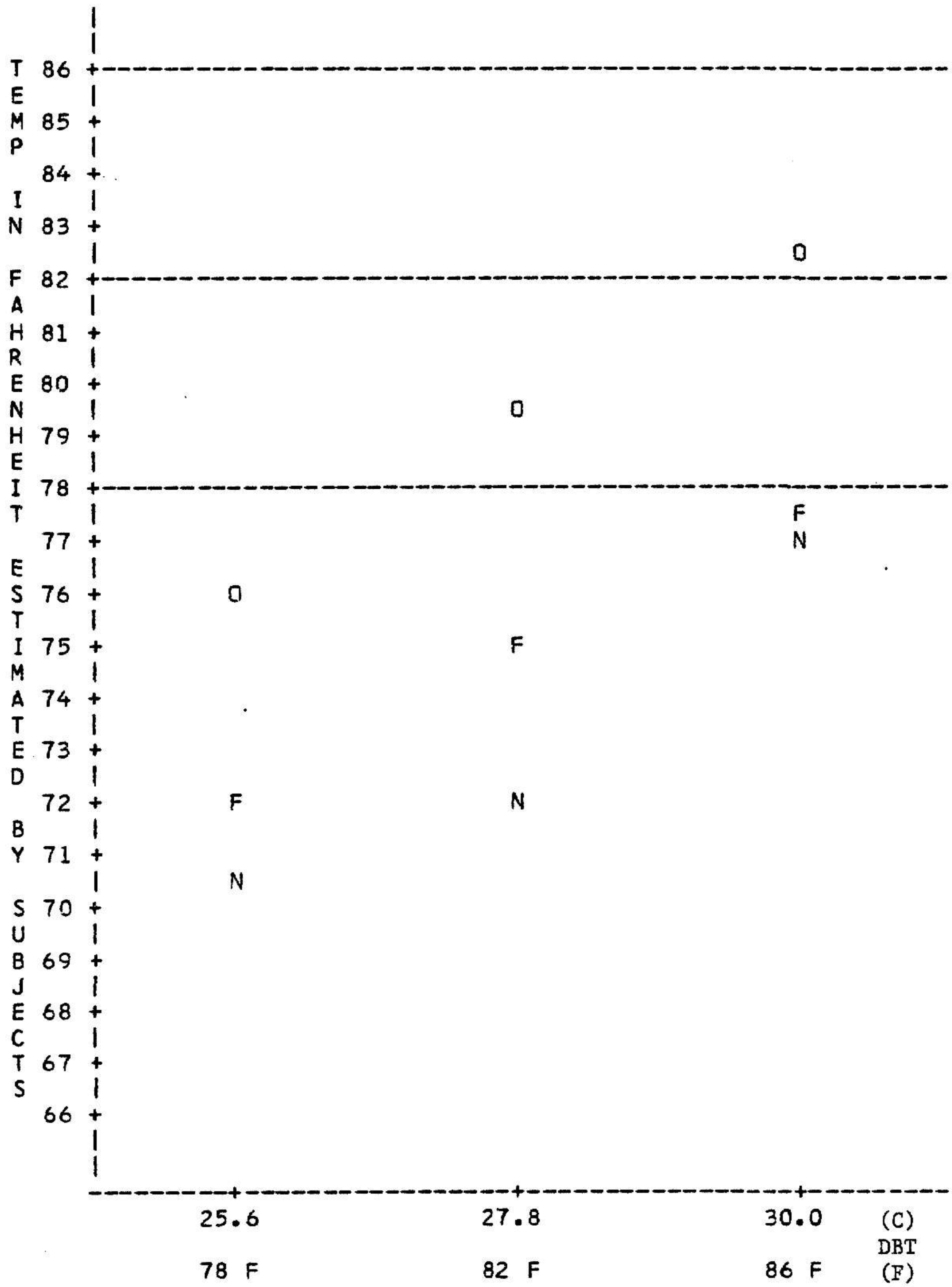

Figure 6. Plot of Temperature Estimate against DBT by fan condition.

temperature by an average of 1.2 C (2.2 F) is readily apparent. Figure 6 also shows that use of a fan at 30.0 C DBT (86 F DBT) results in an estimated temperature lower than the actual lowest temperature of the study. The estimated temperature at 30.0 C DBT (86 F DBT) when the fans are on does not appear to be significantly different from that at 25.6 C DBT (78 F DBT) in the "still air" condition.

Influence of Independent Variables on Thermal Sensation and its Analogs

Table 19 shows that the variations in response with condition were similar for Thermal Sensation (TS), for Preference for Temperature change (PT), and for Temperature Estimate (TE). Thus, these three variables form the Thermal Sensation Variable Group. The order in which the conditions are presented in Table 19 is unique: it is the only order which makes sense for all three dependent variables for the predetermined 2 hour fan condition. This table shows that both the fan velocity and the chamber temperature have an impact on the Thermal Sensation Variable Group. This table also shows that from the standpoint of this variable group within the condition range studied, a rise in average fan velocity of 0.4 m/s (80 ft/min) offsets a rise in temperature of 2.2 C (4.0 F). This is consistent with the figures derived from the Temperature Estimate, already shown in Table 18; since a rise in fan speed from ≤0.35 m/s to 0.8 m/s, a difference of 0.45 m/s, produced a TE lower by 2.5 C (4.5 F), to produce a TE lower by 2.2 C (4.0 F) would require a rise in fan speed of (4.0 F/4.5 F)(0.45 m/s) = 0.40 m/s. The 0.5 m/s rise in fan speed from 0.8 m/s to 1.3 m/s produced only a (3.5 C - 2.5 C) = 1.0 C (= 1.8 F) drop in TE, consistent with the decline in cooling power with increasing air velocity described by Mitchell and Whillier (1971). Even so, the decline in cooling power with temperature is not so large, considering that the average fan speed of 0.8 m/s is rounded down from 0.85 m/s.

The female subjects chose a higher selected velocity for the final half hour of exposure than did the male subjects, on the average. Yet the females exhibited significantly greater sensitivity to the cooling effect of the fans than did the males, in contrast with the findings of Rohles, Bennett, and Milliken (1980) that... "In a condition of thermal neutrality there is no difference in the thermal sensations of men and women; in an environment that is cooler than neutral, women feel cooler than men." While the differences by sex were consistent in the present study, there were no consistent significant variations by group number.

The Duncan's multiple range test for the Thermal Sensation Variable Group during the fan condition selected by the subject for the final half hour of the day is shown on the right side of Table 19. In no case did different preconditioning exposures result in significantly different voting on the Thermal Sensation Variable Group in the final half hour of the experiment at any one temperature. All significant differences can be explained entirely on the basis of temperature differences. This is in line with the work of Rohles and Wells (1977) concerning temperature preconditioning. They found that previous exposure for one hour to an environment 7.6 CET* (14 FET*) cooler resulted in only short-lived differences in TS "...of little engineering significance."

Tables 20 to 22 show the relationships between each of the nine predetermined conditions on the basis of paired t-tests for each of the dependent variables TS, PT, and TE. The order of the conditions in these tables is the same as that shown in the Duncan's multiple range rankings of Table 19. The paired t-tests separate the conditions somewhat better. For example, Table 20 shows that 0.8 m/s (160 ft/min) at 30.0 C DBT (86 F DBT) is significantly warmer than 0.8 m/s (160 ft/min) at 27.8 C DBT (82 F DBT). In contrast, Table 19 does not show a significant difference between these two conditions. The experiment was designed with analysis by the paired t-test specifically in mind, so this result is expected.

Negative t-values indicate differences opposite the direction expected. Tables 20 (TS) and 22 (TE) each contain only one negative difference, far fewer than would be expected by chance. Table 21 (PT) contains only positive differences. So even where the differences are not significant, they are consistent with the present ordering of the conditions from warmest to coolest.

Figures 7 and 8 display the relationship of the means of TS and PT with the predetermined exposure condition. As with Figure 6, these plots graphically show the same relationships portrayed statistically in Tables 19 to 22.

Influence of Independent Variables on Thermal Comfort, Raw and Loaded

Figures 9 to 12 display the relationship of the means of 4 different measures of Thermal Comfort with the predetermined exposure condition. Use of the fan is seen to raise Thermal Comfort by 8 - 20% of the maximum no matter which measure is used. The slope of these graphs is negative where the relationship is not curvilinear. This contrasts sharply with the slope of the graphs for the Thermal Sensation Variable Group, already seen in Figures 6 to 8.

Duncan's multiple range analyses for the various measures of Thermal Comfort described in the Measurements section are presented in Table 23.

TABLE 19

Summary of Duncan's multiple range rankings for the Thermal Sensation Variable Group: Conditions with the same letter had means for the dependent variable indicated which were not significantly different for alpha = 0.05, A representing the highest (warmest) range; the lowest priority letter representing the lowest (coolest) range of mean values (more specific information in Appendix N)

Predetermined Condition			Duncan's Multiple Range Ranking for the Dependent Variable Indicated for Alpha = 0.05 during the Fan Condition						
			Predetermined for the Day			Selected by the Subject for the Final ½ hr			
Average Fan Velocity (m/s)	Temperature (C DBT)	Comment	TS	PT	TE	TS	PT	TE	Selected Velocity
≤0.35	30.0		A	A	A	A B	A	A	A Mean=1.3m/s
			A		A	A B	A	A	A
≤0.35	27.8		A B	B	A B	A B	A B	A B	A B Mean=1.2m/s
			B	B	B	A B	A B	A B	A B
0.8	30.0		C B	C B	C B	A B	A B	A B	C A B Mean=1.1m/s
			C	C	C B	A	A B	A	A
1.3	30.0		C	C	C B	A	A B	A	A Mean=1.2m/s
			C	C	C B		A B	A	
≤0.35	25.6		C	C	C D B	B	A B	A B	D Mean=0.6m/s
			C	C	C D	B	A B	A B	
0.8	27.8		C D	C D	C D	A B	A B	A B	C A B Mean=1.0m/s
			D	D	D	B	B	B	
0.8	25.6	Voted Most Comfortable	D E	D E	D E	B	B	B	D Mean=0.6 m/s
			D E	E	D E	B	B	B	D
1.3	27.8		D E	E	D E	A B	A B	A B	C D B Mean=0.8m/s
			E	E	E	B	B	B	C D
1.3	25.6		E	E	E	B	B	B	C D Mean=0.7m/s
		Sex: Male	A	A	A	A	A	A	A Mean=0.9m/s
				A			A		A
		Female	B	A	B	B	A	B	A Mean=1.0m/s

TABLE 20

Probability that the difference by subject (n=8) for the daily mean (n=8) of the Thermal Sensation Vote for the condition listed on the horizontal is the same as that for the condition listed on the vertical (df=7 in each case); except for the 9 insignificant differences, the daily mean of the TSV for any one condition is significantly cooler (lower in value) than that for conditions to its upper left and warmer than that for conditions to its lower right

Paired t-test for any 2 sets of Predetermined Conditions for the Dependent Variable TS									Mean and SE of Daily Mean: Percent (and Actual) Vote	
									$\overline{TS}$	S.E. (n=8)
Warmest 30.0 C, ≤0.35 m/s	t=2.58* p,0.03	t=4.88* p,0.002	t=3.57* p,0.01	t=5.11* p,0.002	t=4.28* p,0.004	t=6.11* p,0.0005	t=4.76* p,0.003	t=6.92* p,0.0002	75% (7.0)	3.2% (0.26)
	27.8 C, ≤0.35 m/s	t=3.07* p,0.02	t=2.91* p,0.03	t=2.89* p,0.03	t=3.86* p,0.007	t=6.94* p,0.0002	t=5.06* p,0.002	t=7.92* p,0.0001	70% (6.4)	1.6% (0.13)
		30.0 C, 0.8 m/s	t=1.31 p,0.24	t=1.58 p,0.16	t=3.05* p,0.02	t=6.47* p,0.0003	t=3.94* p,0.006	t=6.23* p,0.0004	61% (5.9)	2.7% (0.22)
Predetermined			30.0 C, 1.3 m/s	t=-0.18 p,0.86	t=1.47 p,0.19	t=3.90* p,0.006	t=4.07* p,0.005	t=5.58* p,0.0008	57% (5.6)	4.0% (0.32)
Exposure				25.6 C, ≤0.35 m/s	t=1.19 p,0.28	t=3.05* p,0.02	t=2.28 p,0.06	t=4.47* p,0.003	58% (5.6)	3.9% (0.31)
Conditions					27.8 C, 0.8 m/s	t=2.24 p,0.06	t=2.43* p,0.05	t=4.63* p,0.003	54% (5.2)	3.7% (0.30)
						25.6 C, 0.8 m/s	t=0.67 p,0.53	t=3.20* p,0.02	49% (4.9)	3.0% (0.24)
							27.8 C, 1.3 m/s	t=2.23 p,0.07	48% (4.8)	4.0% (0.32)
								25.6 C, 1.3 m/s Coolest	43% (4.4)	3.0% (0.24)

Probability that the difference by subject (n=8) for the daily mean (n=8) of Preference for Temperature change for the condition listed on the horizontal is the same as that for the condition listed on the vertical (df=7 in each case); except for the 11 insignificant differences, the subjects want the temperature to be raised significantly more than for conditions to the upper left and lowered significantly more than for conditions to the lower right

Paired t-test for any 2 sets of Predetermined Conditions for the Dependent Variable PT

Predetermined Exposure Conditions

									Mean and SE of Daily Mean: Percent (and Actual) Vote	
									$\overline{PT}$	S.E.(n=8)
Warmest 30.0 C, ≤0.35 m/s	t=1.36 p,0.22	t=3.31 p,0.02*	t=3.67 p,0.008*	t=3.48 p,0.01*	t=3.18 p,0.02*	t=7.34 p,0.0002*	t=4.83 p,0.002*	t=5.13 p,0.002*	75% (7.0)	3.3% (0.27)
	27.8 C, ≤0.35 m/s	t=1.52 p,0.18	t=3.53 p,0.01*	t=3.51 p,0.01*	t=4.91 p,0.002*	t=5.25 p,0.002*	t=5.71 p,0.0007*	t=5.30 p,0.002*	68% (6.4)	4.1% (0.33)
		30.0 C, 0.8 m/s	t=2.57 p,0.04*	t=2.17 p,0.07	t=2.06 p,0.08	t=5.88 p,0.0006*	t=6.00 p,0.0005*	t=5.47 p,0.0009*	63% (6.1)	2.9% (0.23)
			30.0 C, 1.3 m/s	t=0.00 p,1.00	t=0.31 p,0.77	t=3.67 p,0.008*	t=3.62 p,0.009*	t=3.67 p,0.008*	58% (5.7)	2.9% (0.23)
				25.6 C, ≤0.35 m/s	t=0.30 p,0.78	t=2.16 p,0.07	t=3.29 p,0.02*	t=3.99 p,0.006*	58% (5.7)	3.9% (0.31)
					27.8 C, 0.8 m/s	t=1.82 p,0.12	t=2.55 p,0.04*	t=2.72 p,0.03*	58% (5.6)	4.7% (0.38)
						25.6 C, 0.8 m/s	t=0.73 p,0.49	t=1.63 p,0.15	51% (5.1)	1.1% (0.09)
							27.8 C, 1.3 m/s	t=2.50 p,0.05*	48% (4.9)	3.5% (0.28)
								25.6 C, 1.3 m/s Coolest	45% (4.6)	3.8% (0.30)

TABLE 22

Probability that the difference by subject (n=8) for the daily mean (n=8) of the Temperature Estimate for the condition listed on the horizontal is the same as that for the condition listed on the vertical (df=7 in each case); except for the 15 insignificant differences, the daily mean of the TE for any one condition is significantly lower than that for conditions to its upper left and higher than that for conditions to its lower right

Predetermined Exposure Conditions	Paired t-test for any 2 sets of Predetermined Conditions for the Dependent Variable TE								Mean and SE of Daily Mean: Percent (and Actual) Vote $\bar{TE}$	S.E.(n=8)
	27.8 C, ≤0.35 m/s	30.0 C, 0.8 m/s	30.0 C, 1.3 m/s	25.6 C, ≤0.35 m/s	27.8 C, 0.8 m/s	25.6 C, 0.8 m/s	27.8 C, 1.3 m/s	25.6 C, 1.3 m/s		
Warmest 30.0 C, ≤0.35 m/s	t=1.53 p,0.17	t=2.26 p,0.06	t=1.89 p,0.10	t=3.01 p,0.02*	t=2.70 p,0.04*	t=3.65 p,0.009*	t=3.00 p,0.02*	t=3.77 p,0.007*	82.5	2.18
27.8 C, ≤0.35 m/s		t=3.21 p,0.02*	t=1.60 p,0.16	t=3.44 p,0.02*	t=3.34 p,0.02*	t=4.95 p,0.002*	t=3.57 p,0.01*	t=5.34 p,0.002*	79.6	1.08
30.0 C, 0.8 m/s			t=0.60 p,0.57	t=1.82 p,0.12	t=2.78 p,0.03*	t=4.62 p,0.003*	t=3.08 p,0.02*	t=5.14 p,0.002*	77.6	1.33
30.0 C, 1.3 m/s				t=0.47 p,0.66	t=1.36 p,0.22	t=2.95 p,0.03*	t=2.16 p,0.07	t=3.59 p,0.009*	76.9	2.00
25.6 C, ≤0.35 m/s					t=0.93 p,0.39	t=2.58 p,0.04*	t=1.92 p,0.10	t=3.30 p,0.02*	76.1	1.80
27.8 C, 0.8 m/s						t=4.36 p,0.004*	t=2.25 p,0.06	t=5.27 p,0.002*	75.1	1.62
25.6 C, 0.8 m/s							t=-0.12 p,0.91	t=2.30 p,0.06	72.0	1.44
27.8 C, 1.3 m/s								t=2.23 p,0.07	72.1	2.12
25.6 C, 1.3 m/s Coolest									70.3	1.89

RELATIONSHIP OF MEAN OVER 2.5 HRS OF EXPOSURE FOR DEP VAR SHOWN TO TEMP FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S), F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

PLOT OF MTHERML*CTEMP   SYMBOL IS VALUE OF FANCOND

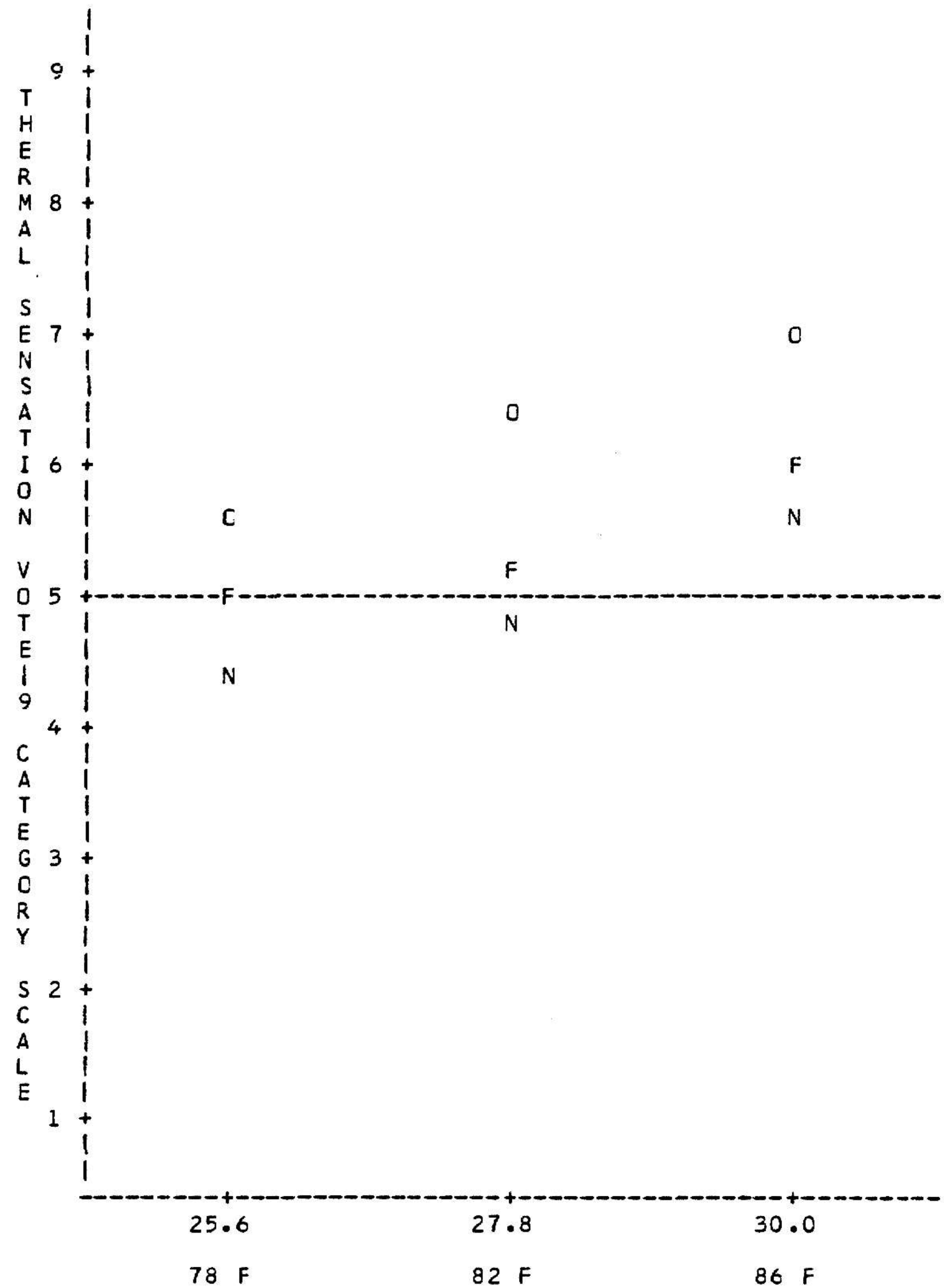

Figure 7. Plot of Thermal Sensation against DBT by fan condition.

RELATIONSHIP OF MEAN OVER 2.5 HRS OF EXPOSURE FOR DEP VAR SHOWN
TO TEMP FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

PLOT OF MPREFTM*CTEMP   SYMBOL IS VALUE OF FANCOND

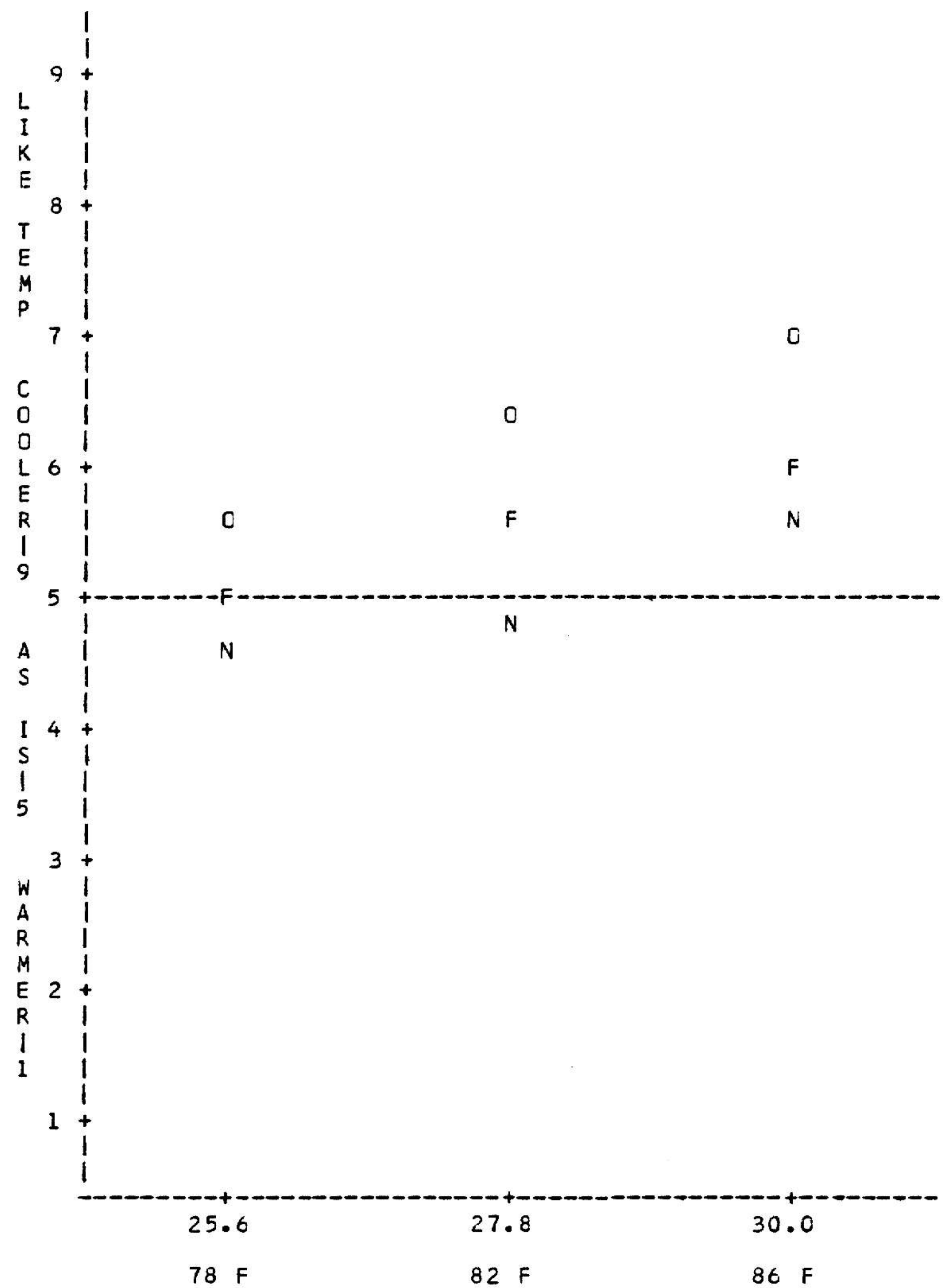

Figure 8. Plot of Preference for Temp. change against DBT by fan condition.

RELATIONSHIP OF MEAN OVER 2.5 HRS OF EXPOSURE FOR DEP VAR SHOWN TO TEMP FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S), F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

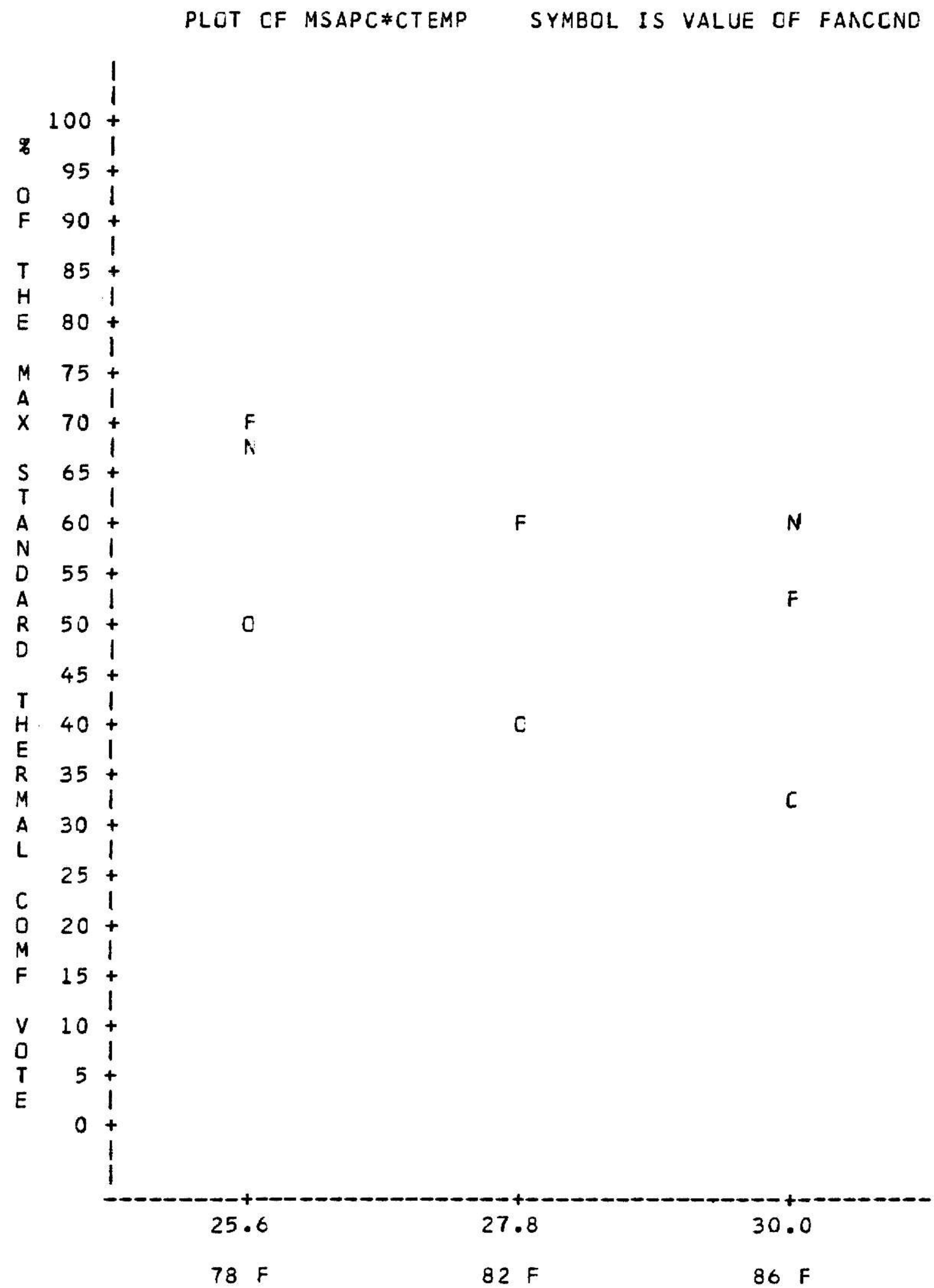

Figure 9. Plot of Thermal Comfort as STCV (%) against DBT by fan condition.

RELATIONSHIP OF MEAN OVER 2.5 HRS OF EXPOSURE FOR DEP VAR SHOWN TO TEMP FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S), F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

PLOT OF MLAPC_R*CTEMP SYMBOL IS VALUE OF FANCOND

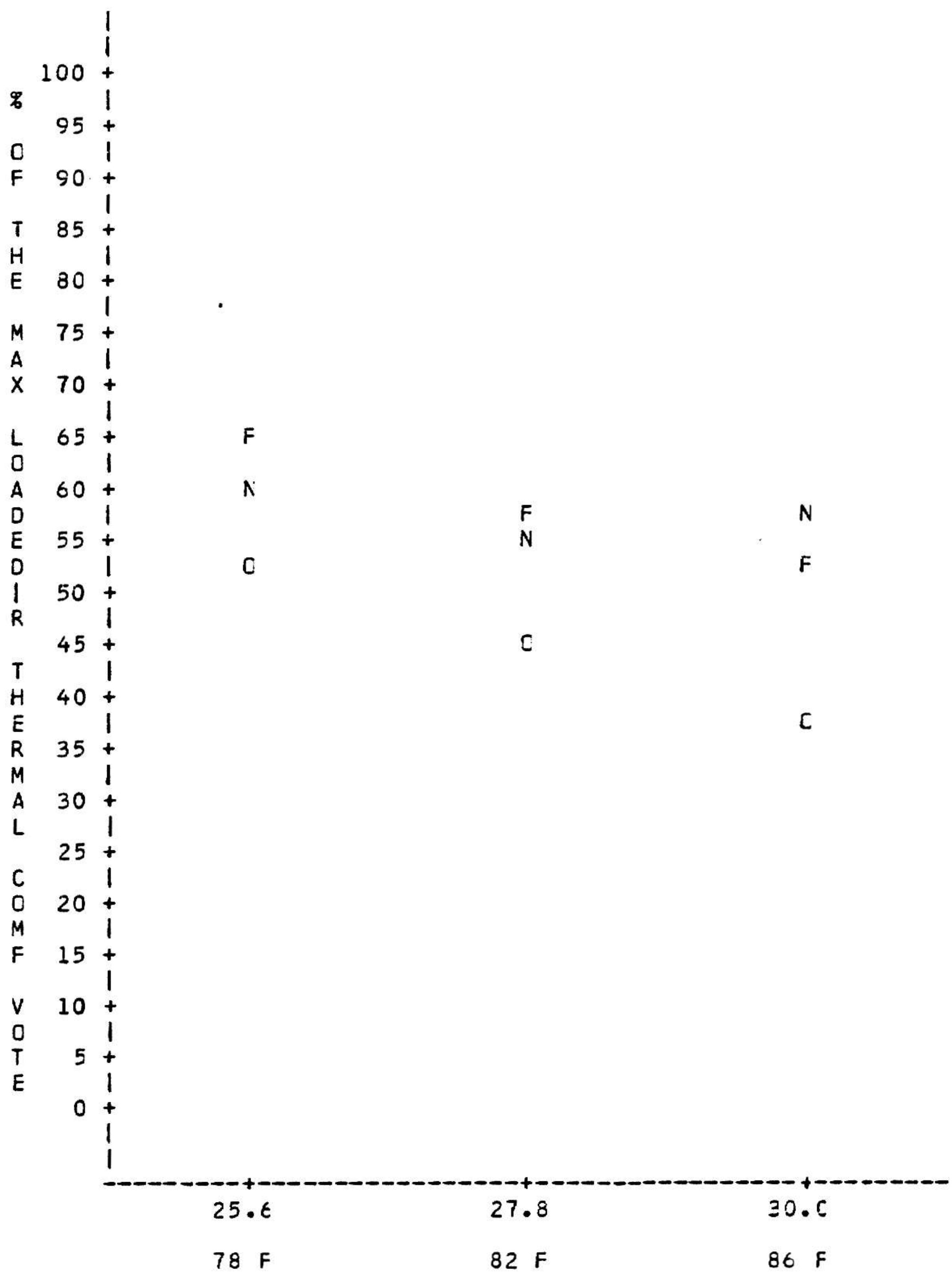

Figure 10. Plot of Thermal Comfort R Scale against DBT by fan condition.

RELATIONSHIP OF MEAN OVER 2.5 HRS OF EXPOSURE FOR DEP VAR SHCWN TO TEMP FOR EACH FAN CCNDITION: O=OFF--LIKE 6 M (0.35 M/S), F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

PLOT CF MLAPC_A*CTEMP SYMBOL IS VALUE CF FANCCND

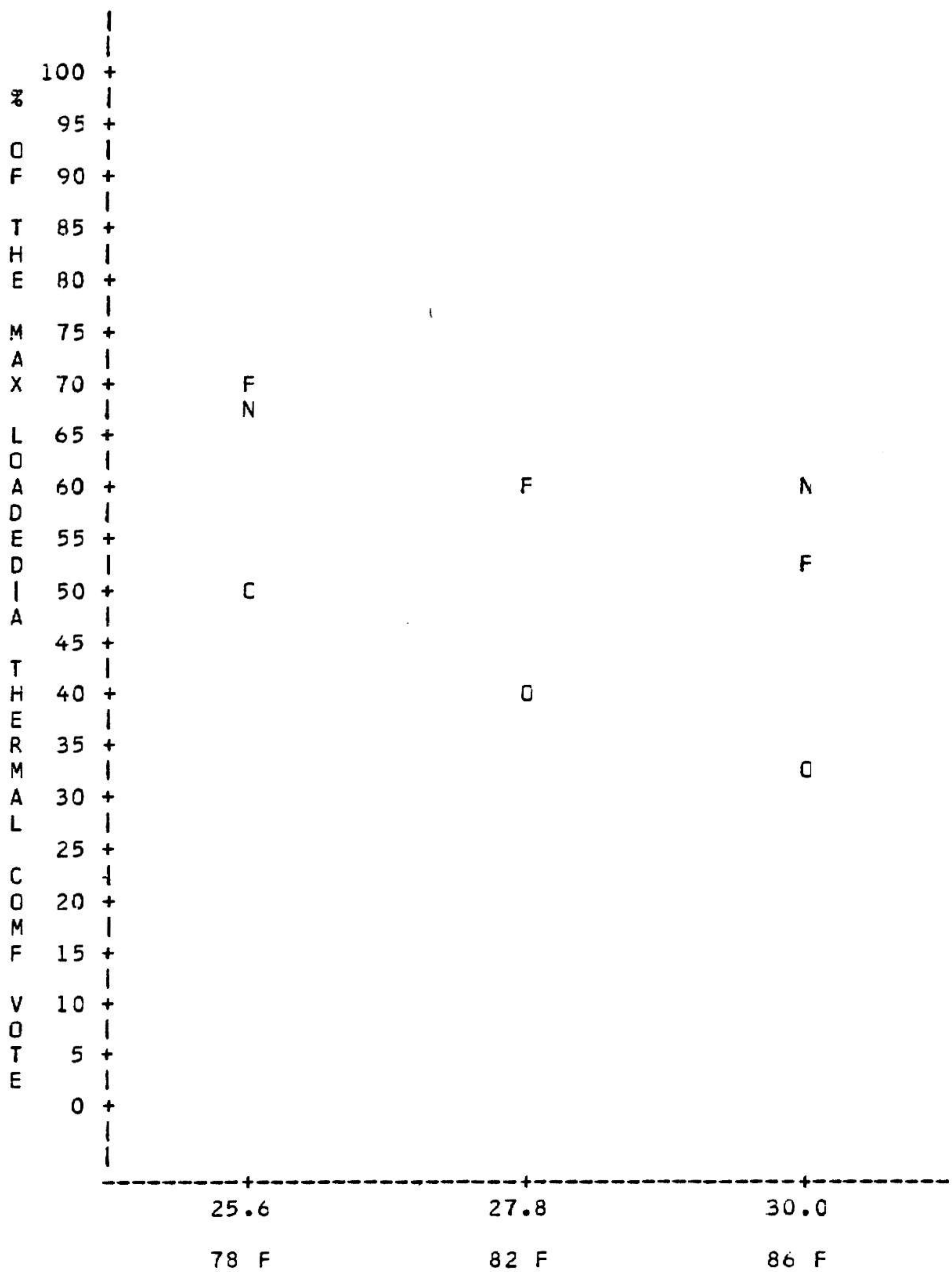

Figure 11. Plot of Thermal Comfort A Scale against DBT by fan conditon.

RELATIONSHIP OF MEAN OVER 2.5 HRS OF EXPOSURE FOR DEP VAR SHOWN
TO TEMP FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

PLOT OF MLAPC_B*CTEMP   SYMBOL IS VALUE OF FANCOND

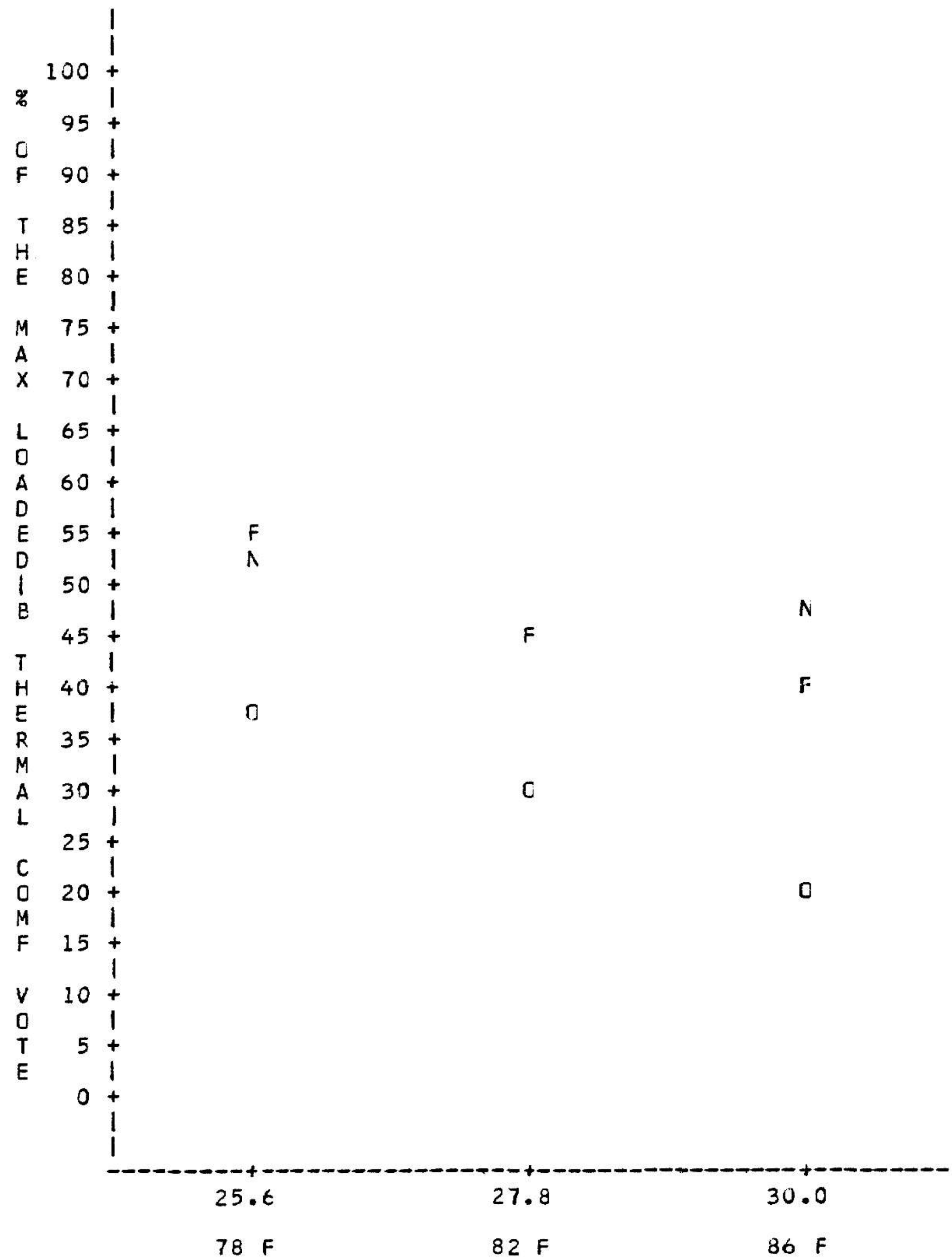

Figure 12. Plot of Thermal Comfort B Scale against DBT by fan condition.

The predetermined conditions form 5 groups for measures STCV and LAPC_A and 4 groups for measures LAPC_R and LAPC_B for voting during the fan condition predetermined for the day (left side of Table 23). The reduced separation for the latter two scales apparently is due to confounding of Thermal Comfort with Thermal Sensation, represented by the adjective pair warm - cool within the Thermal Comfort (B) scale. Figures 13, 14, and 15 show that this adjective pair (represented by W in graphs) does not behave in the same way as the other scale components within the condition range studied with respect to the Thermal Sensation Group Variables.

Contrast of the groupings based on STCV with those based on LAPC_A, its loaded counterpart, shows that loading the scale components is not as important as the nature of the scale components themselves in the condition range studied. Even though the adjective pair warm - cool as a component of LAPC_R and of LAPC_B blunted the sensitivity of the Thermal Comfort scale, all 4 measures of Thermal Comfort gave the same qualitative response. This is fortunate; it means that results from earlier experiments in Thermal Comfort can be compared with later experiments using slightly different scales without undue concern about those differences. Even so, the scale of preference appears to be LAPC_A. This is the loaded analog of Rohles' old TC scale, which uses the adjective pair good ventilation - poor ventilation in place of the adjective pair warm - cool, which confounds Thermal Comfort with Thermal Sensation. Of course, loadings must be determined within the context of each experiment individually.

Comparison of Table 23 with Table 19 immediately shows that the ranking of conditions based upon comfort, however it is determined, is different from the ranking dictated by the Thermal Sensation Variable Group. Fan

TABLE 23

Summary of Duncan's multiple range rankings for Thermal Comfort Variable Group: Conditions with the same letter had means for the dependent variable indicated which were not significantly different for alpha = 0.05, A representing the highest (most comfortable) range; the lowest priority letter representing the lowest (least comfortable) range of mean values (more specific information in Appendix O)

Predetermined Condition		Duncan's Multiple Range Ranking for the Dependent Variable Indicated for Alpha = 0.05 during the Fan Condition									
		Predetermined for the Day				Selected by the Subject for the Final ½ hr					
Average Fan Velocity (m/s)	Temperature (C DBT)	STCV	LAPC_R	LAPC_A	LAPC_B	STCV	LAPC_R	LAPC_A	LAPC_B	Selected Velocity	
0.8	25.6	A	A	A	A	A	A B	A	A	D	Mean=0.6m/s
		A	A	A	A	A	A	A	A	D	
1.3	25.6	A B	A B	A B	A	A	A	A	A	C D	Mean=0.7m/s
		A B	A B	A B	A	A		A	A		
1.3	30.0	C A B	A B	C A B	A B	A	B	A	A	A	Mean=1.2m/s
		C A B	A B	C A B	A B	A	B	A	A	A	
0.8	27.8	C A B	A B	C A B	A B	A	A B	A	A	C A B	Mean=1.0m/s
		C A B	A B	C A B	A B	A	A B	A	A	C B	
1.3	27.8	C A B	C A B	C A B	A B	A	A B	A	A	C D B	Mean=0.8m/s
		C B	C B	C B	B	A	A B	A	A	C B	
0.8	30.0	C D B	C B	C D B	C B	A	A B	A	A	C A B	Mean=1.1m/s
		C D	C B	C D	C B	A	A B	A	A		
≤0.35	25.6	C D	C B	C D	C B	A	A B	A	A	D	Mean=0.6m/s
		D	C	D	C	A	A B	A	A		
≤0.35	27.8	D E	C D	D E	C D	A	A B	A	A	A B	Mean=1.2m/s
		E	D	E	D	A	B	A	A	A	
≤0.35	30.0	E	D	E	D	A	B	A	A	A	Mean=1.3m/s
Sex:	Male	A	A	A	A	A	A	A	A	A	Mean=0.9m/s
		A	A	A	A					A	
	Female	A	A	A	A	B	B	B	B	A	Mean=1.0m/s

INFLUENCE OF TEMPERATURE (C) ON ADJECTIVE INTERCORRELATIONS
ABSOLUTE VALUES BELOW 0.15 ARE INSIGNIFICANT FOR P<=0.05
LETTERS DISPLAY CORRELATIONS OF THE SEMANTIC DIFFERENTIAL VALUES
FOR COMFORTABLE TO UNCOMFORTABLE TEMPERATURE-T, SATISFACTION-S,
COMFORT-C, GOOD OR BAD TEMPERATURE-G, WARM TO COOL-W,
PLEASNANTNESS-P, VENTILATION-V, AND ACCEPTABILITY-A
WITH THE THERMAL SENSATION VOTE

PLOT OF SV*CTEMP   SYMBOL IS VALUE OF _NAME_

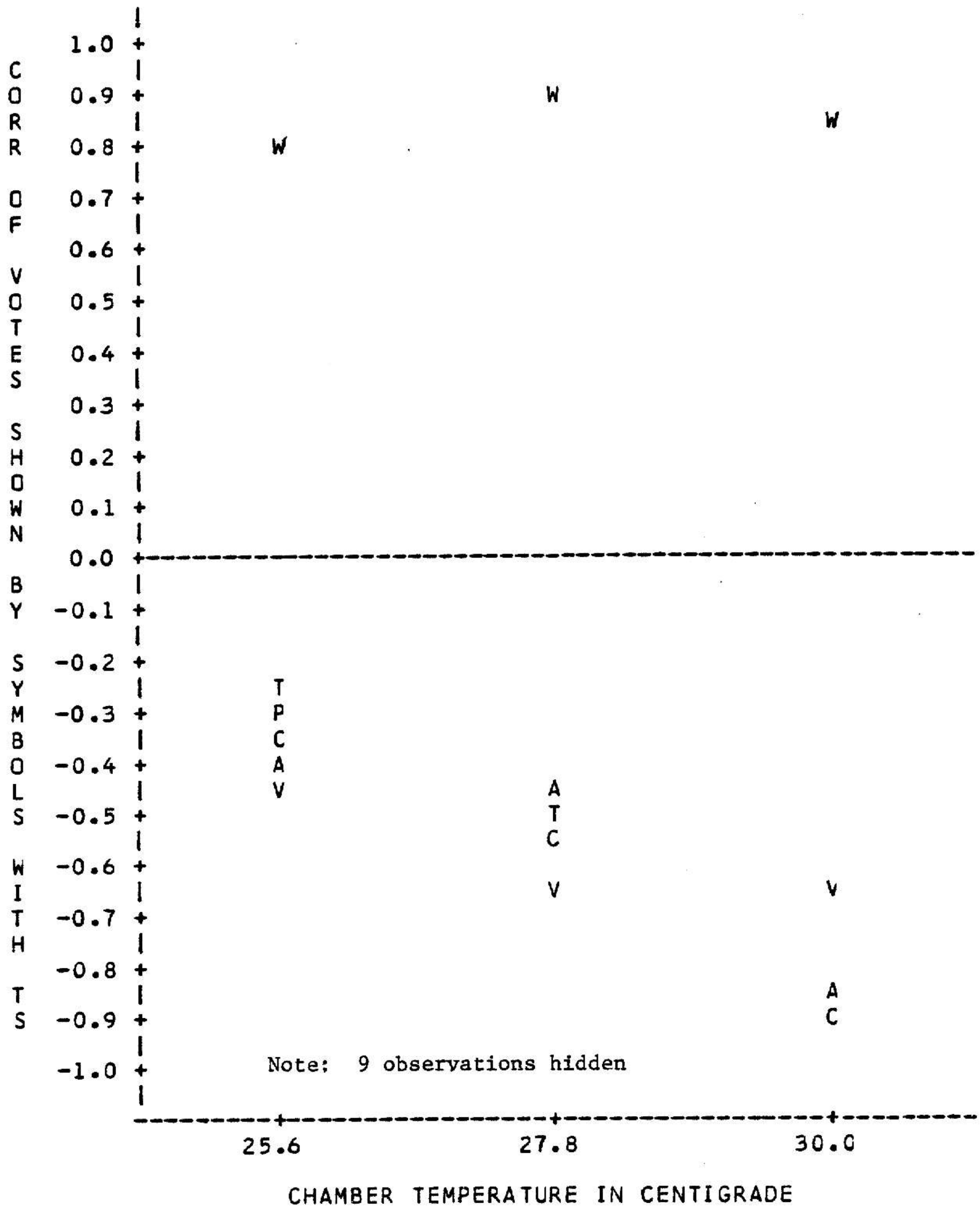

Figure 13. Correlation of Thermal Comfort scale components with TS.

INFLUENCE OF TEMPERATURE (C) CN ADJECTIVE INTERCORRELATICNS
ABSOLUTE VALUES BELOW 0.15 ARE INSIGNIFICANT FOR P<=0.05
LETTERS DISPLAY CORRELATICNS OF THE SEMANTIC DIFFERENTIAL VALUES
FOR COMFORTABLE TO UNCOMFORTABLE TEMPERATURE-T, SATISFACTICN-S,
COMFORT-C, GOOD OR BAD TEMPERATURE-G, WARM TO COCL-W,
PLEASNANTNESS-P, VENTILATICN-V, AND ACCEPTABILITY-A
WITH THE PREFERENCE TO HAVE THE TEMPERATURE LOWERED CR RAISED

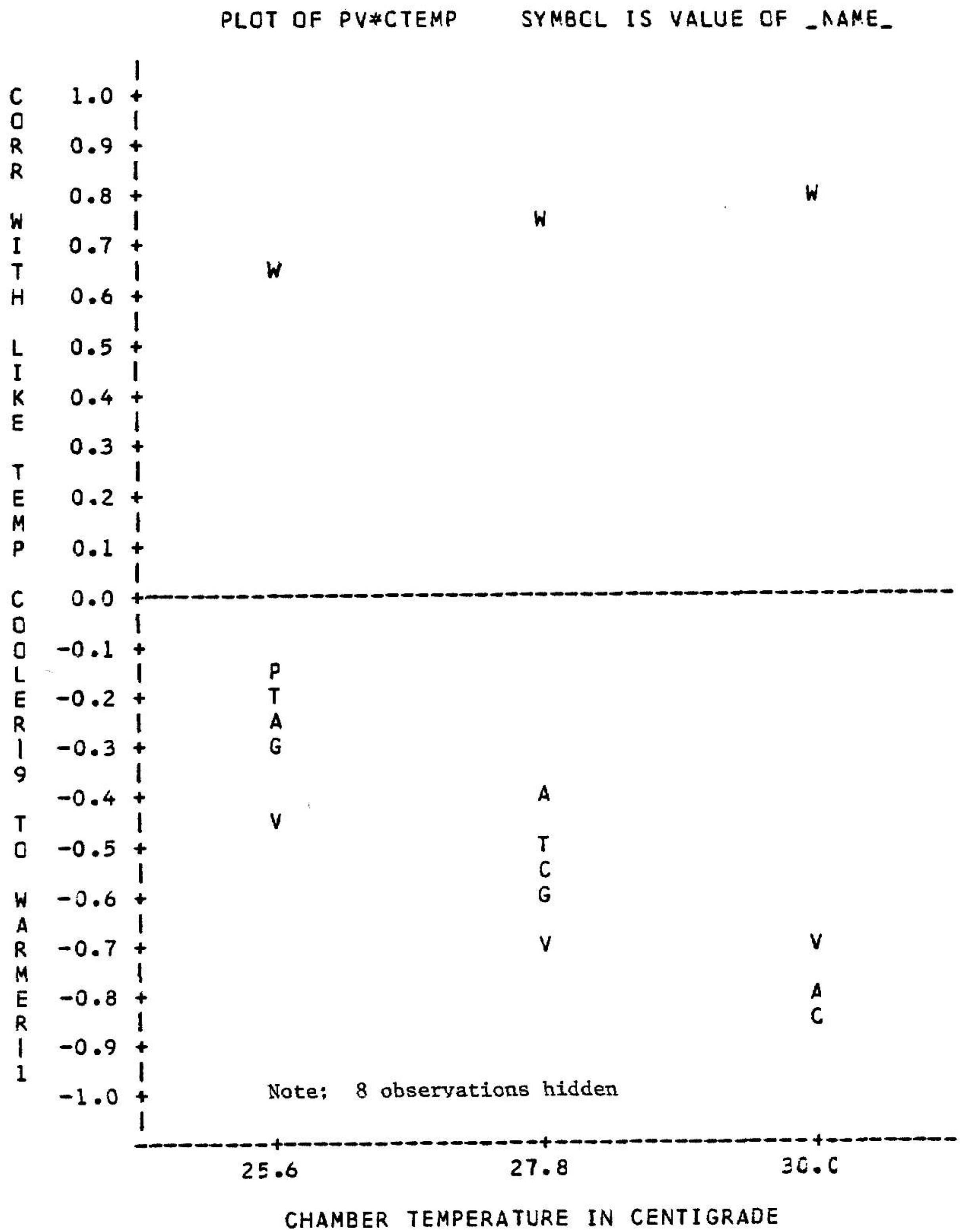

Figure 14. Correlation of Thermal Comfort scale components with PT.

INFLUENCE OF TEMPERATURE (C) ON ADJECTIVE INTERCORRELATICNS
ABSOLUTE VALUES BELOW 0.15 ARE INSIGNIFICANT FOR P<=0.05
LETTERS DISPLAY CORRELATICNS OF THE SEMANTIC DIFFERENTIAL VALUES
FOR COMFORTABLE TO UNCCMFCRTABLE TEMPERATURE-T, SATISFACTICN-S,
COMFORT-C, GOOD OR BAD TEMPERATURE-G, WARM TO CCCL-W,
PLEASNANTNESS-P, VENTILATION-V, AND ACCEPTABILITY-A
WITH THE TEMPERATURE IN FAHRENHEIT ESTIMATED BY THE SUBJECTS

PLOT OF ET*CTEMP   SYMBOL IS VALUE OF _NAME_

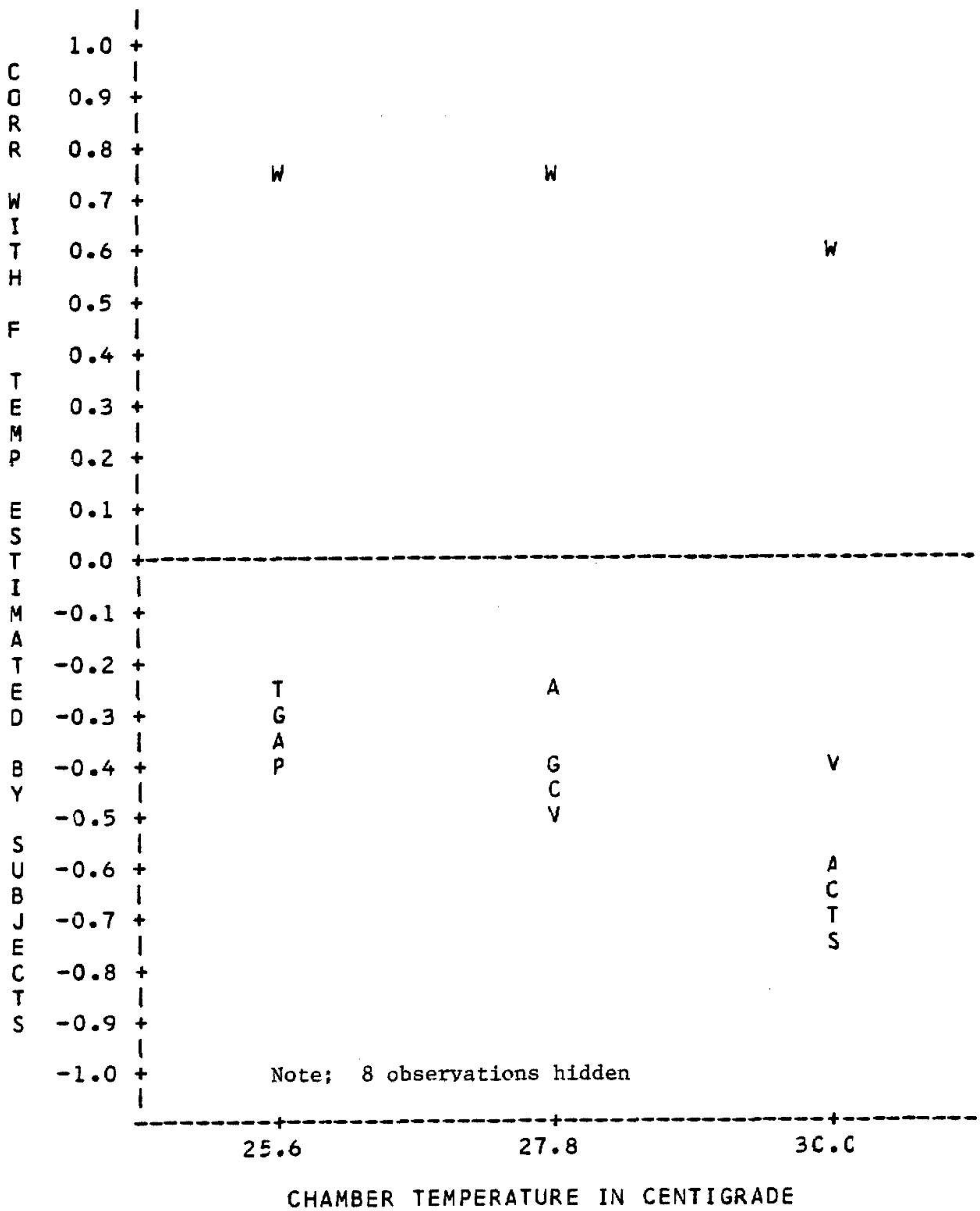

Figure 15. Correlation of Thermal Comfort scale components with TE.

velocity seems to play a much greater role in the determination of Thermal Comfort than it does in the determination of values for the Thermal Sensation Variable Group: the three least comfortable conditions were the three "still air" control conditions. Also in contrast with the results for the Thermal Sensation Variable Group was the failure to find a sex difference for exposure to the daily predetermined condition.

The ANOVA results for the predetermined conditions are duplicated in the paired t-tests shown in Tables 24 to 27. Again there is not more than one negative t value per table so that the order of predetermined conditions shown is consistent even from the point of view of the nonsignificant differences.

The right side of Table 23 displays the results of the Duncan's multiple range test for the Thermal Comfort Variable Group during the fan condition selected by the subject for the final half hour of the day. Preconditioning had even less of an effect on the Thermal Comfort Variable Group than it had on the Thermal Sensation Variable Group; except for the LAPC_R, preconditioning had no significant impact on the final comfort level. The significant differences for LAPC_R can be explained entirely on the basis of chamber temperature differences. But the separation found in the last half hour of the experiment for LAPC_R may have been due just as easily to inappropriate factor loadings. This scale was included in the study only to contrast the results for a scale with loadings determined for different conditions with the results for a scale with loadings determined within the context of the experiment. Thus, the favored interpretation of the data is that the subjects had sufficient control of their environment in the last half hour to negate the effect of temperature

TABLE 24

Probability that the difference by subject (n=8) for the daily mean (n=8) of the Thermal Comfort Vote (STCV) for the condition listed on the horizontal is the same as that for the condition listed on the vertical (df=7 in each case); except for the 15 insignificant differences, the subjects voted that for any one condition they were significantly more comfortable than for conditions to the lower right and less comfortable than for those to the upper left

Paired t-test for any 2 sets of Predetermined Conditions for the Thermal Comfort Vote, STCV									Mean and SE of Daily Mean: Percent (and Actual) Vote: Mean	S.E. (n=8)
Highest Comfort Vote 25.6 C, 0.8 m/s	t=0.49 p,0.64	t=2.44 p,0.05*	t=2.37* p,0.05	t=1.47 p,0.19	t=3.58* p,0.009	t=3.58* p,0.009	t=6.71* p,0.0003	t=5.25* p,0.002	70% (46)	3.4% (1.9)
	25.6 C, 1.3 m/s	t=0.94 p,0.38	t=0.96 p,0.37	t=1.23 p,0.26	t=1.91 p,0.10	t=2.64* p,0.04	t=4.51* p,0.003	t=5.44* p,0.001	68% (45)	4.7% (2.6)
		30.0 C, 1.3 m/s	t=0.53 p,0.62	t=0.16 p,0.88	t=2.22 p,0.07	t=2.50* p,0.05	t=5.11* p,0.002	t=4.14* p,0.005	61% (41)	4.1% (2.3)
Predetermined			27.8 C, 0.8 m/s	t=-0.04 p,0.97	t=2.08 p,0.08	t=2.06 p,0.08	t=4.06* p,0.005	t=3.61* p,0.009	59% (40)	5.2% (2.9)
Exposure				27.8 C, 1.3 m/s	t=1.33 p,0.23	t=2.55* p,0.04	t=4.46* p,0.003	t=7.32* p,0.0002	61% (41)	4.4% (2.5)
Conditions					30.0 C, 0.8 m/s	t=1.11 p,0.31	t=4.14* p,0.005	t=3.64* p,0.009	54% (37)	3.7% (2.1)
						25.6 C, ≤0.35 m/s	t=3.17* p,0.02	t=4.94* p,0.002	50% (35)	4.3% (2.4)
							27.8 C, ≤0.35 m/s	t=2.08* p,0.08	41% (30)	2.0% (1.1)
								30.0 C, ≤0.35 m/s Lowest Comfort Vote	32% (25)	5.0% (2.8)

Probability that the difference by subject (n=8) for the daily mean (n=8) of the Thermal Comfort Vote (R Scale) for the condition listed on the horizontal is the same as that for the condition listed on the vertical (df=7 in each case); except for the 18 insignificant differences, the subjects voted that for any one condition they were significantly more comfortable than for conditions to the lower right and less comfortable than for those to the upper left

Paired t-test for any 2 sets of Predetermined Conditions for the Thermal Comfort R Scale									Mean and SE of Daily Mean for LAPC_R measure of TC: Mean	S.E.(n=8)
Highest Comfort Vote 25.6 C, 0.8 m/s.	t=1.00 p,0.35	t=2.63* p,0.04	t=3.03* p,0.02	t=1.71 p,0.13	t=3.72* p,0.008	t=3.48* p,0.01	t=7.06* p,0.0002	t=4.97* p,0.002	65%	2.7%
	25.6 C, 1.3 m/s	t=0.51 p,0.63	t=0.72 p,0.50	t=1.20 p,0.28	t=1.49 p,0.18	t=1.85 p,0.11	t=3.51* p,0.01	t=4.84* p,0.002	61%	4.2%
		30.0 C, 1.3 m/s	t=1.01 p,0.35	t=0.49 p,0.64	t=2.15 p,0.07	t=1.69 p,0.14	t=4.07* p,0.005	t=3.61* p,0.009	58%	3.5%
Predetermined			27.8 C, 0.8 m/s	t=0.19 p,0.86	t=1.77 p,0.12	t=1.30 p,0.24	t=3.49* p,0.01	t=3.20* p,0.02	56%	3.9%
	Exposure			27.8 C, 1.3 m/s	t=0.68 p,0.52	t=0.96 p,0.37	t=2.60* p,0.04	t=6.69* p,0.0003	55%	4.3%
		Conditions			30.0 C, 0.8 m/s	t=0.19 p,0.86	t=3.34* p,0.02	t=3.12* p,0.02	52%	2.8%
						25.6 C, ≤0.35 m/s	t=3.00* p,0.02	t=5.20* p,0.002	52%	3.5%
							27.8 C, ≤0.35 m/s	t=1.91 p,0.10	45%	1.4%
								30.0 C, ≤0.35 m/s Lowest Comfort Vote	38%	4.0%

Probability that the difference by subject (n=8) for the daily mean (n=8) of the Thermal Comfort Vote (A Scale) for the condition listed on the horizontal is the same as that for the condition listed on the vertical (df=7 in each case); except for the 16 insignificant differences, the subjects voted that for any one condition they were significantly more comfortable than for conditions to the lower right and less comfortable than for those to the upper left

Paired t-test for any 2 sets of Predetermined Conditions for the Thermal Comfort A Scale; Mean and SE of Daily Mean for LAPC A measure of TC

Highest Comfort Vote

Predetermined Exposure Conditions	25.6 C, 1.3 m/s	30.0 C, 1.3 m/s	27.8 C, 0.8 m/s	27.8 C, 1.3 m/s	30.0 C, 0.8 m/s	25.6 C, ≤0.35 m/s	27.8 C, ≤0.35 m/s	30.0 C, ≤0.35 m/s	Mean	S.E.(n=8)
25.6 C, 0.8 m/s	t=0.54 p,0.61	t=2.50* p,0.05	t=2.45* p,0.05	t=1.51 p,0.18	t=3.63* p,0.009	t=3.57* p,0.01	t=6.81* p,0.0003	t=5.20* p,0.002	69%	3.4%
25.6 C, 1.3 m/s		t=0.91 p,0.40	t=0.95 p,0.38	t=1.23 p,0.26	t=1.90 p,0.10	t=2.57* p,0.04	t=4.45* p,0.003	t=5.40* p,0.001	67%	4.7%
30.0 C, 1.3 m/s			t=0.54 p,0.61	t=0.18 p,0.86	t=2.19 p,0.07	t=2.35 p,0.06	t=4.92* p,0.002	t=4.03* p,0.005	61%	4.2%
27.8 C, 0.8 m/s				t=-0.02 p,0.99	t=2.05 p,0.08	t=1.95 p.0.10	t=3.99* p,0.006	t=3.54* p,0.01	59%	5.2%
27.8 C, 1.3 m/s					t=1.30 p,0.24	t=2.38* p,0.05	t=4.26* p,0.004	t=7.23* p,0.0002	59%	4.5%
30.0 C, 0.8 m/s						t=0.96 p,0.38	t=4.02* p,0.006	t=3.57* p,0.01	53%	3.7%
25.6 C, ≤0.35 m/s							t=3.19* p,0.02	t=4.97* p,0.002	50%	4.3%
27.8 C, ≤0.35 m/s								t=2.07 p,0.08	41%	1.9%
30.0 C, ≤0.35 m/s									33%	5.1%

Lowest Comfort Vote

TABLE 27

Probability that the difference by subject (n=8) for the daily mean (n=8) of the Thermal Comfort Vote (B Scale) for the condition listed on the horizontal is the same as that for the condition listed on the vertical (df=7 in each case); except for the 17 insignificant differences, the subjects voted that for any one condition they were significantly more comfortable than for conditions to the lower right and less comfortable than for those to the upper left

Paired t-test for any 2 sets of Predetermined Conditions for the Thermal Comfort B Scale; Mean and SE of Daily Mean for LAPC_B measure of TC

Predetermined Exposure Conditions

Highest Comfort Vote

Condition	25.6 C, 1.3 m/s	30.0 C, 1.3 m/s	27.8 C, 0.8 m/s	27.8 C, 1.3 m/s	30.0 C, 0.8 m/s	25.6 C, ≤0.35 m/s	27.8 C, ≤0.35 m/s	30.0 C, ≤0.35 m/s	Mean	S.E.(n=8)
25.6 C, 0.8 m/s	t=0.53 p,0.62	t=2.85* p,0.03	t=2.79* p,0.03	t=1.64 p,0.15	t=3.94* p,0.006	t=3.44* p,0.02	t=7.27* p,0.0002	t=5.03* p,0.002	55%	3.3%
25.6 C, 1.3 m/s		t=0.99 p,0.36	t=0.99 p,0.36	t=1.31 p,0.23	t=2.10 p,0.08	t=2.42* p,0.05	t=4.59* p,0.003	t=5.46* p,0.0009	53%	4.3%
30.0 C, 1.3 m/s			t=0.32 p,0.76	t=0.11 p,0.92	t=1.98 p,0.09	t=1.62 p,0.15	t=4.03* p,0.005	t=3.52* p,0.01	46%	4.4%
27.8 C, 0.8 m/s				t=0.01 p,1.00	t=1.98 p,0.09	t=1.47 p,0.19	t=3.64* p,0.009	t=3.28* p,0.02	46%	5.1%
27.8 C, 1.3 m/s					t=1.65 p,0.15	t=1.94 p,0.10	t=3.90* p,0.006	t=6.49* p,0.0003	46%	4.1%
30.0 C, 0.8 m/s						t=0.23 p,0.83	t=3.27* p,0.02	t=3.30* p,0.02	39%	3.6%
25.6 C, ≤0.35 m/s							t=3.34* p,0.02	t=4.96* p,0.002	39%	4.2%
27.8 C, ≤0.35 m/s								t=2.08 p,0.08	29%	1.9%
30.0 C, ≤0.35 m/s									20%	5.2%

Lowest Comfort Vote

differences on Thermal Comfort (See also ANOVA discussion which follows).

The males were significantly more comfortable than the females during the time the subjects were allowed to choose their own fan setting (Table 23, bottom right) despite the fact that no significant differences were found for the first part of the experiment. Several interpretations are possible: (1) males feel more comfortable than females when they feel (subjectively) warmer than females, (2) males and females respond to preconditioning differently, or (3) males heavily weigh control of their environment within their notion of (Thermal) Comfort. But since these results are based on the responses of only 4 males and 4 females, any interpretation must be accepted with great caution, even with 9 runs for each subject.

Tables 19 and 23 also show the values of the selected velocity for the final half hour of the experiment. The order of these values shows that the explicit velocity preference is more nearly approximated by the ranking of predetermined conditions for the Thermal Sensation Variable Group than that for the Thermal Comfort Variable Group. The votes for the Thermal Sensation Variable Group cast during the time of the explicit velocity preference also reflect that preference. This does not happen for the votes for the Thermal Comfort Variable Group.

The distinction which subjects make between the Thermal Comfort and Thermal Sensation Variable Groups results in (1) different rankings of the predetermined exposure conditions and (2) a generally greater number of significant differences for the Thermal Sensation Variable Group (See t-tests). This last seems to indicate that the range of personal tolerance, or adaptability, is wider than the ability to discriminate between subjective differences in warmth (See Tables 19 and 23, upper left groupings).

ANOVA for Thermal Sensation Group and Thermal Comfort Group Variables

The explicitly selected fan velocity already has been shown to increase significantly (p = 0.05) with temperature (p. 61) within the temperature range studied, while the fan preconditioning has been found to have no significant effect. These results have been mirrored in the balloting as well. Table 28 summarizes 30 separate ANOVA analyses, presented in Appendices L and P for closer examination. Table 28 shows that neither the fan preconditioning (FANCOND) nor any of its interactions had a significant effect on the voting during the final fan condition selected by the subject. But DBT (CTEMP) had a significant effect on the voting even during the final fan condition selected by the subject for each of the dependent variables composing the Thermal Sensation Variable Group.

Table 28 (TCOND not significant for TS and for the Thermal Comfort Variable Group during the final ½ hr) also indicates that the subjects were able to use the fans to adjust the environment to suit themselves. This is in sharp contrast with the significant distinctions between the predetermined conditions (TCOND) found during the first part of the experiment. The three sources of variance Sex, Number, and Sex*Number combined represent the single source, Subject. So the significance of the Sex*Number interaction shown in Table 28 simply provides an indication of the importance of individual differences in tests of subjective differences, a fact already known. As with this result, Table 28 simply provides a broad overview of the experiment for both Thermal Sensation and Thermal Comfort Variable Groups.

TABLE 28

Summary of 30 sequential ANOVA analyses for each of the various dependent variables for both the predetermined 2 hour fan condition and the final fan condition chosen by each individual (Separate analyses are shown in Appendices L & P)

Source--Analysis		Significance Level P ≤ (* = 0.05, ** = 0.01, *** = 0.001, **** = 0.0001) during the Fan Condition														
		Predetermined for the Day							Selected by the Subject for the Final ½ hr							Selected Velocity
		TS	PT	TE	STCV	PC_R	PC_A	PC_B	TS	PT	TE	STCV	PC_R	PC_A	PC_B	
CTEMP	I	****	****	****	**	**	***	***	*	***	**		*	*	*	****
FANCOND	I	****	****	****	****	****	****	****								
SEX	I	****		****					***		****	**	**	**	**	
NUMBER	I	*	***			**		*		*		**	***	**	**	****
CTEMP*FANCOND	I															
CTEMP*SEX	I															
FANCOND*SEX	I															
CTEMP*NUMBER	I								*	*						
FANCOND*NUMBER	I															
SEX*NUMBER	I	****	****	****	**	*	**	**	***	***	****	***	***	***	****	***
TCOND	II	****	****	****	****	***	****	****		*	*					***
SEX	II	***		****					***		****	*	**	**	**	
NUMBER	II	*	***			*						*	**	*	**	****
TCOND*SEX	II															
TCOND*NUMBER	II															
SEX*NUMBER	II	****	****	***	*	*	*	*	***	**	****	**	**	**	***	**

Relationship of Comfort to Coolness

Figures 16 to 19 display the correlation of each of the measures of Thermal Comfort with the Thermal Sensation Group Variables. Correlations of the variables derived from the fan - task ballot are also shown (F, T, and I represent LAPFV, LAPTV, and LAPIV, derived in Tables 13, 15, and 17, respectively). These relationships are seen to vary with temperature. Values for these correlations are reported in tabular form in Tables 29 to 31. Table 32 shows the overall correlations disregarding temperature.

With the exception of correlations with LAPC_R, already seen to be at variance with the other three measures of Thermal Comfort, all the plots are essentially identical. With this final illustration of the similarity between the various measures of Thermal Comfort, all attention will be focused on results dealing with the A scale (Figure 18). First, the absolute values of the correlations of the Thermal Sensation Variable Group with LAPC_A increase with temperature within the limited temperature range studied. This means that temperature is not of so much concern at the low end of the range, 25.6 C (78 F), as at the high end of the range. The correlation should be lowest in the range of the Thermal Comfort Zone. In fact, a plot of correlation of TS with TC versus temperature should provide a simple way of defining the "ideal temperature" for Thermal Comfort: it will be that temperature at which no relationship between Thermal Comfort and Thermal Sensation can be found. In other words, when the thermal needs are satisfied, temperature should have no impact on Thermal Comfort.

Figure 20 shows the projected relationship between the 9 category Thermal Sensation and Thermal Comfort (A) Scales. The "ideal temperature"

INFLUENCE OF TEMPERATURE (C) ON ADJECTIVE INTERCORRELATICNS
ABSOLUTE VALUES BELOW 0.15 ARE INSIGNIFICANT FOR P<=0.05
LETTERS DISPLAY CORRELATICNS OF THERMAL SENSTICN-S,
WHETHER THE SUBJECTS PREFERRED TO HAVE THE TEMPERATURE CHANGEC-P,
THE TEMPERATURE (F) OF THE CHAMBER ESTIMATED BY THE SUBJECTS-E,
THE LOADED FAN VCTE-F, THE LCADED TASK VOTE-T, AND THE LOADED
INTERACTION VOTE-I WITH THE VARIABLE SPECIFIED ON THE ORDINATE

PLOT OF STC*CTEMP   SYMBOL IS VALUE OF _NAME_

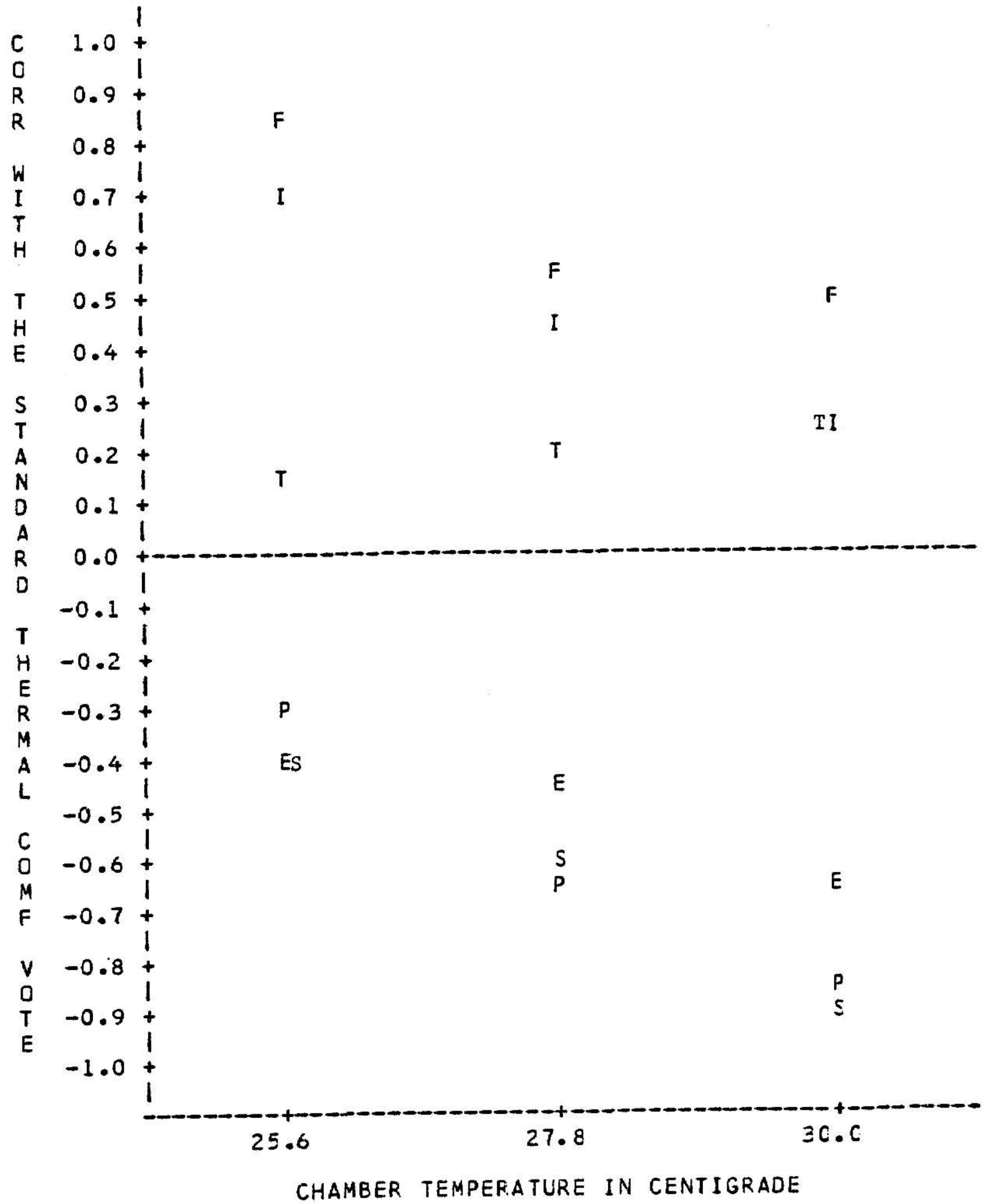

Figure 16. Correlation of STCV with Thermal Sensation Group Variables and with variables derived from the Fan - Task Ballot.

INFLUENCE OF TEMPERATURE (C) ON ADJECTIVE INTERCORRELATIONS
ABSOLUTE VALUES BELOW 0.15 ARE INSIGNIFICANT FOR P<=0.05
LETTERS DISPLAY CORRELATIONS OF THERMAL SENSTION-S,
WHETHER THE SUBJECTS PREFERRED TO HAVE THE TEMPERATURE CHANGED-P,
THE TEMPERATURE (F) OF THE CHAMBER ESTIMATED BY THE SUBJECTS-E,
THE LOADED FAN VOTE-F, THE LOADED TASK VOTE-T, AND THE LOADED
INTERACTION VOTE-I WITH THE VARIABLE SPECIFIED ON THE ORDINATE

PLOT OF RTC*CTEMP   SYMBOL IS VALUE OF _NAME_

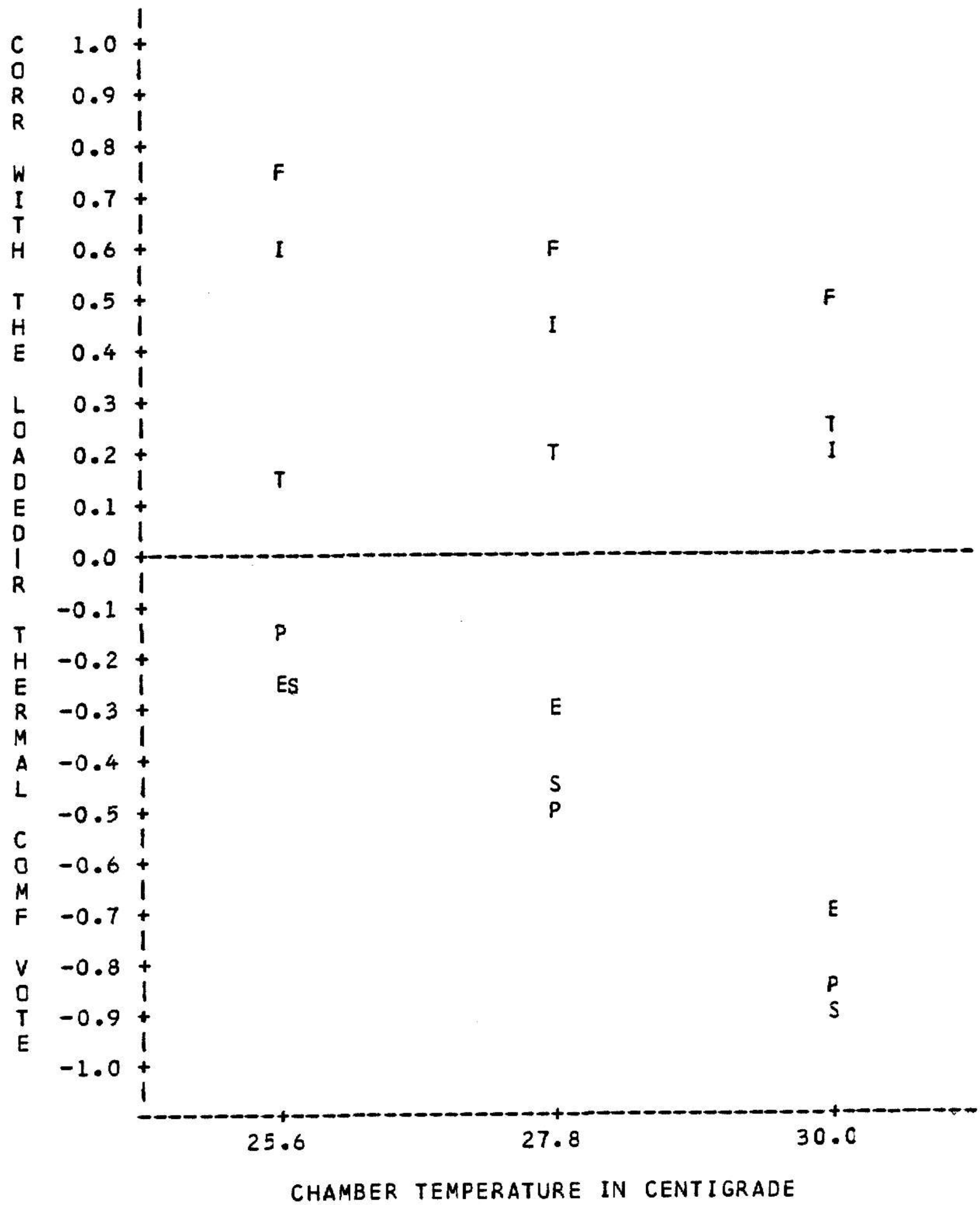

Figure 17. Correlation of Thermal Comfort (R Scale) with Thermal Sensation Group Variables and with variables derived from the Fan - Task Ballot.

INFLUENCE OF TEMPERATURE (C) ON ADJECTIVE INTERCORRELATICNS
ABSOLUTE VALUES BELOW 0.15 ARE INSIGNIFICANT FOR P<=0.05
LETTERS DISPLAY CORRELATIONS OF THERMAL SENSTICN-S,
WHETHER THE SUBJECTS PREFERRED TO HAVE THE TEMPERATURE CHANGED-P,
THE TEMPERATURE (F) OF THE CHAMBER ESTIMATED BY THE SUBJECTS-E,
THE LOADED FAN VOTE-F, THE LOADED TASK VOTE-T, AND THE LOADED
INTERACTION VOTE-I WITH THE VARIABLE SPECIFIED ON THE ORDINATE

PLOT OF ATC*CTEMP   SYMBOL IS VALUE OF _NAME_

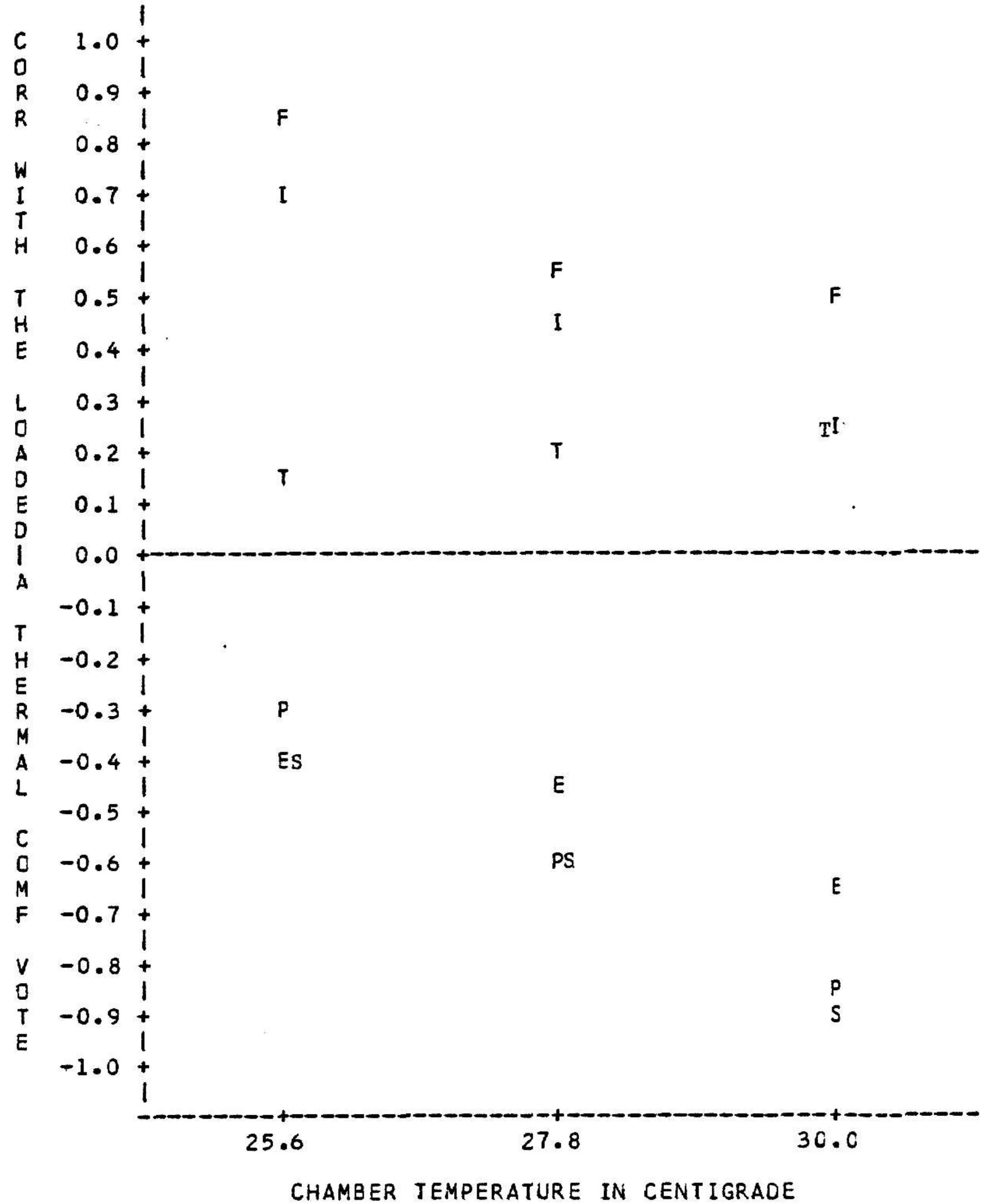

Figure 18. Correlation of Thermal Comfort (A Scale) with Thermal Sensation Group Variables and with variables derived from the Fan - Task Ballot.

INFLUENCE OF TEMPERATURE (C) ON ADJECTIVE INTERCORRELATIONS
ABSOLUTE VALUES BELOW 0.15 ARE INSIGNIFICANT FOR P<=0.05
LETTERS DISPLAY CORRELATIONS OF THERMAL SENSATION-S,
WHETHER THE SUBJECTS PREFERRED TO HAVE THE TEMPERATURE CHANGED-P,
THE TEMPERATURE (F) OF THE CHAMBER ESTIMATED BY THE SUBJECTS-E,
THE LOADED FAN VOTE-F, THE LOADED TASK VOTE-T, AND THE LOADED
INTERACTION VOTE-I WITH THE VARIABLE SPECIFIED ON THE ORDINATE

PLOT OF BTC*CTEMP   SYMBOL IS VALUE OF _NAME_

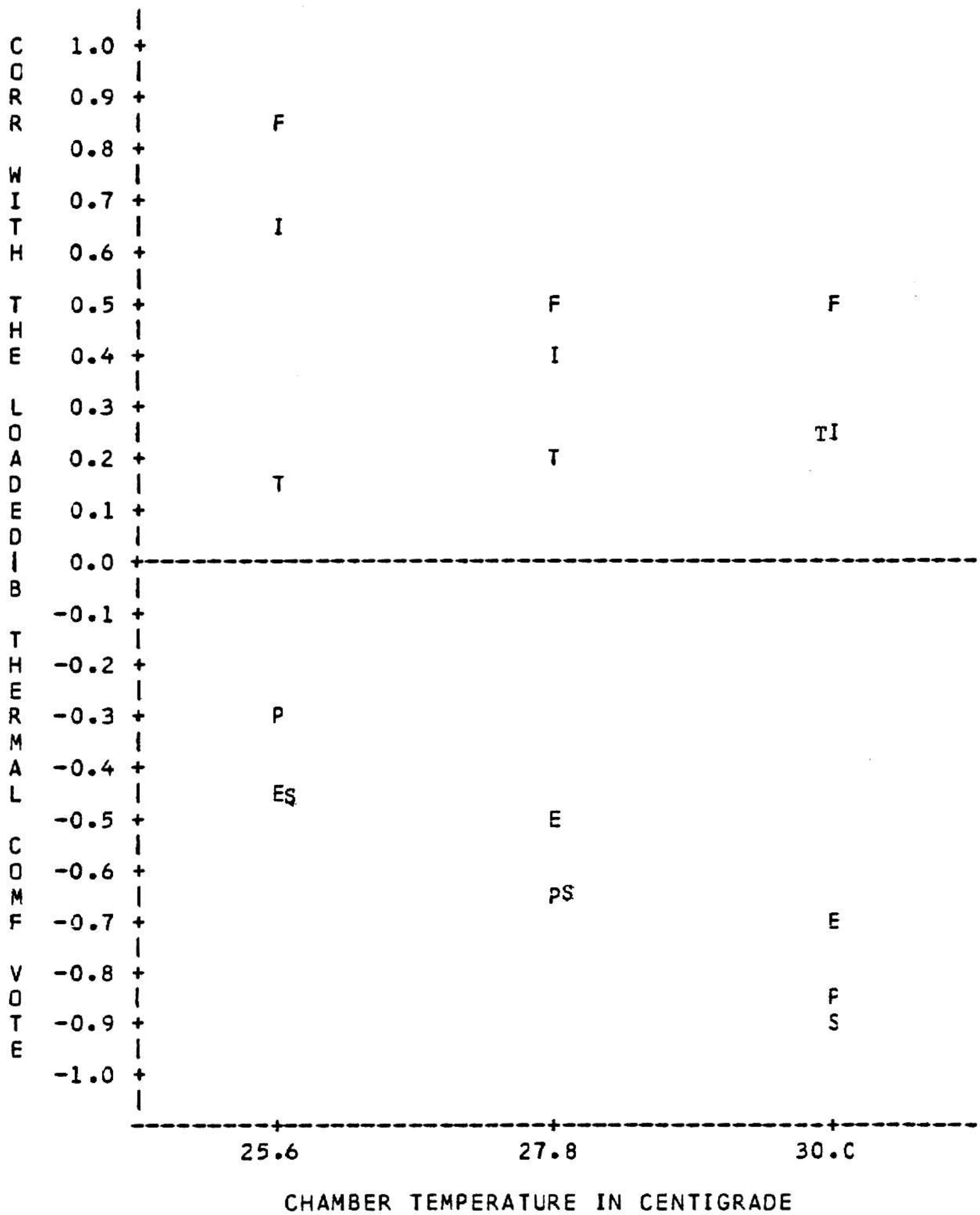

Figure 19. Correlation of Thermal Comfort (B Scale) with Thermal Sensation Group Variables and with variables derived from the Fan - Task Ballot.

TABLE 29

Correlation of the Thermal Sensation Group Variables and of the Fan - Task variables with each of the components (left) of Thermal Comfort and with each of the various derived measures of Thermal Comfort (right) at 25.6 C

TEST OF THE NULL HYPOTHESIS THAT COMFORT IS NOT CORRELATED
WITH COOLNESS OVER A TWO HOUR PERIOD IN A PRESET CONDITION
THE HIGHER THE COMFORT VOTE OR ONE OF ITS ANALOGS, THE MORE
COMFORTABLE, WHILE THE HIGHER THE TS VOTE, THE WARMER THE PERSON
A NEGATIVE CORRELATION BETWEEN THERMAL COMFORT AND TS THUS
INDICATES A POSITIVE CORRELATION BETWEEN COMFORT AND COOLNESS
AT 25.6 C (78 F) ONLY

PEARSON CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	COMFTM	SATSFD	CMFTBL	GDTM	COOL	PLSNTM	GDVENT	ACCPTBL	SAFC	LAPC_R	LAPC_A	LAPC_B
TSPV	-0.26331	-0.31317	-0.35234	-0.36242	0.78917	-0.28907	-0.46193	-0.38027	-0.40434	-0.24629	-0.39626	-0.42697
	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0006	0.0001	0.0001
	192	192	192	192	192	192	192	192	192	192	192	192
PRFTMPV	-0.18673	-0.17247	-0.25441	-0.27624	0.66992	-0.16170	-0.46623	-0.23167	-0.30348	-0.13887	-0.29147	-0.29783
	0.0095	0.0167	0.0004	0.0001	0.0001	0.0250	0.0001	0.0012	0.0001	0.0547	0.0001	0.0001
	192	192	192	192	192	192	192	192	192	192	192	192
ESTTM	-0.24406	-0.31923	-0.34123	-0.32467	0.73934	-0.40253	-0.38206	-0.37390	-0.39328	-0.26339	-0.38877	-0.42992
	0.0006	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001
	192	192	192	192	192	192	192	192	192	192	192	192
LAPFV	0.60486	0.76903	0.72211	0.61718	-0.30001	0.84191	0.65093	0.82440	0.85374	0.75357	0.64751	0.83984
	0.0001	0.0001	0.0001	0.0001	0.0006	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	128	128	128	128	128	128	128	128	128	128	128	128
LAPTV	0.14002	0.12799	0.13819	0.14079	-0.04564	0.18011	0.16038	0.12649	0.16654	0.15657	0.16476	0.15082
	0.0527	0.0769	0.0559	0.0514	0.5296	0.0124	0.0263	0.0804	0.0210	0.0301	0.0224	0.0368
	192	192	192	192	192	192	192	192	192	192	192	192
LAPIV	0.44947	0.58215	0.57294	0.45246	-0.22422	0.69960	0.76614	0.68712	0.71956	0.59429	0.70618	0.66090
	0.0001	0.0001	0.0001	0.0001	0.0109	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	128	128	128	128	128	128	128	128	128	128	128	128
LAPTID	-0.07721	-0.20827	-0.20861	-0.13092	0.09666	-0.23525	-0.33631	-0.29057	-0.25673	-0.19169	-0.24926	-0.22507
	0.3863	0.0183	0.0181	0.1407	0.2778	0.0075	0.0001	0.0009	0.0034	0.0302	0.0046	0.0106
	128	128	128	128	128	128	128	128	128	128	128	128

Correlation of the Thermal Sensation Group Variables and of the Fan - Task variables with each of the components (left) of Thermal Comfort and with each of the various derived measures of Thermal Comfort (right) at 27.8 C

TEST OF THE NULL HYPOTHESIS THAT COMFORT IS NOT CORRELATED
WITH COOLNESS OVER A TWO HOUR PERIOD IN A PRESET CONDITION
THE HIGHER THE COMFORT VOTE OR ONE OF ITS ANALOGS, THE MORE
COMFORTABLE, WHILE THE HIGHER THE TS VOTE, THE WARMER THE PERSON
A NEGATIVE CORRELATION BETWEEN THERMAL COMFORT AND TS THUS
INDICATES A POSITIVE CORRELATION BETWEEN COMFORT AND COOLNESS
AT 27.8 C (82 F) ONLY

PEARSON CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	COMFTM	SATSFD	CMFTBL	GDTM	COOL	PLSNTM	GDVENT	ACCPTBL	SAPC	LAPC_R	LAPC_A	LAPC_B
TSPV	-0.48693 0.0001 192	-0.54362 0.0001 192	-0.57285 0.0001 192	-0.55037 0.0001 192	0.87909 0.0001 192	-0.57076 0.0001 192	-0.65091 0.0001 192	-0.42743 0.0001 192	-0.62015 0.0001 192	-0.45278 0.0001 192	-0.61195 0.0001 192	-0.63768 0.0001 192
PRFTMPV	-0.50326 0.0001 192	-0.57121 0.0001 192	-0.57301 0.0001 192	-0.59197 0.0001 192	0.74644 0.0001 192	-0.55265 0.0001 192	-0.67752 0.0001 192	-0.41378 0.0001 192	-0.63339 0.0001 192	-0.48876 0.0001 192	-0.62443 0.0001 192	-0.62781 0.0001 192
ESTTM	-0.39202 0.0001 192	-0.37967 0.0001 192	-0.4501[illegible] 0.0001 192	-0.40139 0.0001 192	0.74045 0.0001 192	-0.45391 0.0001 192	-0.50092 0.0001 192	-0.26443 0.0002 192	-0.46525 0.0001 192	-0.32287 0.0001 192	-0.45864 0.0001 192	-0.48631 0.0001 192
LAPFV	0.46332 0.0001 128	0.51704 0.0001 128	0.50681 0.0001 128	0.43297 0.0001 128	0.10334 0.2457 128	0.54319 0.0001 128	0.24706 0.0049 128	0.64596 0.0001 128	0.54990 0.0001 128	0.59499 0.0001 128	0.55310 0.0001 128	0.52436 0.0001 128
LAPTV	0.15888 0.0277 192	0.17714 0.0140 192	0.18157 0.0117 192	0.14076 0.0515 192	-0.10807 0.1357 192	0.20664 0.0040 192	0.19238 0.0075 192	0.13765 0.0569 192	0.19444 0.0069 192	0.17663 0.0143 192	0.19241 0.0075 192	0.18042 0.0123 192
LAPIV	0.33320 0.0001 128	0.45912 0.0001 128	0.39740 0.0001 128	0.25773 0.0033 128	0.13741 0.1219 128	0.46684 0.0001 128	0.42159 0.0001 128	0.49567 0.0001 128	0.46875 0.0001 128	0.47024 0.0001 128	0.46358 0.0001 128	0.40115 0.0001 128
LAPTID	-0.12055 0.1753 128	-0.19400 0.0282 128	-0.13807 0.1201 128	-0.08366 0.3478 128	-0.17364 0.0500 128	-0.14309 0.1071 128	-0.09189 0.3023 128	-0.22038 0.0124 128	-0.16335 0.0654 128	-0.19435 0.0279 128	-0.16346 0.0652 128	-0.13347 0.1331 128

Correlation of the Thermal Sensation Group Variables and of the Fan - Task variables with each of the components (left) of Thermal Comfort and with each of the various derived measures of Thermal Comfort (right) at 30.0 C

TEST OF THE NULL HYPOTHESIS THAT COMFORT IS NOT CORRELATED
WITH COOLNESS OVER A TWO HOUR PERIOD IN A PRESET CONDITION
THE HIGHER THE COMFORT VOTE OR ONE OF ITS ANALOGS,THE MORE
COMFORTABLE, WHILE THE HIGHER THE TS VOTE, THE WARMER THE PERSON
A NEGATIVE CORRELATION BETWEEN THERMAL COMFORT AND TS THUS
INDICATES A POSITIVE CORRELATION BETWEEN COMFORT AND COOLNESS
AT 30.0 C (86 F) ONLY

PEARSON CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	COMFTM	SATSFD	CMFTBL	GDTM	COOL	PLSNTM	GDVENT	ACCPTBL	SAPC	LAPC_R	LAPC_A	LAPC_B
TSPV	-0.89043	-0.85794	-0.89205	-0.86799	0.85424	-0.87986	-0.65134	-0.83878	-0.89990	-0.90187	-0.90297	-0.91466
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	192	192	192	192	192	192	192	192	192	192	192	192
PRFTMPV	-0.83551	-0.79889	-0.83982	-0.83547	0.81772	-0.84533	-0.68533	-0.78157	-0.86250	-0.85080	-0.86314	-0.86508
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	192	192	192	192	192	192	192	192	192	192	192	192
ESTTM	-0.70348	-0.74272	-0.65154	-0.66297	0.58848	-0.64091	-0.37752	-0.60709	-0.66736	-0.70239	-0.67367	-0.69327
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	192	192	192	192	192	192	192	192	192	192	192	192
LAPFV	0.44219	0.44000	0.45883	0.46753	-0.30762	0.45394	0.35835	0.48787	0.50587	0.50073	0.50384	0.48262
	0.0001	0.0001	0.0001	0.0001	0.0004	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	128	128	128	128	128	128	128	128	128	128	128	128
LAPTV	0.23450	0.27701	0.24475	0.26560	-0.25100	0.26763	0.20321	0.22357	0.26287	0.26017	0.26329	0.26495
	0.0011	0.0001	0.0006	0.0002	0.0004	0.0002	0.0047	0.0018	0.0002	0.0003	0.0002	0.0002
	192	192	192	192	192	192	192	192	192	192	192	192
LAPIV	0.16982	0.19470	0.23324	0.15816	-0.18276	0.21548	0.32952	0.32244	0.26311	0.22410	0.25719	0.23133
	0.0553	0.0276	0.0081	0.0746	0.0389	0.0146	0.0001	0.0002	0.0027	0.0110	0.0034	0.0086
	128	128	128	128	128	128	128	128	128	128	128	128
LAPTID	0.24042	0.20731	0.19011	0.23149	-0.23476	0.22439	0.07984	0.13959	0.21366	0.21319	0.21528	0.22636
	0.0063	0.0189	0.0316	0.0086	0.0076	0.0109	0.3703	0.1161	0.0154	0.0157	0.0147	0.0102
	128	128	128	128	128	128	128	128	128	128	128	128

TABLE 32

Correlation of the Thermal Sensation Group Variables and of the Fan - Task variables with each of the components of Thermal Comfort (left) and with each of the derived measures of Thermal Comfort (right) for all conditions combined

TEST OF THE NULL HYPOTHESIS THAT COMFORT IS NOT CORRELATED
WITH COOLNESS OVER A TWO HOUR PERIOD IN A PRESET CONDITION
THE HIGHER THE COMFORT VOTE OR ONE OF ITS ANALOGS,THE MORE
COMFORTABLE, WHILE THE HIGHER THE TS VOTE, THE WARMER THE PERSON
A NEGATIVE CORRELATION BETWEEN THERMAL COMFORT AND TS THUS
INDICATES A POSITIVE CORRELATION BETWEEN COMFORT AND COOLNESS
FOR ALL CONDITIONS COMBINED

PEARSON CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / NUMBER OF OBSERVATIONS

	COMFTM	SATSFD	CMFTBL	GDTM	COOL	PLSNTM	GDVENT	ACCPTBL	SAPC	LAPC_R	LAPC_A	LAPC_B
TSPV	-0.63180	-0.63104	-0.66478	-0.65678	0.86425	-0.65174	-0.59527	-0.61257	-0.69805	-0.60494	-0.69578	-0.72386
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	576	576	576	576	576	576	576	576	576	576	576	576
PRFTMPV	-0.58783	-0.57902	-0.61588	-0.62675	0.78086	-0.59655	-0.61589	-0.54093	-0.65695	-0.56139	-0.65245	-0.66518
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	576	576	576	576	576	576	576	576	576	576	576	576
ESTTM	-0.54114	-0.55012	-0.54995	-0.54154	0.72881	-0.57383	-0.44801	-0.49440	-0.57831	-0.51177	-0.57841	-0.61121
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	576	576	576	576	576	576	576	576	576	576	576	576
LAPFV	0.51232	0.59674	0.55568	0.50368	-0.14734	0.62327	0.43337	0.67378	0.63590	0.63120	0.63446	0.60638
	0.0001	0.0001	0.0001	0.0001	0.0038	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	384	384	384	384	384	384	384	384	384	384	384	384
LAPTV	0.18182	0.19781	0.19287	0.18739	-0.14943	0.21987	0.18746	0.16392	0.20969	0.19857	0.20864	0.20241
	0.0001	0.0001	0.0001	0.0001	0.0003	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	576	576	576	576	576	576	576	576	576	576	576	576
LAPIV	0.33238	0.43929	0.39479	0.29796	-0.05416	0.47339	0.51066	0.52294	0.46651	0.45388	0.47891	0.42528
	0.0001	0.0001	0.0001	0.0001	0.2898	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	384	384	384	384	384	384	384	384	384	384	384	384
LAPTID	0.00437	-0.08100	-0.04550	0.00122	-0.11670	-0.05711	-0.11643	-0.14567	-0.07301	-0.07590	-0.07023	-0.04119
	0.9320	0.1130	0.3739	0.9811	0.0222	0.2642	0.0225	0.0042	0.1533	0.1376	0.1696	0.4209
	384	384	384	384	384	384	384	384	384	384	384	384

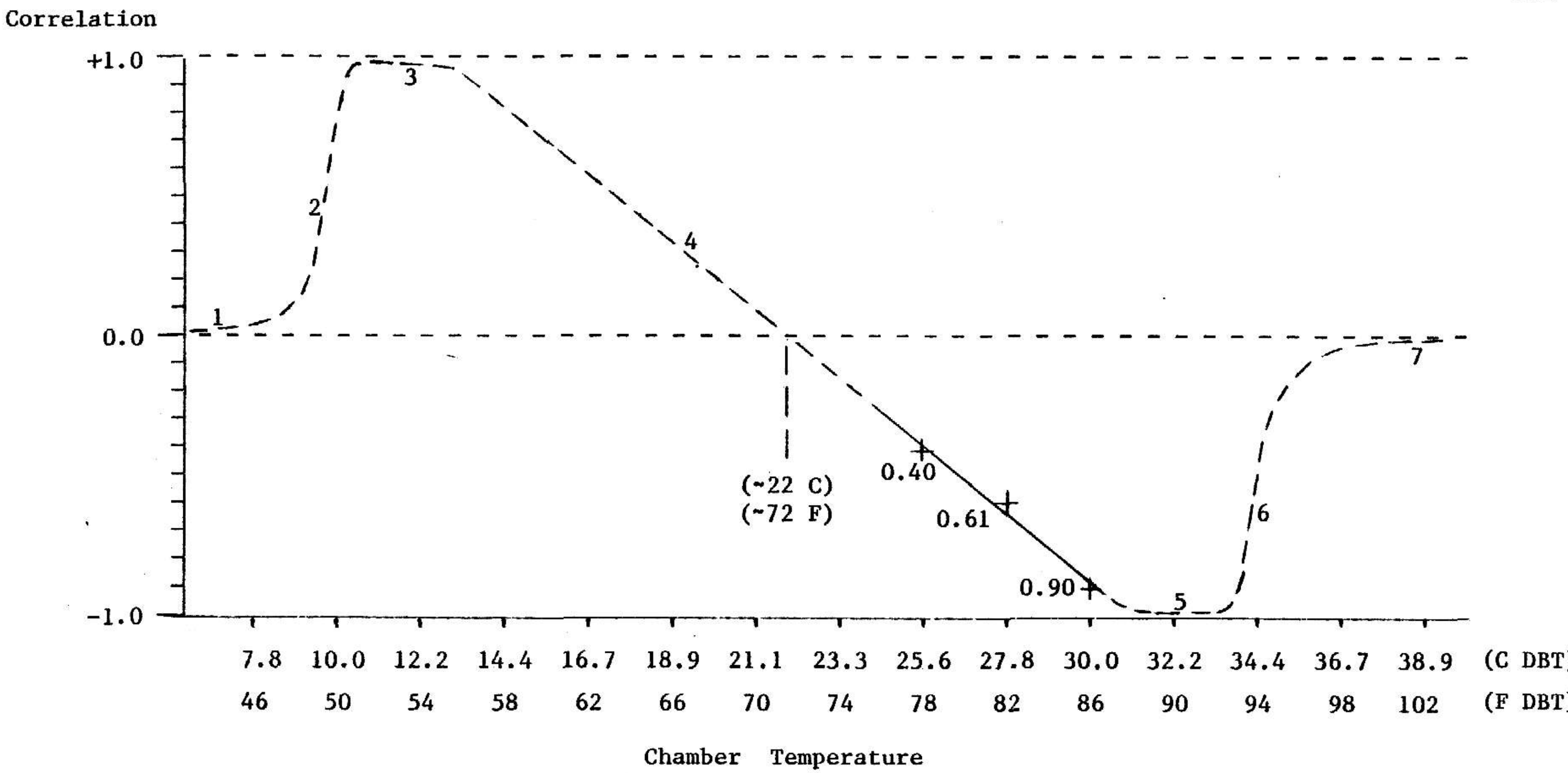

Figure 20. Projected relationship of correlation between Thermal Sensation and Thermal Comfort (A Scale) with temperature using variations in air velocity to develop correlation values (numbers define the 7 zones expected).

based on the projection of the straight line segment is 22 C DBT (72 F DBT) at 45% rh. However, there is no guarantee that the relationship is linear in the projected region of zero correlation. The regions of tolerable thermal discomfort will probably be marked by a continuously increasing absolute correlation as the departure from the Zone of Thermal Comfort (the region between 20.0 and 26.1 CET* (68 and 79 FET*)) increases. The zones of thermal intolerance must have high absolute correlations of zero slope since thermal (dis-)comfort must have a large temperature component. But the correlation should drop abruptly to zero when the votes cluster at the ends of the scales. This point marks the limit of the scale usefulness (See p. 22). All of the zones should be definable by the intersections of straight lines drawn through each of the seven region sections.

Projections aside, the present study shows only that the correlation of Thermal Sensation with Thermal Comfort changes with temperature. But this means that the way in which we relate to and deal with our environment changes as our environment changes. Since we use words to characterize our environment, this means that the referent of a word can change as the environment changes. The generalization indicated is that work with subjective values requires clarity in communication.

Looking back at Figure 18, the correlations for the Thermal Sensation Variable Group with Thermal Comfort are all negative. This occurs because high values for TS (hot end of the scale) tend to be associated with low values for TC (uncomfortable end of the scale), and conversely, above the Thermal Comfort Zone. Understanding of this relationship explains Figure 20.

A more basic comparison of comfort with coolness is presented in Figure 21, which is a plot of TC versus the corresponding TS. This graph shows

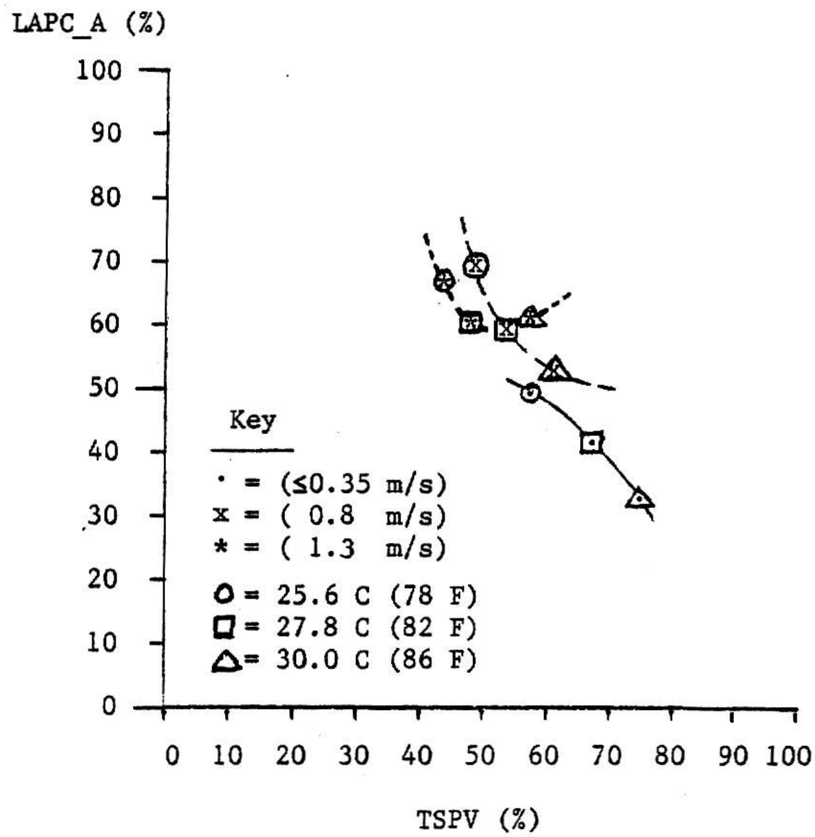

Figure 21. Variation in comfort (Loaded Average Percent Comfortable - A Scale) with coolness (Thermal Sensation Percent Vote) according to the predetermined exposure condition. Each point represents 64 observations made up of 8 observations daily for each of 8 subjects.

that both temperature and air velocity affect the relationship in an interactive manner. While it presents all the relevant information, Figure 21 is difficult to interpret because it is the ratio of TC to TS that is important. The calculated values for this ratio are presented in tabular form in Table 33 and in graphic form in Figure 22. Figure 22 shows that at any one fan speed a change in the relationship between TS and TC with temperature is consistent with the change shown in Figure 20. But Figure 22 also shows that the relationships between TS and TC (A Scale) are dependent on fan speed as well as on temperature, so that the correlation of TS and TC (A Scale) with temperature already seen in Figure 20 must be influenced by the particular variation in fan speed used in the study.

<u>Relationship of Comfort to Perception of Fan and Task</u>

The correlations of LAPFV, LAPTV, and of LAPIV with TC in Figure 18 have already been pointed out. In contrast with the Thermal Sensation Variable Group, their correlations are all positive. This means that each subject's feelings of Thermal Comfort had a positive association with his perception of the fan and of the task. Those who liked the task (Table 15) tended to vote that they were more comfortable than those who disliked the task, but this tendency did not appear to change much with temperature. Similarly, those who liked the fan (Table 13) tended to vote that they were more comfortable than those who disliked the fan. But Figure 18 shows that the correlation between LAPFV and LAPC_A drops with temperature. A convergence of agreement about the fan with the rise in temperature explains the change (S.D.(%) = 13.5, 11.0, 8.2 for LAPFV and S.D.(%) = 14.9, 14.7, and 17.6 for LAPC_A at 25.6 C, 27.8 C, and 30.0 C respectively with N = 128 and N = 192). A similar convergence of agreement explains the drop in correlation

TABLE 33

Mean values for Thermal Sensation and for Thermal Comfort (A Scale) as percent of the maximum vote, and the corresponding ratio TS/TC for each of the predetermined exposure conditions (* represents overall ratio by temperature)

Condition	N	Mean Values for TSPV	Mean Values for LAPC_A	Ratio: TSPV / LAPC_A
25.6 C (78 F)	192	49.9	61.9	0.81 *
≤0.35 m/s	64	58.0	49.7	1.17
0.8 m/s	64	49.0	69.2	0.71
1.3 m/s	64	42.6	66.8	0.64
27.8 C (82 F)	192	56.5	53.3	1.06 *
≤0.35 m/s	64	68.0	41.0	1.66
0.8 m/s	64	53.7	59.4	0.90
1.3 m/s	64	47.9	59.5	0.80
30.0 C (86 F)	192	64.6	48.8	1.32 *
≤0.35 m/s	64	75.2	32.5	2.31
0.8 m/s	64	61.3	53.4	1.15
1.3 m/s	64	57.2	60.6	0.94

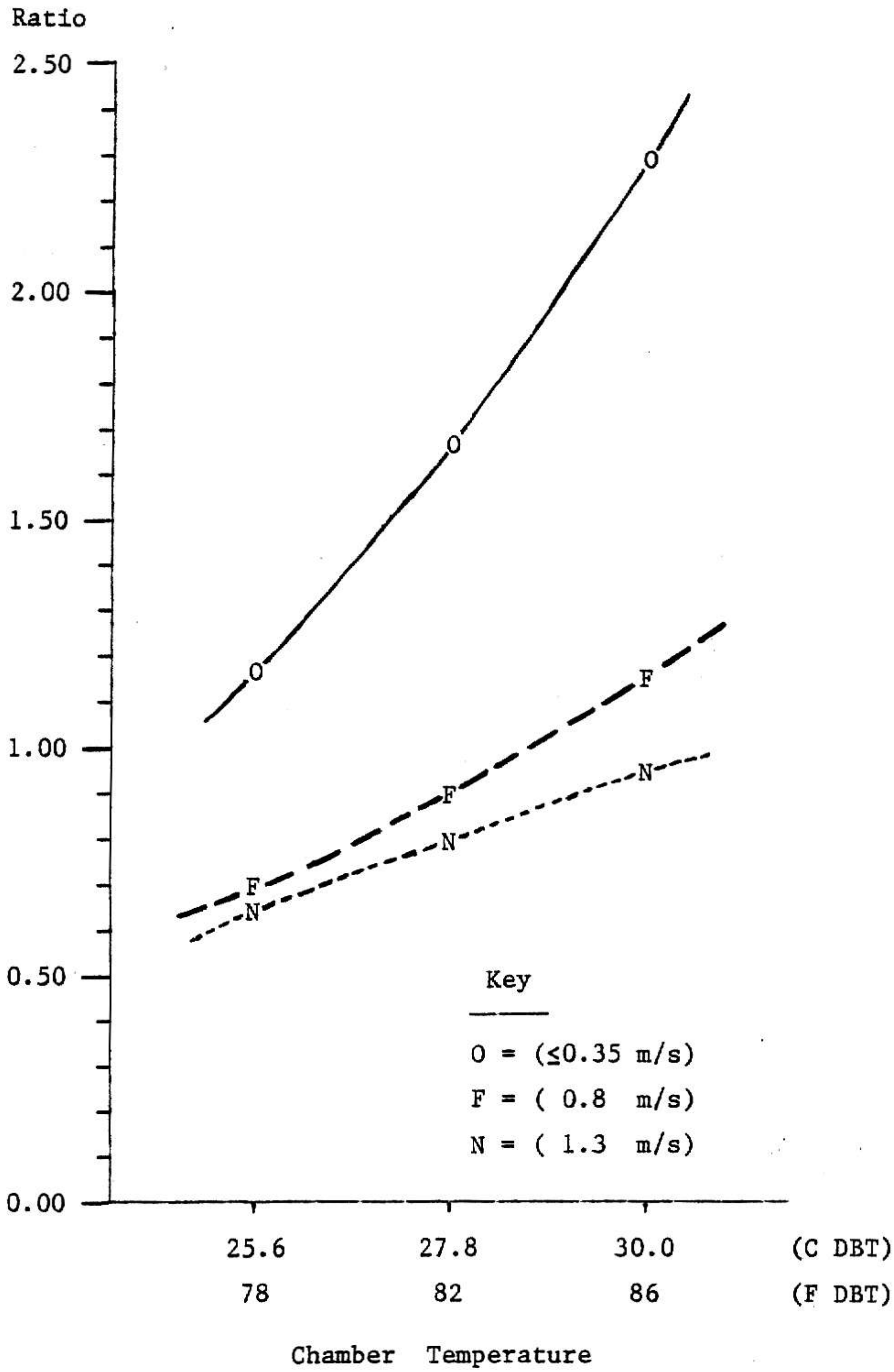

Figure 22. Relationship of Ratio (TSPV/LAPC_A) to chamber temperature according to fan condition. Each point represents 64 observations made up of 8 observations daily for each of 8 subjects.

between LAPIV and LAPC_A with temperature (S.D.(%) = 9.9, 7.9, and 5.6 for LAPIV at 25.6 C, 27.8 C, and 30.0 C respectively with N = 128 and N = 192).

Interrelationship of Fan - Task and of Thermal Sensation Group Variables

Table 34 shows that the two variables Preference for Temperature change and Temperature Estimate correlate less well with each other than Thermal Sensation does with either of them. Thus, the Thermal Sensation scale appears to be the scale of choice for the Thermal Sensation Variable Group. The values for the intercorrelations fluctuated more with the variable pair than with the temperature over the temperature range studied for the Thermal Sensation Group Variables. The values for the average Pearson correlation coefficients indicate that the interrelationship between the Thermal Sensation Group Variables, taken as a whole, is constant with temperature.

Table 35 shows the intercorrelations between the Loaded Average (daily) Fan Vote, the Loaded Average (daily) Task Vote, and the Loaded Average (daily) fan-task Interaction Vote. The low correlations between the LAPFV and the LAPTV indicate that the two scales measured different aspects of the environment, as had been intended. A similar situation exists between LAPIV and LAPTV (also shown in Table 35), as well as for the relationship of each of the Thermal Sensation Group Variables with each of the measures derived from the Fan - Task Ballot (not shown). The high correlation between the LAPFV and the LAPIV indicates that the two scales represent effectively the same aspect of the environment. This is indicated also by the similar behavior of the two scales in Figures 16 to 19.

Predetermined Conditions Influence PPC and PPD

Figures 23 and 24 show the changes in the Predicted Percent Comfortable and in the Predicted Percent Dissatisfied, respectively, with temperature.

TABLE 34

Pearson Correlation Coefficients for the Thermal Sensation Variable Group

DBT (C)	DBT (F)	Pearson Correlation Coefficients, P > |R| under H 0 : rho = 0, and Number of Observations for the Relationship: TS - PT	TS - TE	PT - TE	Average Pearson Correlation Coefficients
25.6	78	0.7616	0.8262	0.6164	0.7347
		0.0001	0.0001	0.0001	
		192	192	192	
27.8	82	0.7664	0.8294	0.5758	0.7239
		0.0001	0.0001	0.0001	
		192	192	192	
30.0	86	0.8533	0.7180	0.6618	0.7444
		0.0001	0.0001	0.0001	
		192	192	192	
Overall		0.8292	0.8272	0.6807	
		0.0001	0.0001	0.0001	
		576	576	576	

TABLE 35

Pearson Correlation Coefficients for the measures derived from the Fan - Task ballot

DBT (C)	DBT (F)	Pearson Correlation Coefficients, P > |R| under H 0: rho = 0, and Number of Observations for the Relationship: LAPFV - LAPTV	LAPFV - LAPIV	LAPTV - LAPIV
25.6	78	0.2208	0.8385	0.4187
		0.0123	0.0001	0.0001
		128	128	128
27.8	82	0.0492	0.7726	0.2766
		0.5809	0.0001	0.0016
		128	128	128
30.0	86	0.1624	0.6861	0.2440
		0.0670	0.0001	0.0055
		128	128	128
Overall		0.1467	0.7968	0.3135
		0.0040	0.0001	0.0001
		384	384	384

RELATIONSHIP OF MEAN OVER 2.5 HRS OF EXPOSURE FOR DEP VAR SHOWN TO TEMP FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S), F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

PLOT OF PPC_*CTEMP   SYMBOL IS VALUE OF FANCOND

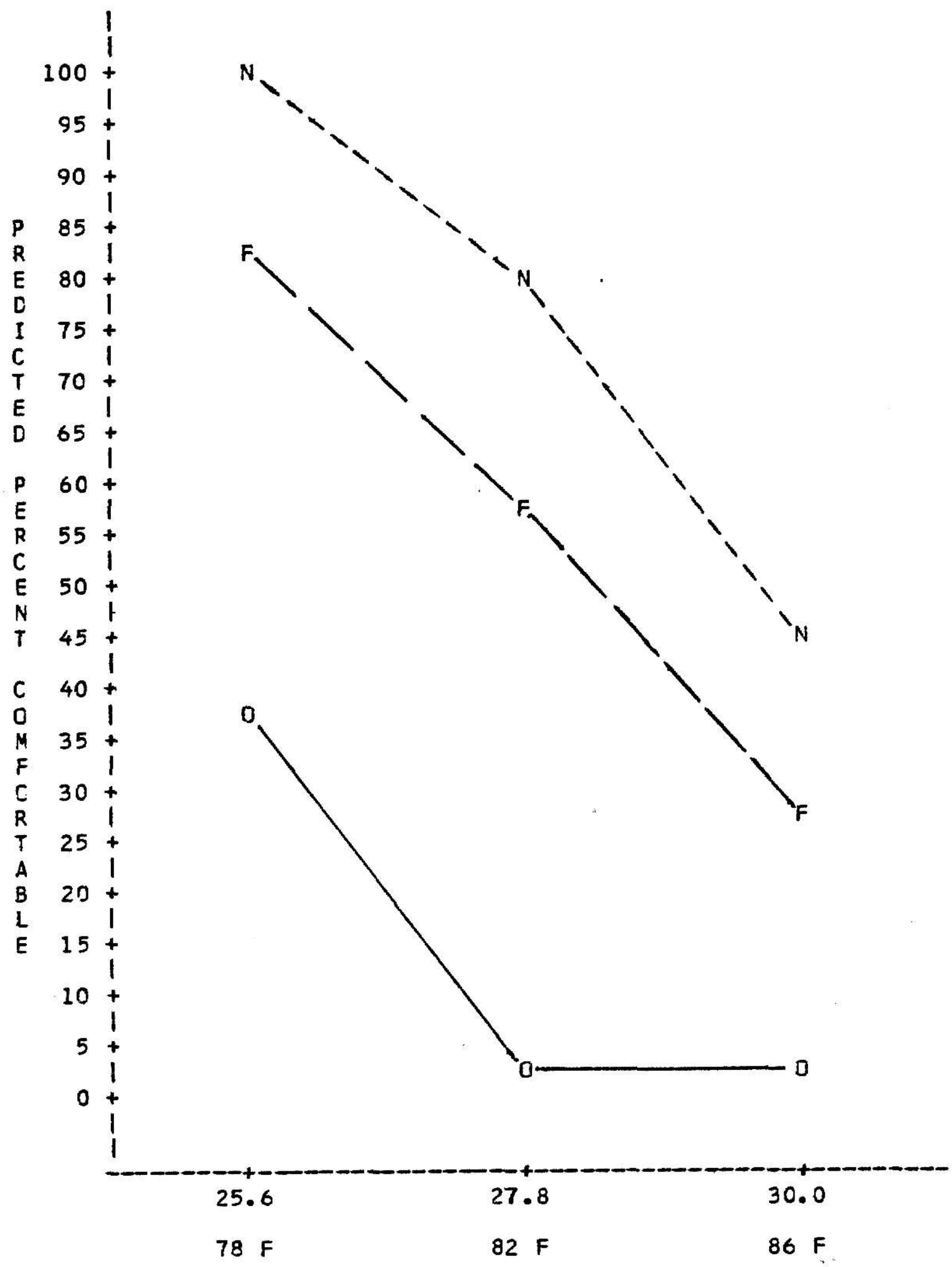

Figure 23. Change in the Predicted Percent Comfortable with chamber DBT.

RELATIONSHIP OF MEAN OVER 2.5 HRS OF EXPOSURE FOR DEP VAR SHOWN TO TEMP FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S), F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

PLOT OF PPD_*CTEMP   SYMBOL IS VALUE OF FANCOND

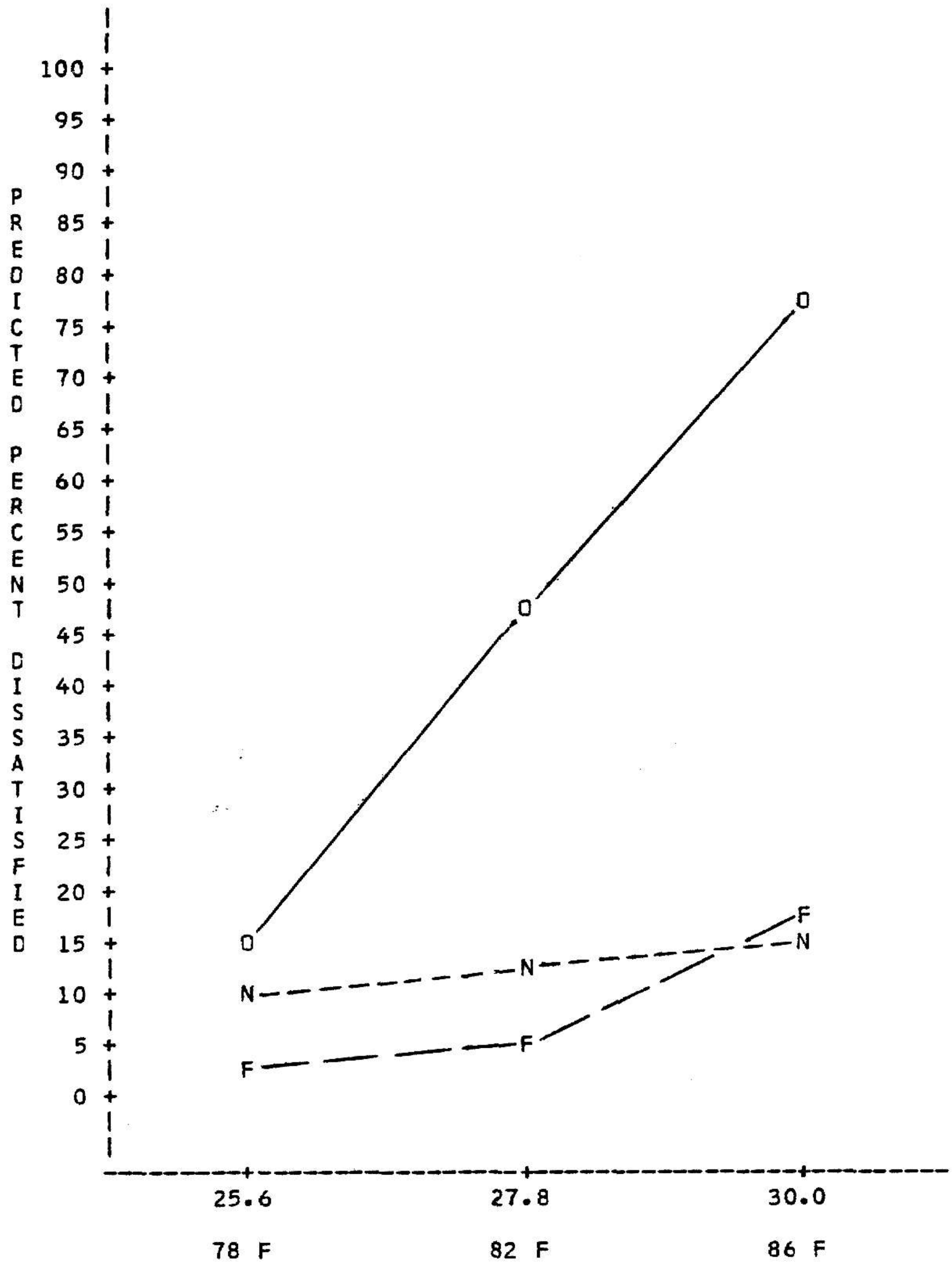

Figure 24. Change in the Predicted Percent Dissatisfied with chamber DBT.

Although the PPC sounds as if it relates to Thermal Comfort, both PPC and PPD are defined entirely in relation to Thermal Sensation (p. 25). Thus, Figure 23 shows that 38% of the subjects (3 out of 8) were "neutral" or cooler at 25.6 C DBT (78 F DBT) when the fan was off (See also Table 36). At this temperature the fans were so effective they raised this percentage to 83% and 100% at 0.8 m/s and at 1.3 m/s, respectively. Since the PPD is lower at 0.8 m/s than at 1.3 m/s (Figure 24), a wind velocity of 1.3 m/s is unnecessarily high at 25.6 C DBT (78 F DBT). The same is true at 27.8 C DBT (82 F DBT). But Figure 23 shows that the subjects voted they were cooler at the higher fan velocity. There is only one way the PPD can be lower for 0.8 m/s than for 1.3 m/s while the PPC is always higher for the higher fan velocity. The subjects had to vote that they were cooler than "slightly cool" at the two lower temperatures of the study. Only at 30.0 C DBT (86 F DBT) is a wind velocity of 1.3 m/s favored over 0.8 m/s (Figure 24). This result is mirrored in the Thermal Comfort data as well (Figure 11).

Figures 25 to 30 show how the PPC and the PPD varied over time. There was a tendency for the PPC to rise as the exposure time increased, especially noticeable at 30.0 C DBT (86 F DBT) with the fans working. The PPD rose noticeably over time at this temperature when the fans were off. But the fans allowed the maintainance of a continuous low level of dissatisfaction with the TS aspect of the environment. Figures 28 and 29 show that the preference for the fan velocity of 0.8 m/s rather than 1.3 m/s at 25.6 and 27.8 C DBT (78 and 82 F DBT) evolved midway through the experiment. In contrast, the higher fan velocity of 1.3 m/s was preferred only in the first half of the experiment at 30.0 C DBT (86 F DBT). Thus, while the higher fan velocity is at first preferred at this temperature, it is unnecessary to maintain the air velocity at 1.3 m/s to minimize the PPD.

TABLE 36

Mean values for Predicted Percent Dissatisfied (PPD) and for Predicted Percent Comfortable (PPC) by temperature - fan velocity (≤0.35 m/s represents "still air", 0.8 m/s represents distance of 3.0 m, and 1.3 m/s represents distance of 1.5 m; original values shown in Appendix Q)

	DBT	PPD for Velocity (m/s)			PPC for Velocity (m/s)		
Condition	(C)	≤0.35	0.8	1.3	≤0.35	0.8	1.3
First Hour of exposure to predetermined fan condition, ending at 1.5 hours	25.6	16	3	0	34	78	100
	27.8	47	9	12	0	56	78
	30.0	72	22	16	0	19	41
Last Hour of exposure to predetermined fan condition, ending at 2.5 hours	25.6	12	0	22	41	88	100
	27.8	47	3	12	6	59	84
	30.0	84	16	16	3	38	50
Overall for predetermined fan condition	25.6	14	2	11	38	83	100
	27.8	47	6	12	3	58	81
	30.0	78	19	16	2	28	45
Overall for subject's choice of fan condition from T = 2.5 to T = 3.0 hours	25.6	0	0	0	82	94	100
	27.8	0	0	0	82	56	82
	30.0	19	12	19	56	82	50

RELATIONSHIP OF DEP VAR SHOWN TO EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=25.6

PLOT OF PPC_*EXPINT SYMBOL IS VALUE OF FANCOND

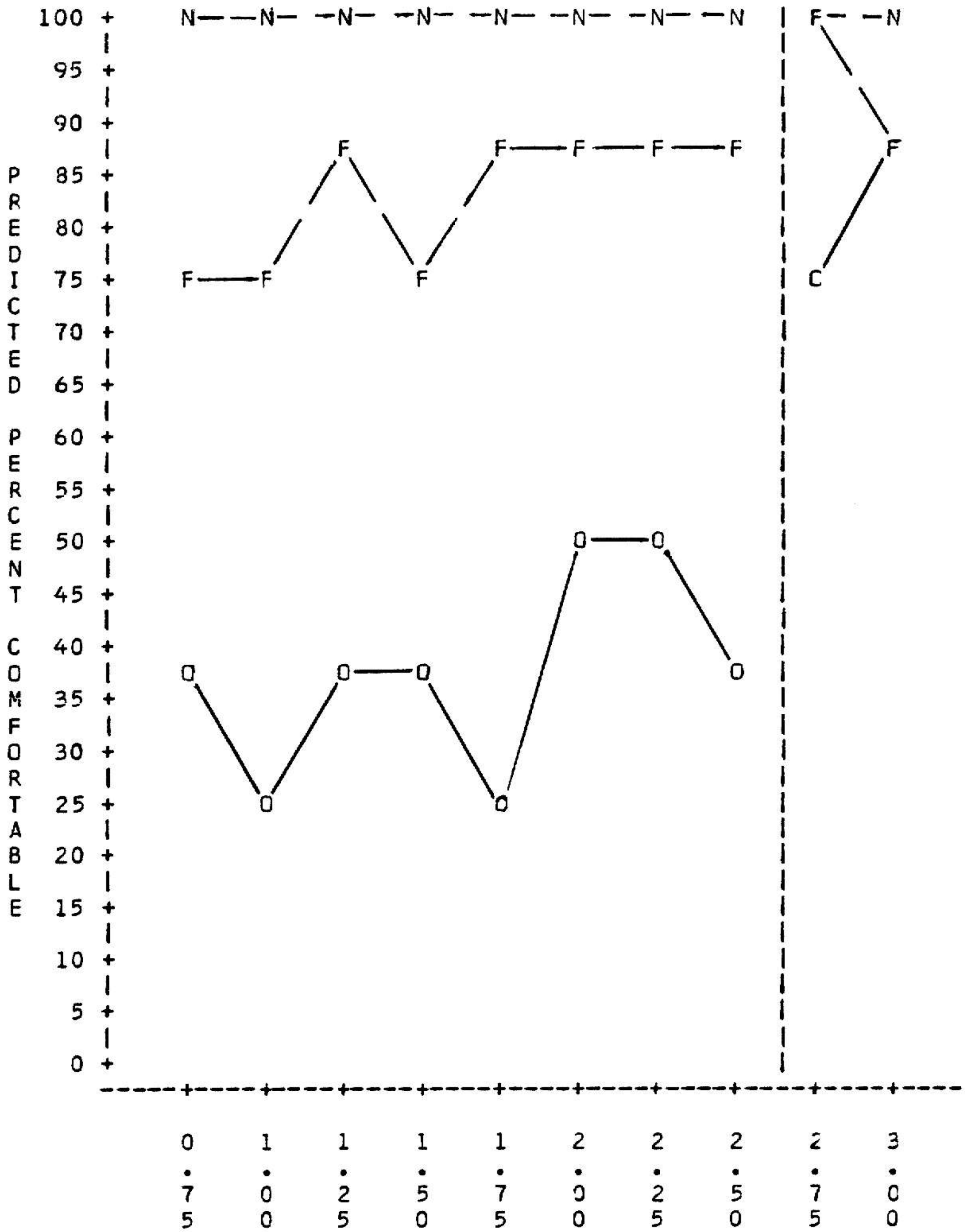

Figure 25. Change in the PPC with exposure time at 25.6 C (78 F) DBT.

RELATIONSHIP OF DEP VAR SHOWN TO EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=27.8

PLOT OF PPC_*EXPINT SYMBOL IS VALUE OF FANCOND

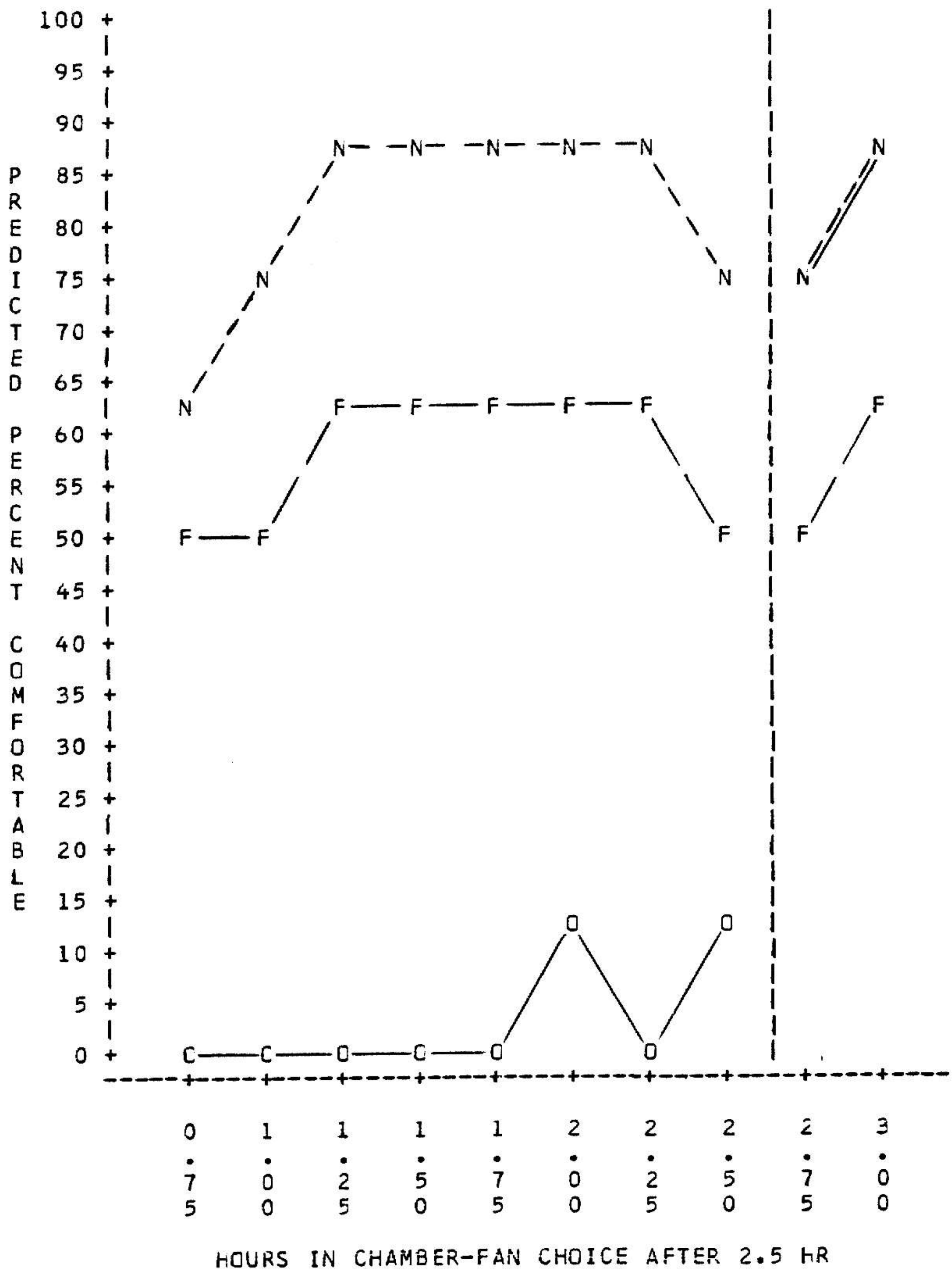

Figure 26. Change in the PPC with exposure time at 27.8 C (82 F) DBT.

RELATIONSHIP OF DEP VAR SHCWN TC EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=30

PLOT CF PPC_*EXPINT SYMBOL IS VALUE CF FANCCND

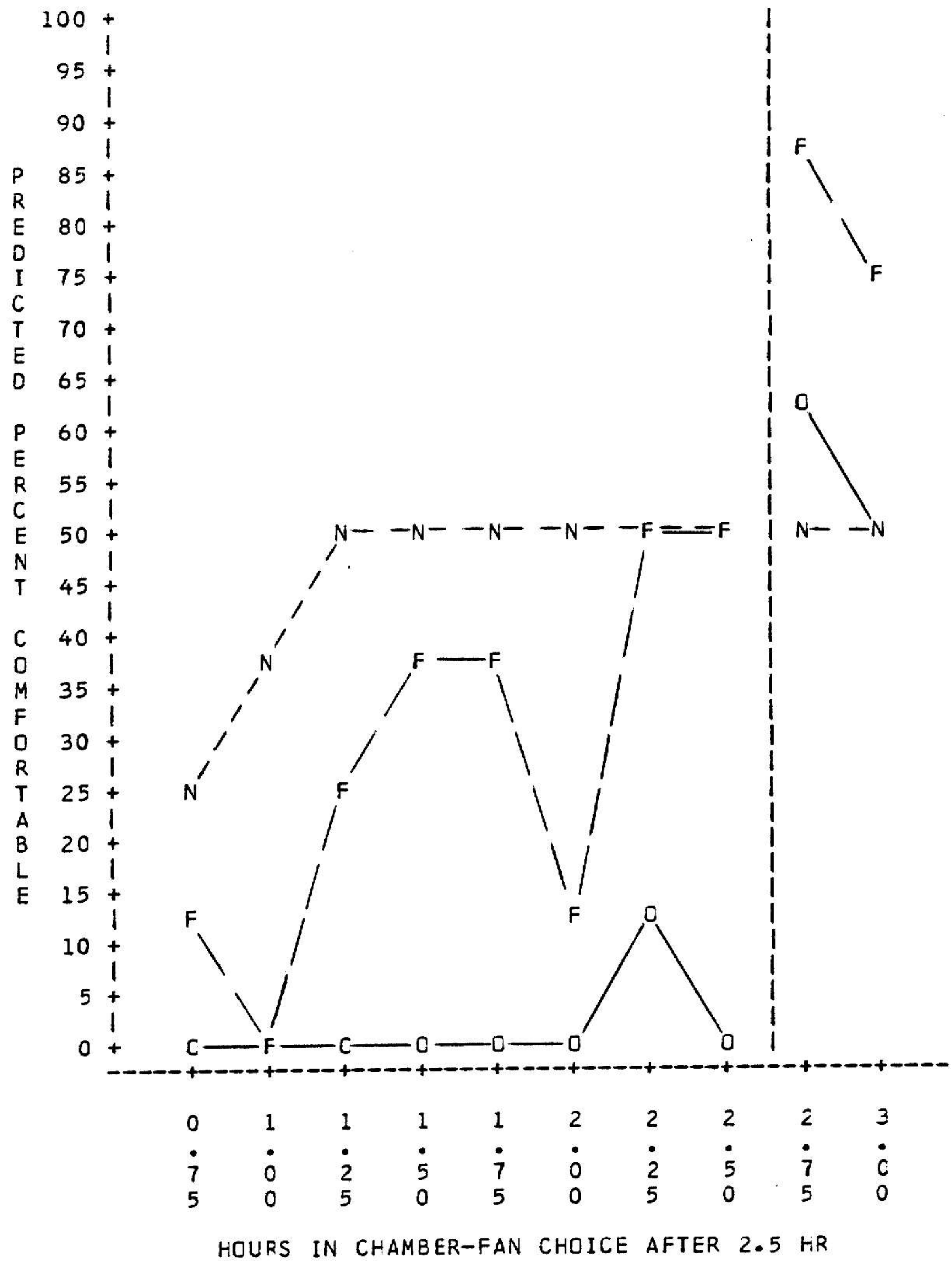

Figure 27. Change in the PPC with exposure time at 30.0 C (86 F) DBT.

RELATIONSHIP OF DEP VAR SHOWN TO EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=25.6

PLOT OF PPD_*EXPINT   SYMBOL IS VALUE OF FANCOND

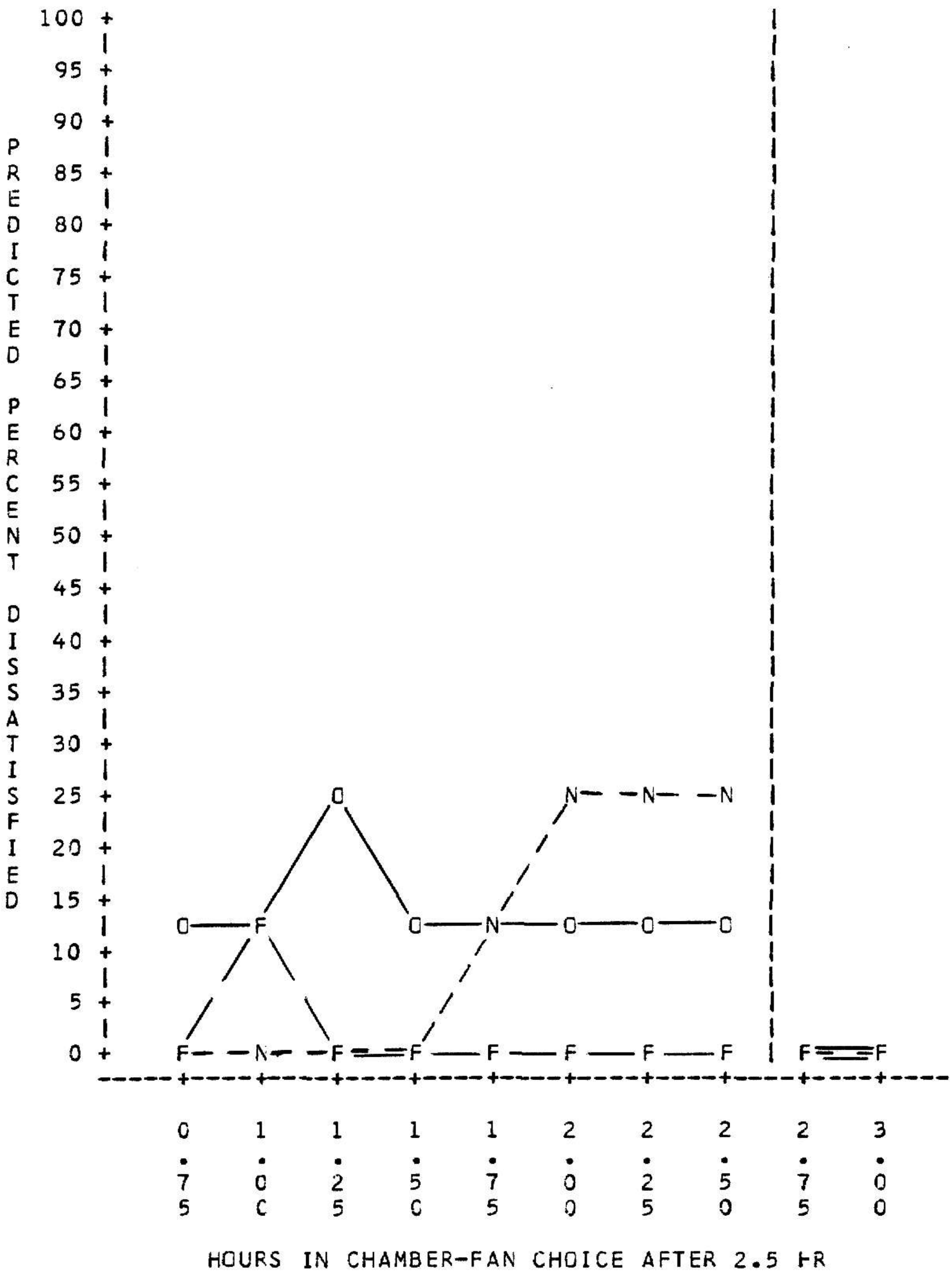

Figure 28. Change in the PPD with exposure time at 25.6 C (78 F) DBT.

RELATIONSHIP OF DEP VAR SHOWN TO EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITICN: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=27.8

PLOT OF PPD_*EXPINT SYMBOL IS VALUE OF FANCCND

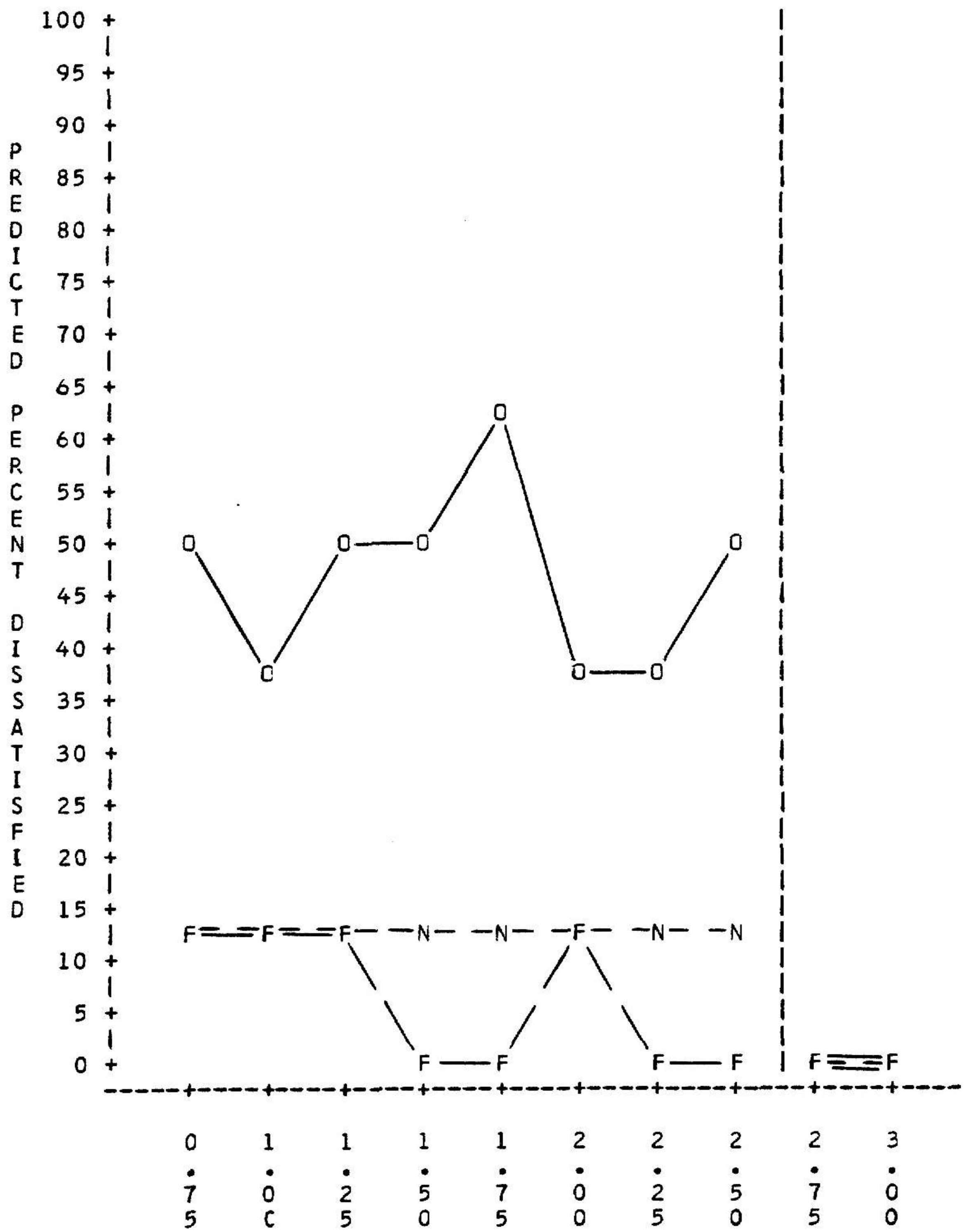

Figure 29. Change in the PPD with exposure time at 27.8 C (82 F) DBT.

RELATIONSHIP OF DEP VAR SHOWN TO EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=30

PLOT OF PPD_*EXPINT SYMBOL IS VALUE OF FANCOND

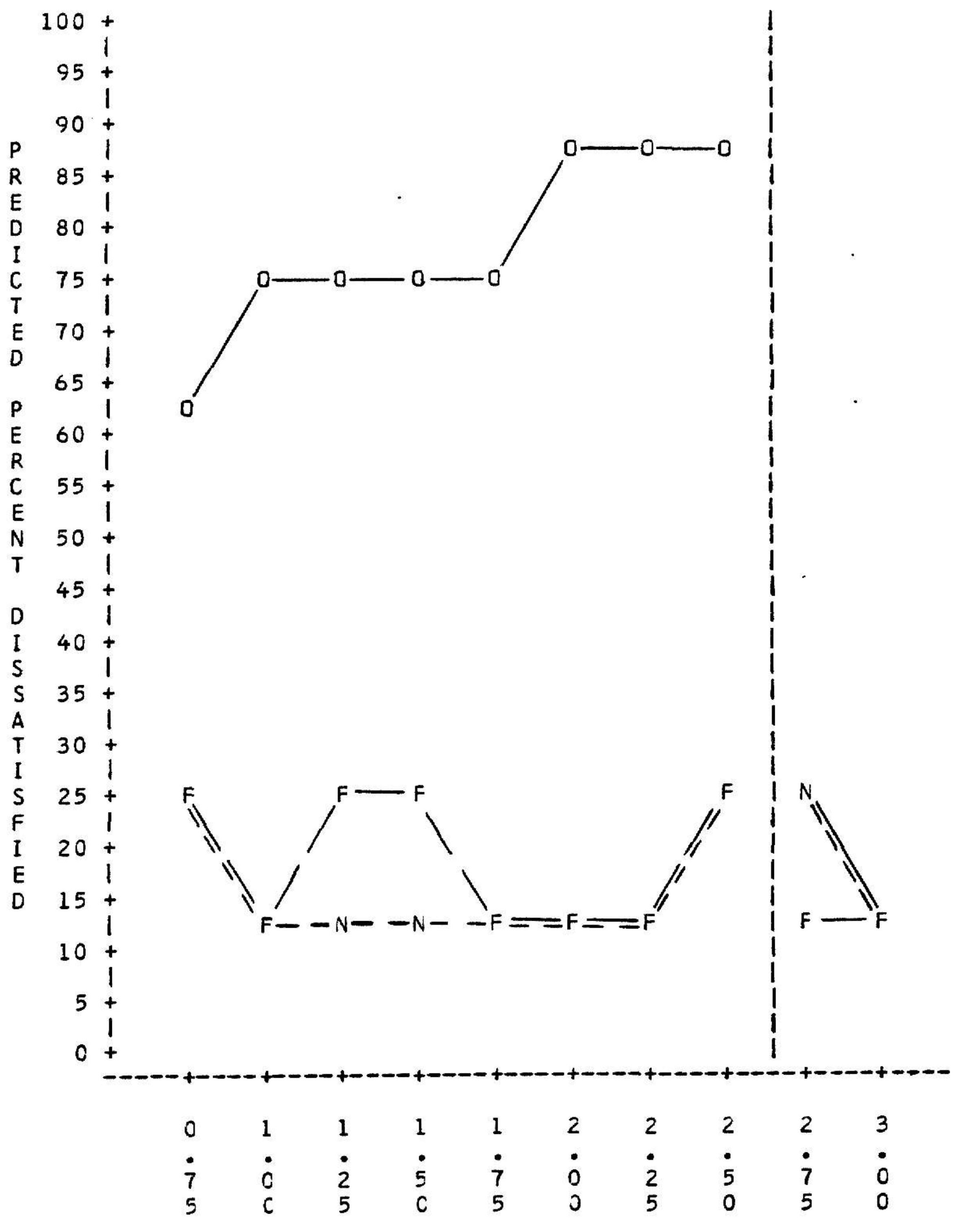

Figure 30. Change in the PPD with exposure time at 30.0 C (86 F) DBT.

Exposure Time Unimportant

While the PPC and the PPD appeared to vary somewhat with the amount of time in the chamber, the absolute fluctuations in Thermal Sensation were minor (Appendix R). The results for the Preference for Temperature change were just as consistent with respect to the neutral line (value = 5) for each condition as those for TS. There appeared to be a slight downward trend with time for the Temperature Estimate in the fan conditions. In fact, paired t-tests showed that the TE for the first hour was significantly higher than that for the succeeding half hour intervals ($t(71) \leq -2.91$, $p<0.005$) whether the votes cast during only the maze runs or only during the pegboard runs were examined. But though this effect is statistically significant, it is not of sufficient magnitude to warrant consideration in practice. Overall, the exposure time had a negligible impact on the entire Thermal Sensation Variable Group. These results were confirmed in the preliminary ANOVA analyses (not shown).

The amount of time spent in the chamber did not appear to influence the Thermal Comfort vote (Appendix R includes only the results for the A Scale: the fluctuations for the other variants of TC were nearly identical). Neither did exposure time affect the Task vote (LAPTV), the Fan vote (LAPFV), or the fan - task Interaction vote (LAPIV). This is the reason that the ANOVA analyses and t-tests shown in Tables 19 to 27 were performed on the daily means (n = 8 for the predetermined exposure condition) rather than on the individual values composing the raw scores for the balloting.

Influence of Environment on Task Performance

The performance data was standardized by dividing each value by the mean performance level of the subject for the entire experiment for each of the two tasks. This standard performance data then was modeled according to day and time of day. ANOVA analyses showed that the log of the day, either singly (Model F = 7.48, p = 0.0001) or in combination (Model F = 12.04, p = 0.0001) with the log of the daily exposure time, could be used to model the learning curve for the Standard Pegboard Performance (SPP). Similarly, the learning curve for the Standard Maze Performance (SMP) could be modeled using the reciprocal of the day in combination with the exposure time (Model F = 3.88, p = 0.0001). But the learning curve for the SMP could not be modeled on the basis of the reciprocal of the day alone (Model F = 1.49, p = 0.18).

Since the paired t-tests between conditions ignore exposure time anyway, residuals were determined for the performance on the pegboard and on the maze using the learning curve models including the appropriate day variables alone. Equations used for the learning curves along with the associated probability levels determined by the STEPWISE Procedure of SAS are shown below for both the SPP and for the SMP:

$$SPP = 0.8899 + 0.0774*\log(DAY) \quad (R^2 = 0.46,\ F = 59.90,\ p = 0.0001)$$
$$SMP = 1.0981 - 0.3122/(DAY) \quad (R^2 = 0.12,\ F = 9.25,\ p = 0.003)$$

The residuals represented the Standard Pegboard Performance Adjusted for learning (SPPA) and the Standard Maze Performance Adjusted for learning (SMPA), respectively. Paired t-tests were performed using these residuals for each of the two tasks, comparing each of the 9 exposure conditions with one another. Despite all the effort, only 2 condition differences were found to be significant for the maze task. Both differences involved the 25.6 C DBT, 1.3 m/s condition: performance on the maze was significantly higher in this condition than at either 25.6 C or 27.8 C DBT with the fan off. But the number of significant differences at the 0.05 level expected by chance for 36 analyses is 1.8 (nearly 2), and the ANOVA analysis indicated that the modeling equation was significant only at the 0.18 level of significance. Consequently, the maze performance data must be ignored.

In contrast with the data for the maze task, the SPPA data for the pegboard task proved well suited to analysis by the paired t-test. Even so, all the differences found to be significant at the 0.05 level of significance involved the 30.0 C DBT control (fan "Off") condition; performance on the pegboard was significantly higher ($\underline{t}(7) \geq 2.51$, $\underline{p} < 0.05$) in the 25.6 C DBT, 0.8 m/s fan condition, and in all three 1.3 m/s fan conditions than in the 30.0 C DBT control condition. These results make sense. They indicate that the various conditions of the experiment are thermally equivalent from the point of view of ability to work at a sedentary task, except for the most severe condition of the experiment, already known to be too hot for 50% of the population (See bottom row of Table 5). The inability to find more than 4 significant differences is attributed to the small sample size (n = 8).

The 4 pairs of condition differences which are significant from the point of view of pegboard performance are also the only 4 which are significant ($\underline{t}(7) \geq 2.66$, $\underline{p} < 0.04$) from the point of view of the LAPTV for the maze task. But the values for the LAPTV for the pegboard task are all insignificant at the 0.05 level except for two: the difference between the 25.6 C DBT control condition and 25.6 C DBT, 1.3 m/s and the difference between the 27.8 C DBT control condition and 27.8 C DBT, 0.8 m/s are both significant ($\underline{t}(7) \geq 2.45$, $\underline{p} \leq 0.05$). Thus, the pegboard performance (SPPA) was exactly mirrored in the Task voting associated with the maze runs. The maze performance (SMPA) was nearly mirrored in the Task voting associated with the pegboard runs. Despite repeated examination of the programming, no indication of label reversal could be found. Given that these results are genuine, the only explanation that comes to mind is that while the pegboard is better for displaying performance trends, the maturation of a feeling response can require an altogether different task. Yet the absolute differences on the LAPTV by condition are far too small to be of practical significance (Figure 31). In fact none of the three semantic differential scales on the Fan - Task Ballot (Appendix C) specially designed for this experiment was of any help in identifying acceptability of the fan according to condition (Figures 31 to 33); whatever feelings about the fan, task, and their interaction are related to, they do not appear to be determined by the predetermined conditions inside the chamber for the condition range studied.

Influence of Weather on Balloting

Stepwise analysis of LAPFV indicated that the fan votes were affected by the outside weather. All the variables listed in Appendix M were considered for covariate analysis. Usually only one of these variables ended up in the final model as a covariate. This is not surprising, considering that outside variables should be expected to be interrelated.

The maximum outside daily temperature, in combination with the chamber conditions, showed up in all the Thermal Comfort models (Table 37). In contrast, the three Thermal Sensation Group Variables could all be modeled by one or a combination of two conditions characterizing the outside environment in the hour preceding the test runs, in combination

RELATIONSHIP OF MEAN OVER 2.5 HRS OF EXPOSURE FOR DEP VAR SHOWN TO TEMP FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S), F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

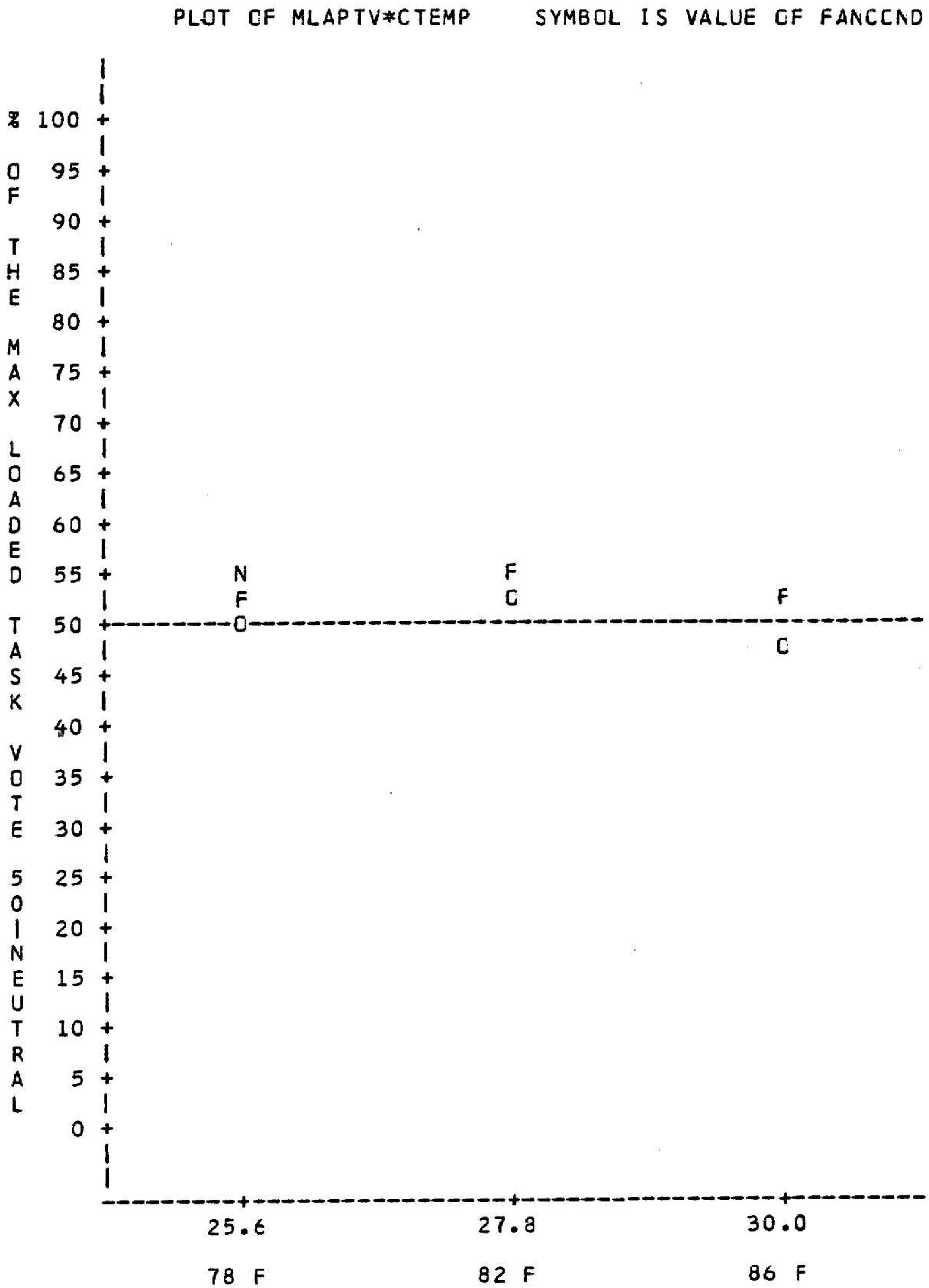

Figure 31. Plot of LAPTV against chamber DBT by predetermined fan condition.

RELATIONSHIP OF MEAN OVER 2.5 HRS OF EXPOSURE FOR DEP VAR SHOWN TO TEMP FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S), F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

PLOT OF MLAPFV*CTEMP   SYMBOL IS VALUE OF FANCOND

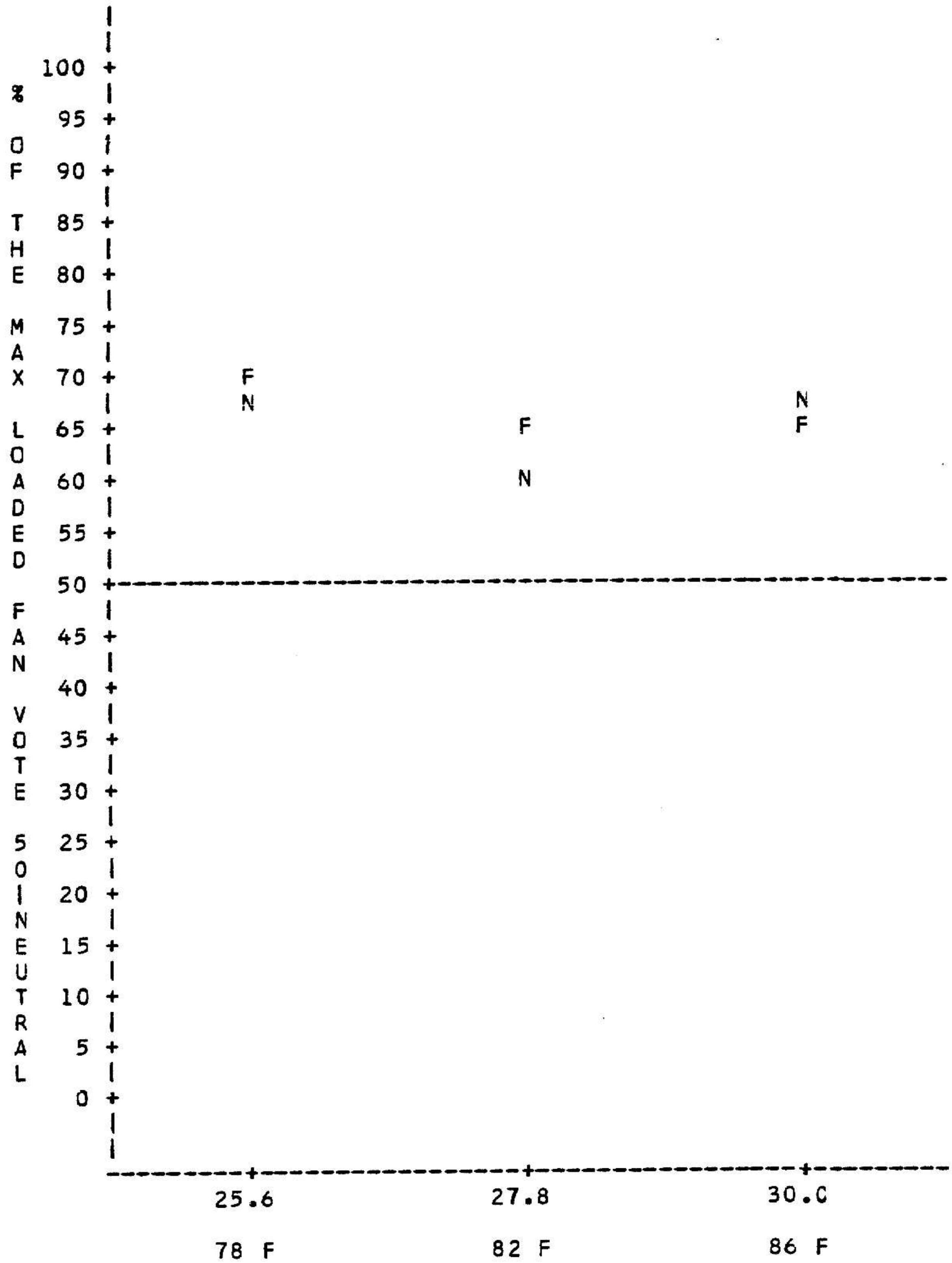

Figure 32. Plot of LAPFV against chamber DBT by predetermined fan condition.

RELATIONSHIP OF MEAN OVER 2.5 HRS OF EXPOSURE FOR DEP VAR SHOWN TO TEMP FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S), F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

PLOT OF MLAPIV*CTEMP   SYMBOL IS VALUE OF FANCOND

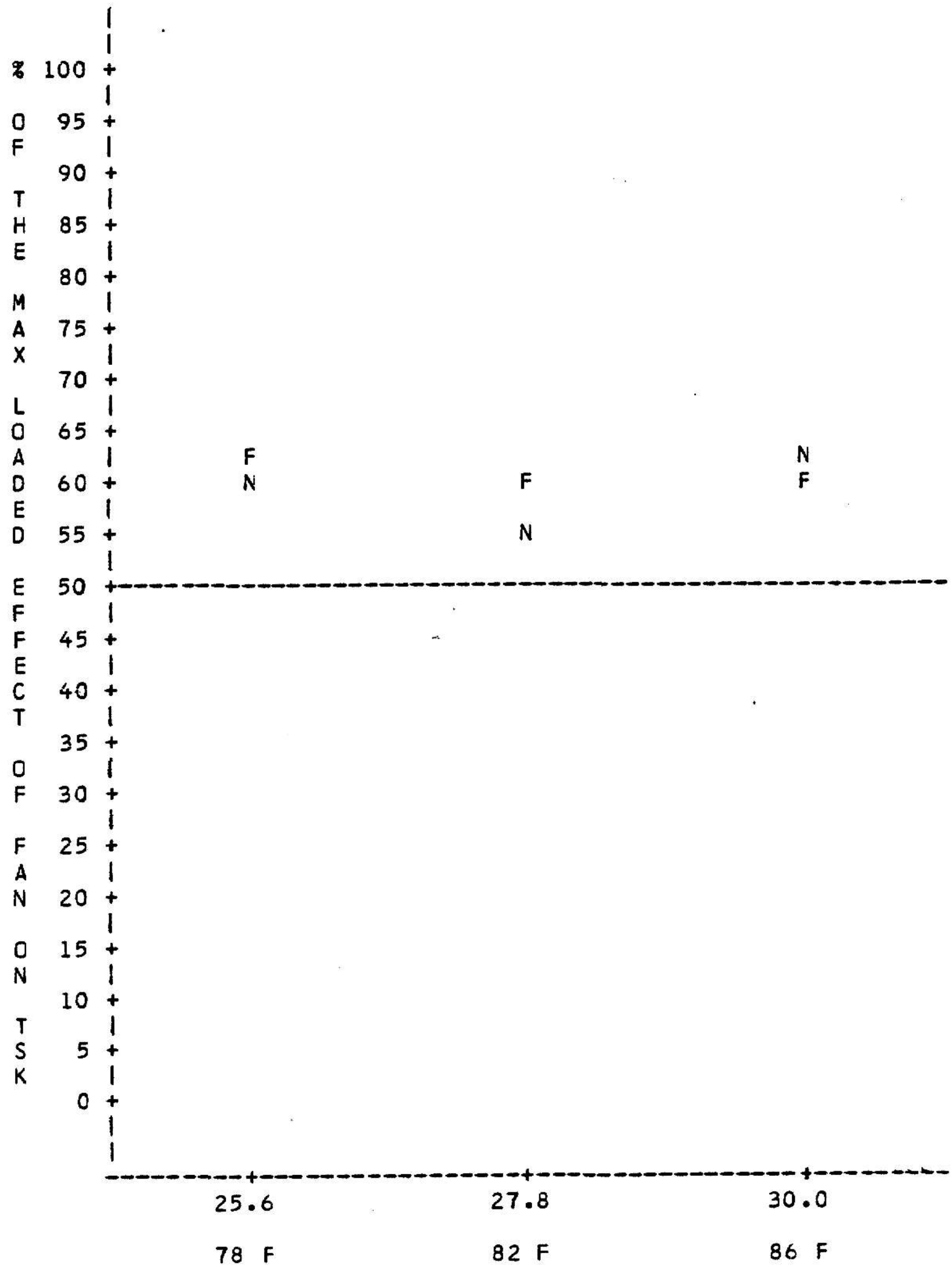

Figure 33. Plot of LAPIV against chamber DBT by predetermined fan condition.

with the predetermined chamber conditions (Table 38). While this weather effect may be an artifact of the small sample size, the wide fluctuation in outside conditions in the narrow time span of the experiment (Appendix M) lends creedence to the notion that such an effect is real (Appendix S).

The equations in Table 38 were derived in order to quantify the effect of the outside variables. But they also indicate that there is a curvilinear relationship between the chamber temperature and the independent variables in the temperature range studied. This is shown by the different magnitudes of the estimates for the dependent variables for the same absolute difference in temperature from 27.8 C (82 F) DBT. This is shown, more importantly, by the failure of the significance test for the correction for 25.6 C (78 F) DBT for TE (Table 38) as well as for the correction for 30.0 C (86 F) DBT for all 4 measures of Thermal Comfort (Table 37).

Initial analyses using the STEPWISE Procedure of SAS indicated that the task performance was affected by the previous hour outside temperature as well as by the previous hour solar radiation. But these effects disappeared when the task performance data was first standardized and then finally corrected for task learning. The results of these analyses were consistent only with the existence of small chamber temperature and velocity effects on task performance. Even so, the models for the residuals for task performance, SPPA and SMPA (See p. 122 for description), were significant only at the 0.07 and 0.09 levels, respectively.

Best models for *daily* mean (n=8) for Thermal Comfort Group Variables and for the Fan vote developed by subjecting various combinations of independent variables to stepwise regression analysis using the STEPWISE *Procedure* (which treats all independent variables as continuous variables) and, where appropriate, confirmed using the GLM Procedure (treating chamber temperature and air velocity as classification *variables and* the outside conditions as continuous variables) of SAS (Appendix S shows F values accompanying these analyses, derived from Type IV SS; values for intercept and discrete variables in equations are biased and do not estimate the parameter but are best linear unbiased estimates for some linear combination of parameters when they are not zero; values for the continuous variable MAXCTEMP, described in Appendix M, in equations are best linear unbiased estimates)

			Parameter					
			Intercept (at 0.8m/s, 27.8 C DBT)	Discrete (Treatment) Variables				Continuous Variable (Covariate)
Description	Variable			Velocity		Dry Bulb Temperature		MAXCTEMP
Estimates for......	STCV	=	26.68	+ [1.64 (for 1.3m/s)	- 10.45 (for 0.35m/s)]	+ [4.46 (for 25.6 C)	- 2.39 (for 30.0 C)]	+ 0.542*MAXCTEMP
S.E. of Estimate			4.98	1.80	1.81	1.79	1.79	0.187
T for HO: Parameter=0			5.36	0.91	-5.78	2.49	-1.34	2.90
Probability > |T|			0.0001	0.37	0.0001	0.02	0.19	0.005
Estimates for......	LAFC_R	=	30.67	+ [1.30 (for 1.3m/s)	- 11.62 (for 0.35m/s)]	+ [6.61 (for 25.6 C)	- 2.38 (for 30.0 C)]	+ 1.021*MAXCTEMP
S.E. of Estimate			7.17	2.60	2.61	2.58	2.58	0.269
T for HO: Parameter=0			4.27	0.50	-4.46	2.56	-0.92	3.80
Probability > |T|			0.0001	0.62	0.0001	0.02	0.36	0.0003
Estimates for......	LAPC_A	=	33.82	+ [2.82 (for 1.3m/s)	- 18.16 (for 0.35m/s)]	+ [8.04 (for 25.6 C)	- 4.26 (for 30.0 C)]	+ 1.009*MAXCTEMP
S.E. of Estimate			8.92	3.23	3.24	3.21	3.21	0.334
T for HO: Parameter=0			3.79	0.87	-5.60	2.50	-1.33	3.02
Probability > |T|			0.0003	0.39	0.0001	0.02	0.19	0.004
Estimates for......	LAPC_B	=	18.84	+ [2.80 (for 1.3m/s)	- 15.86 (for 0.35m/s)]	+ [7.96 (for 25.6 C)	- 4.76 (for 30.0 C)]	+ 1.057*MAXCTEMP
S.E. of Estimate			8.68	3.14	3.15	3.12	3.12	0.325
T for HO: Parameter=0			2.17	0.89	-5.03	2.55	-1.52	3.25
Probability > |T|			0.04	0.38	0.0001	0.02	0.14	0.002
Estimates for......	LAPFV	=	38.02					+ 1.128*MAXCTEMP
S.E. of Estimate			9.74					0.389
T for HO: Parameter=0			3.90					2.90
Probability > |T|			0.0003					0.006

Best models for daily mean (n=8) for Thermal Sensation Group Variables developed by subjecting various combinations of independent variables to stepwise regression analysis using the STEPWISE Procedure and confirmed using the GLM Procedure of SAS (relevant F values are shown in Appendix S and are derived from Type IV SS, which are appropriate for these analyses; values for intercept and discrete variables in equations are biased and do not estimate the parameter but are best linear unbiased estimates for some linear combination of parameters when they are not zero; values for continuous variables, described in Appendix M, are best linear unbiased estimates for the parameter)

Description	Variable	Parameter: Intercept (at 0.8m/s, 27.8 C DBT)	Discrete (Treatment) Variables: Velocity		Discrete (Treatment) Variables: Dry Bulb Temperature		Continuous Variables (Covariates): PRHRRH	Continuous Variables (Covariates): PRHRSRAD
Parameter Est.	TS =	6.06 +	[0.99 (for 0.35m/s)	- 0.45 (for 1.3m/s)] +	[0.63 (for 30.0 C)	- 0.43 (for 25.6 C)]	- 0.00966*PRHRRH	
S.E. of Estimate		0.34	0.20	0.20	0.20	0.21	0.00372	
T for H0: Parameter=0		18.08	4.89	-2.23	3.08	-2.08	-2.60	
Probability > |T|		0.0001	0.0001	0.03	0.003	0.05	0.02	
Parameter Est.	PT =	5.34 +	[0.82 (for 0.35m/s)	- 0.54 (for 1.3m/s)] +	[0.63 (for 30.0 C)	- 0.49 (for 25.6 C)]		+ 0.00591*PRHRSRAD
S.E. of Estimate		0.23	0.22	0.22	0.22	0.22		0.00282
T for H0: Parameter=0		23.67	3.74	-2.46	2.85	-2.22		2.10
Probability > |T|		0.0001	0.0004	0.02	0.006	0.03		0.04
Parameter Est.	TE =	88.79 +	[4.05 (for 0.35m/s)	- 2.12 (for 1.3m/s)] +	[2.93 (for 30.0 C)	- 2.03 (for 25.6 C)]	- 0.145*PRHRRH	- 0.0862*PRHRSRAD
S.E. of Estimate		5.41	1.35	1.35	1.35	1.38	0.053	0.0373
T for H0: Parameter=0		16.41	2.99	-1.58	2.17	-1.47	-2.72	-2.31
Probability > |T|		0.0001	0.004	0.12	0.04	0.15	0.009	0.03

<u>Convective Cooling with Fans Contrasts Favorably with Air Conditioning</u>

Comparison of the effectiveness of fans with air conditioning requires a contrast of cooling power produced for energy consumed. Use of an Amprobe (R) Model ACD-1 inductance meter showed that the continuous current draw is 1.0 amps at 115 v for both McGraw-Edison fans (Model 204001) set on "Low" (See Table 39). In contrast, a Sears Kenmore Air Conditioner (Model 77118) draws 12 amps at 115 v. So air conditioning is just as economical as fan-aided cooling if the area to be cooled is small enough and is insulated well enough that the air conditioner needs to operate only 1/12th (8.3%) of the time. This amounts to 5 minutes of every hour.

The heat removal that a fan must provide to compete with an air conditioning system can also be determined easily. The Sears Kenmore Air Conditioner just described carries a rating of 11,000 BTU/hr. The fan draws as much energy continuously as the air conditioner does for 8.3% of the time. This means that for the fan to be as energy-efficient as the air conditioner, at the same comfort level, it must be capable of removing 0.083*11,000 BTU/hr = 917 BTU/hr (231 kcal/hr) by forced convection alone.

The best method for comparing the fan and the air conditioner for any specific environment is to determine what temperature decrease can be obtained from the air conditioner when it is set so that it is on for 5 minutes of every hour...only 8.3% of the time. If the average temperature decrease of the room established using the air conditioner is greater than the drop in temperature of 3.3 C (6 F) estimated by the subjects sitting 1.5 m (5 ft) from the fan on "Low", then air conditioning is more energy efficient. But when the local environment is open to the outside, air

TABLE 39

Continuous current draw (amps) for motor type 202 PEG in Model 204001 McGraw-Edison fans, measured using an AMPROBE (R) Model ACD-1 inductance meter (motor rating is 2.6 amps)

Fan Type	Fan Setting	
	"Low"	"High"
B	1.0 ± 0.1	1.8 ± 0.1
C	1.0 ± 0.1	2.2 ± 0.1
Average	1.0 ± 0.1	2.0 ± 0.2

conditioning cannot compete with local fan-aided cooling on an energy basis. The possibility of saving energy while maintaining thermal comfort by using fans rather than air conditioning ultimately depends upon the degree of insulation of the work area from both local heat sources and from the outside environment. But the more closed in the space, the more energy-efficient air conditioning becomes.

CONCLUSION

The behavioral approach proved effective in determining a preferred fan velocity at each of the three temperatures chosen. The velocities selected at each of the three temperatures were significantly different from one another at the 0.05 level of significance. The average voting during the period of predetermined condition exposure at any one temperature paralleled the explicit velocity preference on the basis of Thermal Comfort:

1) At 30.0 C (86 F) DBT, the explicit velocity preference was 1.2m/s, while the fan speed for the predetermined condition at that temperature voted to be most comfortable as well as coolest was 1.3 m/s;
2) At 27.8 C (82 F) DBT, the explicit velocity preference was 1.0 m/s, between the two conditions voted most comfortable and coolest at that temperature;
3) At 25.6 C (78 F) DBT, the explicit velocity preference was 0.7 m/s, while the fan speed for the predetermined conditon at that temperature voted to be most comfortable was 0.8 m/s, which was the second coolest (second warmest also) condition at that temperature.

Thus, the current ceiling of 0.8 m/s (158 ft/min) on air velocity in the workplace is inappropriate and should be abolished.

Since the behavioral approach in the last half hour of the experiment produced the same results as the thermal comfort balloting, arguments challenging the voting approach appear to be unfounded. The behavioral approach itself has its own drawbacks: interactions between the subjects comprising any one group cannot be discounted, particularly when the group size is small (2 per group in this case). Allowing each subject to change the fan speed rather than his distance from the fan may not eliminate this effect, but it could certainly reduce it. Unfortunately, speed changes result in turbulence changes, and a continuously variable control does not mirror the selection that is commercially available. But if the behavioral approach is the method of choice for further testing, a commercially available multi-speed fan should be selected.

The Thermal Sensation scale, the Preference for Temperature change, and the question asking for a Temperature Estimate all gave similar rankings for the predetermined exposure conditions. Also, they all displayed high correlations with one another. Further, they all displayed similar relationships with the various measures of Thermal Comfort. Moreover, the intercorrelations of the three scales do not appear to vary with temperature. Thus, these three scales must be measuring primarily the same factor. So results using the different scales can be compared with one another. This also means that only one of these scales need be used at a time. If only one scale is used, use of the 9-category Thermal Sensation scale is recommended. Alternatively, all three measures may be taken and combined into one grand measure of Thermal Sensation. Although this would be reasonable, it is not recommended because of the confusion in interpretation it could cause. While the Thermal Sensation scale appeared to be best suited to formal analysis, the question asking for a Temperature Estimate was most practical: the TE scale provides a quick, easily quantified, and easily understood measure of the effect of thermally perceived changes in the environment.

Four variations of the Thermal Comfort scale were compared. These included the old Standard Total Comfort Vote and the Loaded Average Percent Comfortable with loadings determined within the context of the present experiment. This latter was designated the A scale when its components were the same as those of the STCV. It was designated the B scale when its components were the same as those of a scale used by Rohles, Bennett, and Milliken (1980), which was also used with the loadings determined in the context of their experiment (R Scale). Qualitatively, all the scales gave the same results. However use of either Rohles' old STCV or the LAPC_A scale is recommended in order to avoid confounding of Thermal Comfort with Thermal Sensation, which occurs with the B and R scales. Of the STCV and the LAPC_A, the latter is recommended with loadings determined within the context of the experiment.

Contrast of the Thermal Comfort scales with the Thermal Sensation scales showed that even if the adjective pair warm...cool were to be retained as a component of the Thermal Comfort scale, "cool" should receive the high weighting in a warm environment: comfort is associated with coolness in a warm environment. But this association changes with temperature even within the small temperature range from 25.6 - 30.0 C (78 - 86 F) DBT, so that a projection of the established relationship demonstrates that comfort is associated with warmth in a cool environment. Comparison of the Thermal Comfort and Thermal Sensation scales provides a way of quantifying this relationship. This strongly suggests that the meaning of words relating to the physical environment is context-dependent. By extension, then, it ought to be possible to quantify how all words describing the environment change relationships with one another as the environmental factors related to their particular meaning change. At the very least this result demonstrates the tremendous importance of clarity in communication with experimental participants when subjective criteria are in use.

The influence of environment on the relationships composing the subjective criteria appeared several times. First, the intercorrelations between sets of adjective pairs within each of the various scales changed in a consistent manner with temperature. Second, the factor loadings based upon those intercorrelations of sets of adjective pairs changed in a manner that, overall, was consistent with changes in the relevance of the words composing the adjective pairs to their underlying perceptive structures (Tables 9 to 17). Third, the number of factors or underlying perceptive structures represented by those adjective pairs changed with temperature in three cases (Tables 12, 16, and 17). Fourth, the correlation of each of the measures of Thermal Comfort with each of the Thermal Sensation Group Variables was temperature dependent. It is this last finding which indicates that comfort is associated with coolness in a warm environment. None of these findings is inconsistent with the notion that the semantic value of words relating to the environment changes with temperature.

The Task vote, the Fan vote, and the Thermal Sensation Group Variables all seemed to measure essentially three different aspects of the environment. However, the Fan vote correlated well with all 4 measures of Thermal Comfort (all above 0.60 on the overall Pearson correlations). Similarity between the Fan vote and Thermal Comfort is suggested not only by high correlation between the two scale types, but also by their association with the same outside variable (Table 37). Thus, the Fan vote appears to provide primarily a redundant measure of Thermal Comfort in a fan-cooled environment. But the Fan vote failed to separate the predetermined exposure conditions, whereas the Thermal Comfort vote did provide such separation. For these reasons the Fan Ballot need not be used in further research, except possibly in combination with the Thermal Comfort scale components, as an aid in factor identification.

The residuals for task performance corrected for task learning indicated that performance at a sedentary task is not affected by inside environmental conditions within the condition range studied, 25.6 - 30.0 C (78 - 86 F) DBT at 45% rh. However the data was not inconsistent with the presence of a beneficial effect of fan operation on performance. (Only 6 out of 25 of the t values were in the wrong direction for the pegboard task, and only 1 out of the 25 relevant t values was in the wrong direction for the maze task.)

All the Thermal Sensation and Thermal Comfort Group Variables showed significant differences between group numbers at an alpha level of 0.05. But none of these differences between groups was consistent across the list of dependent variables. Since the sample size was small, the significant differences between groups may be taken as an indication of the importance of individual differences. This means that environmental evaluation is highly subjective: while population means are indispensable, the wide range of subjective evaluation of any one condition by the subject population requires close scrutiny of differences between subjects in the subjective <u>interpretation</u> of experimental considerations as well as in the subjective <u>evaluation</u> of environmental conditions.

Differences between group numbers may have been due also to differences in the weather, producing differences in preconditioning: while the first ballots were not cast until the subjects had been in the chamber for 45 minutes (except for practice runs the first day), all models for the balloting examined included one or two terms describing some aspect of the weather. The balloting examined for weather effects included all of the Thermal Sensation Group Variables (TS, PT, and TE), all of the Thermal Comfort Group Variables, and the vote dealing with perception of the Fan, LAPFV. The presence of the weather in these models, which other models fail to show, is defended on the basis that the fluctuation in outside conditions was wider over the brief time span of the experiment than is usual since the experiment was conducted in the spring. The magnitude of the estimates for the weather influence is in line with an influence that will be difficult to detect without such wide fluctuations. While it is true that metabolic changes as well as changes in ways of relating to the environment occur with changes in season, the presence of weather in the models for the balloting is consistent with the finding that the balloting is season-dependent (pp. 30 - 32, with reference to McIntyre, 1978c; Rohles and Wallis, 1979; Rohles, 1980a and 1980b).

The assumption which underlies this study is that convective cooling with a box fan is energetically favored over convective cooling through artificial temperature depression. This assumption appears to hold when such temperature regulation is achieved through the use of air conditioning. However, this assumption may be untrue in the case of evaporative cooling (See Robertson, 1976).

Relative humidity has been held constant in the present study. Rohles (1970b) has shown that men are more subject to humidity influences than women: temperature is seven times as important as relative humidity for men, whereas temperature is nine times as important as relative humidity for women in determining Thermal Sensation using a seven-point scale in still air. The impact of changes in relative humidity in moving air on Thermal Comfort and on Thermal Sensation remains to be determined.

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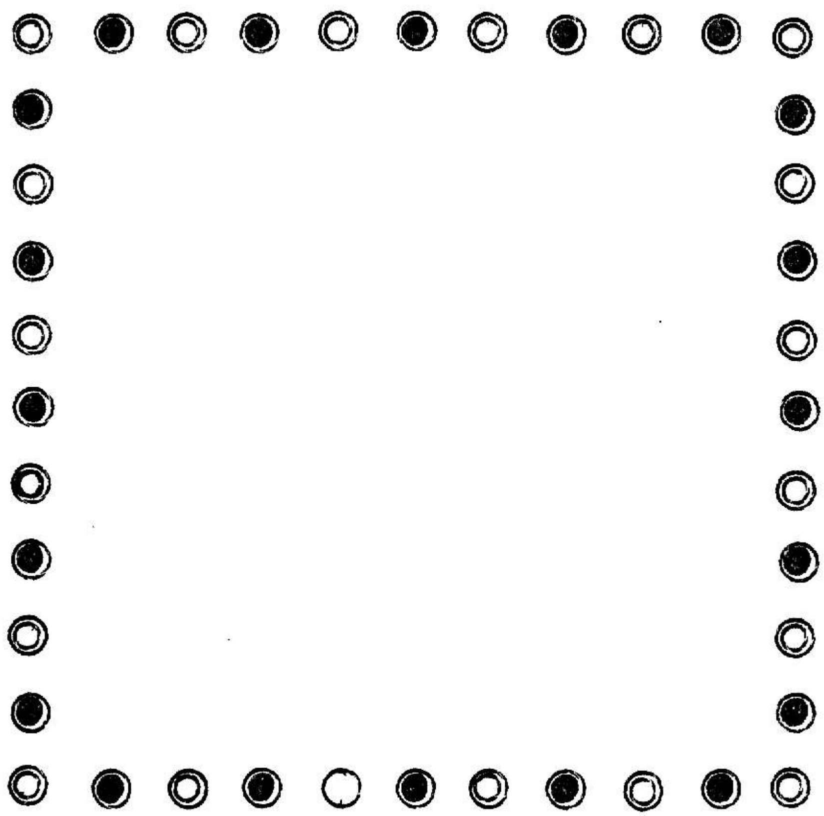
APPENDIX A

Peg Configuration for Pegboard Task



Key

= Red peg

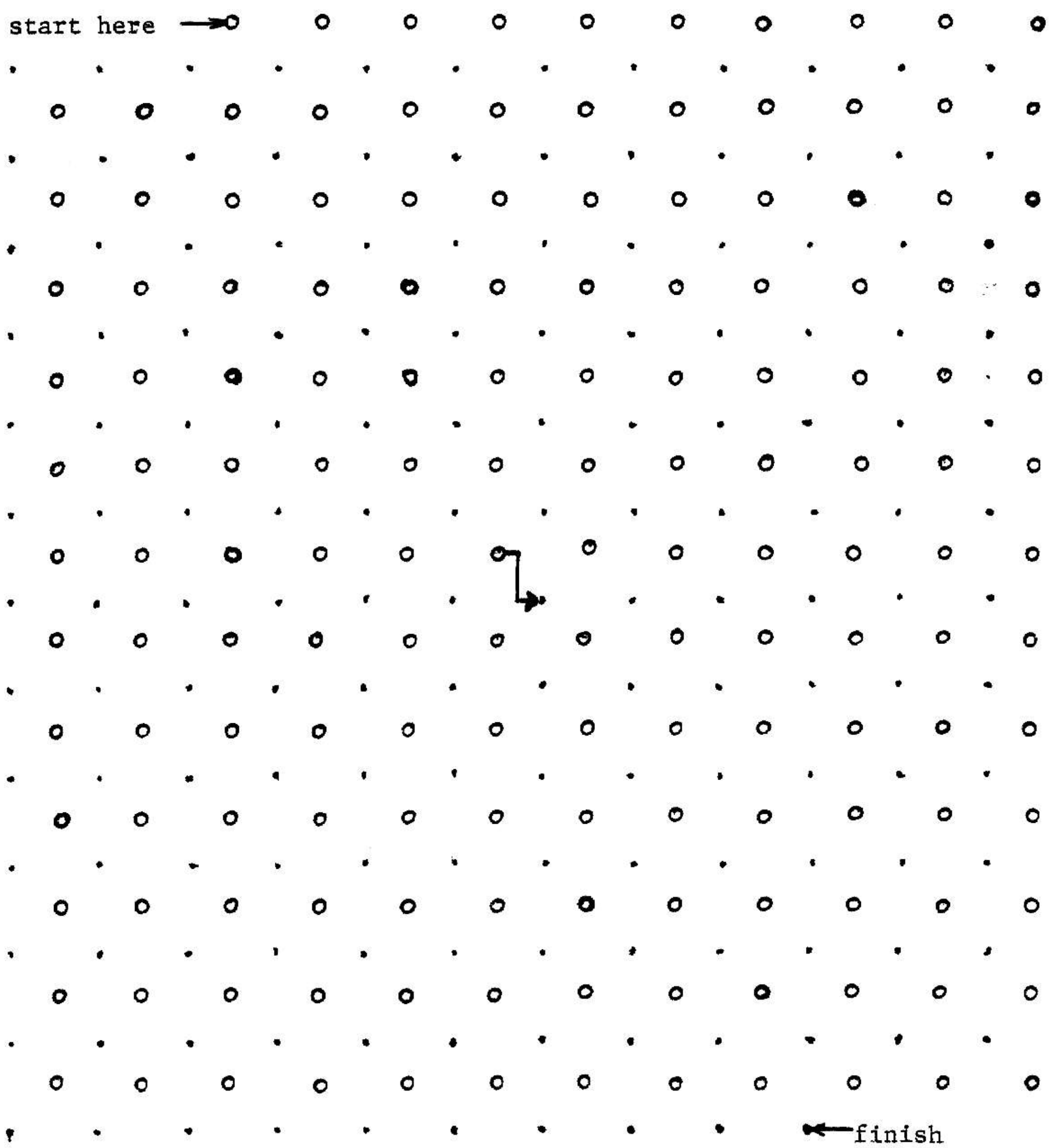
= Yellow peg

= No peg

APPENDIX B

Paperwork Task with Instructions

1) First follow the circles from "start here" to the dots to "finish".
2) Then connect each circle with each adjacent dot, staying between the two lines you have just drawn.
3) Then shade in every other triangle until time is called. If you reach the center, shade in the remaining unshaded triangles.



APPENDIX C

Comfort-Sensation Ballot

The loadings used to determine the Loaded Average Percent Comfortable, R Scale (LAPC_R), have been placed on the high end of each scale for the reader's information. Alternative loadings for the A Scale (LAPC_A) and for the B Scale (LAPC_B) have been determined within the context of this experiment and are indicated in Tables 10 and 11. The ventilation scale has a loading of 0.000 for the LAPC_R and for the LAPC_B since it is not a component of these scales. The LAPC_A as well as the Standard Total Comfort Vote (STCV) include the ventilation scale in place of the warm... cool scale. There are two reasons for this. First, this is a ballot that has been in use for a period of ten years without the warm...cool scale. Second, the side of the scale which should be most heavily weighted in a warm environment appears to be the cool side, rather than the warm side, as is the case for the LAPC_R as well as the LAPC_B.

The second scale is the 9-category Thermal Sensation scale (TS). The third scale is referred to as the Preference for Temperature change (PT). The last scale on the first page is called the Temperature Estimate (TE). These three scales (TS, PT, and TE) produce the same rank order of predetermined exposure conditions. Consequently, they are referred to collectively as the Thermal Sensation Variable Group.

Fan-Task Ballot

The high end of each scale has been marked with a 9 for the reader's information. Each group contains 7 semantic differential pairs. The three scales are used to develop the Loaded Average Percent Fan Vote (LAPFV), the Loaded Average Percent Task Vote (LAPTV), and the Loaded Average Percent fan-task Interaction Vote (LAPIV).

Comfort-Sensation Ballot

What do you think of the overall environment in here?

uncomfortable temperature					0	.	7	2	6	comfortable temperature
satisfied	0	.	5	6	8					dissatisfied
comfortable	0	.	5	5	5					uncomfortable
bad temperature					0	.	6	9	3	good temperature
cool					0	.	5	7	9	warm
pleasant	0	.	6	2	8					unpleasant
good ventilation			0	.	0	0	0			poor ventilation
unacceptable					0	.	5	2	1	acceptable
					X					

Circle the number beside the adjective
that describes how you feel:

1 very cold
2 cold
3 cool
4 slightly cool
5 neutral
6 slightly warm
7 warm
8 hot
9 very hot

Would you like it to be:

warmer___:___:___:___:___:___:___:___:___ cooler
as is

Can you estimate what the temperature is now? _____ ^{o}F

Experimenter's information

SubjCode	Day	Ballot	Task //	One-Set	Two-Set	New	NewDst	Task#
______	___	_____	B M	L M H	O F	N +/-	_____	_____

<u>Fan-Task Ballot</u>

How do you feel about the fan?

buffeting ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : 9 smooth
pleasant 9 : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ unpleasant
cheerful 9 : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ gloomy
noisy ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : 9 quiet
useful 9 : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ useless
convenient 9 : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ inconvenient
dislike ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : 9 like
X

How do you feel about this task?

tense ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : 9 relaxing
pleasant 9 : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ unpleasant
cheerful 9 : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ gloomy
hard ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : 9 easy
consuming 9 : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ boring
agreeable 9 : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ disagreeable
dislike ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : 9 like
X

The fan makes this task;

disturbing ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : 9 soothing
easier 9 : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ harder
more agreeable 9 : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ less agreeable
more frustrating ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : 9 less frustrating
orderly 9 : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ chaotic
cheerful 9 : ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ gloomy
inefficient ___ : ___ : ___ : ___ : ___ : ___ : ___ : ___ : 9 efficient
X

APPENDIX D

Subject's Instruction Sheet

This experiment is concerned with your performance on two different tasks under moderate heat stress. The experiment requires you to stay in an enclosed room for 3 hours at a time. In this room you will find two fans, some padded swivel chairs, and another subject. You will be shown where to sit.

This experiment requires you to go through 12 trial runs on each day. Each trial requires you to do two things. The first is a task that either requires you to move 39 pegs around a square (See pegboard) or to work on a maze (See maze). Work around the pegboard in a clockwise direction, moving each peg 1 space counterclockwise. If you're working on the maze, follow the instructions which come with it. When you do either task, you should work at a pace you feel you could maintain for an eight-hour workday, paid by the hour. If you feel like you're rushing, you're working too fast. You should work at a pace that's comfortable for you. You may talk with the other subject while performing either task, but not during the voting periods. Please do not discuss the experiment at any time.

The second part of a trial run requires you to cast a set of ballots. (See ballots) You should put a check mark or an "X" to show how comfortable you feel. If you have any questions about how to do this, you can ask them during the two practice runs during the first half hour of each day. This first half hour is primarily concerned with getting you accustomed to the room's environment.

Now that you understand what is involved, we would like to start the practice runs. Please tell me when you start.

APPENDIX E

SIGN UP HERE FOR FAN COMFORT STUDY

<u>Subject's Sign-Up Information</u>

Subject Requirement:

You must not have been outside the continental U. S. for the past 60 days.

Background Information:

As you probably know, industry is reducing its use of air conditioning. We seek to determine how effectively fans can be used to make up the difference in a simulated assembly environment. Consequently, we are conducting a study in which you will be asked to do some very simple tasks while seated in an enclosed room measuring 12 feet by 24 feet for 3 hours a day for nine days in a row. The room's temperature will be between 70 and 90 degrees Fahrenheit. The relative humidity will be held constant at 40%.

Clothing Requirement:

You should either wear or bring with you clothes representative of what you might wear to work on a summer day for which a high is forecast in the low to mid eighties. Choose a lightweight short-sleeve shirt, preferably a cotton blend, and a pair of lightweight trousers, in addition to your regular undershorts (briefs for men or bra and panties for women), ankle length socks, and shoes.

You may take this information sheet with you, unless it is the last one available. Thank you for coming to sign up to participate.

APPENDIX F

Subject's Agreement and Release

1. I, _______________________, volunteer to participate in a project in connection with research studies to be conducted by Kansas State University.

2. I realize that participation may impose mental stresses upon me and/or upon the other subjects. I believe that I can withstand such stresses, but agree to withdraw from the experiment before they become serious, should such stresses become overbearing.

3. I understand that I will be permitted to terminate my participation at any time that I find that I am unable to withstand the conditions and request to be relieved.

4. I hereby authorize the Kansas State University to remove me from the evaluation exercise at any time and for any reason. I agree to leave said exercise willingly when asked to do so.

5. As compensation for my voluntary services as a participant in the aforesaid studies, Kansas State University will pay me the sum of _________ ($____) dollars. It is clearly understood and agreed, however, that in no event am I to be considered an employee of Kansas State University during such participation. Therefore, no Social Security, income tax, retirement, or other benefits of employment will be deducted or accrue.

6. I realize that my exercise of the option to withdraw as indicated in paragraphs 2, 3, or 4 above leads to forfeiture of the entire sum stated in paragraph 5, knowing that incomplete data is useless. I am aware that where my personal circumstances require that one date be rescheduled, notification of the experimenter 48 hours prior to the scheduled date will result in a sacrifice of not more than $25 of the compensation agreed upon in paragraph 5, when a rerun is possible.

7. I understand that I will be observed during my participation and that my conduct may be photographed. I also realize that public reports and articles may be made of the experiments and of all of the observations and I consent to the publication of such, including the use of photographs.

8. I hereby agree, under penalty of forfeiture of all compensation due me, not to give information regarding these studies to any public news media nor to publicize any articles or accounts thereof without prior written approval by Kansas State University.

I have signed the herein Subject's Agreement and Release, this _______ day of ___________, 1981.

Signed:____

APPENDIX G

Personal Data Form

Name______________________________
(first) (last)

Address______________________________

Phone number______________________________

Social Security number____-____-________

Date______/______/ 1981

Time of day____:______ AM / PM
(Circle one)

Subject Code__________

Sex M F

Your AGE __________

HEIGHT ___'___"

WEIGHT ______lbs

Are you right-handed? Yes No

Are you left-handed? Yes No

Are you more comfortable outside when there is a light breeze than when the air is still on a warm summer day? Yes No

Do you have a fan at home? Yes No

If you have a fan at home, Is it a box fan? Yes No

Is it an oscillating fan? Yes No

Is it an overhead fan? Yes No

Is your home air-conditioned? Yes No

APPENDIX H

Condition Assignment Sheet

Group 1			Group 2			Temperature		Day's	Fan
Day	Subjects		Day	Subjects		(C)	(F)	Run	Condition
1	1	2	18	5	6	25.6	(78)	Morn	Off
	3	4		7	8			Aft	Near
2	1	2	17	5	6	25.6	(78)	Morn	Far
	3	4		7	8			Aft	Far
3	1	2	16	5	6	25.6	(78)	Morn	Near
	3	4		7	8			Aft	Off
4	1	2	15	5	6	27.8	(82)	Morn	Off
	3	4		7	8			Aft	Near
5	1	2	14	5	6	27.8	(82)	Morn	Far
	3	4		7	8			Aft	Far
6	1	2	13	5	6	27.8	(82)	Morn	Near
	3	4		7	8			Aft	Off
7	1	2	12	5	6	30.0	(86)	Morn	Off
	3	4		7	8			Aft	Near
8	1	2	11	5	6	30.0	(86)	Morn	Far
	3	4		7	8			Aft	Far
9	1	2	10	5	6	30.0	(86)	Morn	Near
	3	4		7	8			Aft	Off
	C	B		B	C	Fan type			
	P	P		M	M	First task of the day			

APPENDIX I

Daily Log

Day__________ Date___/___/ 81 Morning or Afternoon?

Fan Condition: Off Near Far

Description	Subject Odd	Subject Even	Subject Make-up
Start Acclimation (Practice runs first time only) at time:			
	+30	+30	+30
O.K. to start first trial of first task after:			
	+15	+15	+15
O.K. to start first trial of second task after:			

Time		Odd	Even	Make-up
______	Start first trial of first task.			
	Pegboard performance after ½ hr:	____	____	____
______	Start second trial of first task.			
	Pegboard performance after 1 hr:	____	____	____
______	Start third trial of first task.			
	Pegboard performance after 1 ½ hr:	____	____	____
______	Start fourth trial of first task.			
	Pegboard performance after 2 hr:	____	____	____

Before last trial of first task:

"Would you like to have the fan turned off, or would you rather leave it on? If you leave it on, you may choose a different distance from the fan."

	Odd	Even	Make-up
Fan On or Off?	____	____	____
Distance chosen for last trial of first task:	____	____	____
Distance chosen for last trial of second task:	____	____	____
Pegboard task performance for last trial:	____	____	____

APPENDIX J

Subject Discharge and Disclosure Sheet

Subject Code______

The experiment is over. The prime concern of this experiment is with how the fan affects your comfort and with how this comfort is influenced by what you are doing. Did you like the fan more with one task than with another? Which task did you prefer? ____________________________

Do you feel that your comfort votes adequately represented your feelings?

exceptionally representative___:___:___:___:___:___:___:___:___exceptionally inadequate

(Put an "X" where you feel it fits best.)

Have the weeks of the experiment gone exceptionally well or exceptionally poorly for you, or have they been otherwise ordinary?

good period___:___:___:___:___:___:___:___:___bad period

usual

If this period has been out of the ordinary for you, do you think that this factor has caused you to vote generally too high or too low?

yes, too high___:___:___:___:___:___:___:___:___yes, too low

no

Do you feel that too much was asked of you?

yes, too much___:___:___:___:___:___:___:___:___no, too little

just right

Did anything about this experiment bother you? ______________________

____

Thank you for participating. Don't forget to sign the receipt form for cash payment so we can pay you now.

P.S. Do you have a favorite temperature? ______________

APPENDIX K

Explicitly Selected Fan Velocities

List of fan velocities corresponding to the average of the two positions explicitly selected by each subject in the final half hour of the test.

OBS	= Observation Number
FANCOND	= Fan Condition, N=Near (1.5m), F=Far (3.0m), O=Off (like 6.0m)
SUBJCODE	= Subject Code: odd for males, even for females
NUMBER	= Group Number: 1 male and 1 female per group
DAY	= Order in which subject exposed to the temperature-fan combination of the Day
PREVEL	= Preferred Velocity, determined by the explicit position preference

PREFERRED FAN VELOCITY FOR FINAL HALF HOUR OF EXPT

-------- SEX=F CHAMBER TEMPERATURE IN CENTIGRADE=25.6 --------

OBS	FANCOND	SUBJCODE	NUMBER	DAY	PREVEL
1	F	2	1	2	1.30
2	F	4	2	9	0.35
3	F	6	3	8	0.40
4	F	8	4	8	0.40
5	N	2	1	3	1.20
6	N	4	2	8	0.35
7	N	6	3	7	0.35
8	N	8	4	9	1.20
9	O	2	1	1	0.35
10	O	4	2	7	0.35
11	O	6	3	9	0.35
12	O	8	4	7	1.20

-------- SEX=F CHAMBER TEMPERATURE IN CENTIGRADE=27.8 --------

OBS	FANCOND	SUBJCODE	NUMBER	DAY	PREVEL
13	F	2	1	5	1.30
14	F	4	2	2	1.40
15	F	6	3	5	0.40
16	F	8	4	5	1.60
17	N	2	1	6	0.35
18	N	4	2	1	0.35
19	N	6	3	4	1.20
20	N	8	4	6	1.20
21	O	2	1	4	1.30
22	O	4	2	3	1.30
23	O	6	3	6	1.20
24	O	8	4	4	1.60

--------- SEX=F CHAMBER TEMPERATURE IN CENTIGRADE=30 ---------

OBS	FANCOND	SUBJCODE	NUMBER	DAY	PREVEL
25	F	2	1	8	1.4
26	F	4	2	5	1.3
27	F	6	3	2	0.4
28	F	8	4	2	1.4
29	N	2	1	9	1.4
30	N	4	2	4	1.4
31	N	6	3	1	1.2
32	N	8	4	3	1.6
33	O	2	1	7	1.4
34	O	4	2	6	1.4
35	O	6	3	3	1.2
36	O	8	4	1	1.2

PREFERRED FAN VELOCITY FOR FINAL HALF HOUR OF EXPT

-------- SEX=M CHAMBER TEMPERATURE IN CENTIGRADE=25.6 --------

OBS	FANCOND	SUBJCODE	NUMBER	DAY	PREVEL
37	F	1	1	2	0.40
38	F	3	2	1	0.40
39	F	5	3	9	0.35
40	F	7	4	8	1.30
41	N	1	1	3	0.40
42	N	3	2	2	0.70
43	N	5	3	7	0.35
44	N	7	4	9	1.40
45	O	1	1	1	0.50
46	O	3	2	3	0.70
47	O	5	3	8	0.35
48	O	7	4	7	1.40

-------- SEX=M CHAMBER TEMPERATURE IN CENTIGRADE=27.8 --------

OBS	FANCOND	SUBJCODE	NUMBER	DAY	PREVEL
49	F	1	1	5	0.4
50	F	3	2	5	0.4
51	F	5	3	5	1.3
52	F	7	4	5	1.4
53	N	1	1	6	0.4
54	N	3	2	4	0.4
55	N	5	3	4	1.4
56	N	7	4	6	1.5
57	O	1	1	4	0.4
58	O	3	2	6	0.4
59	O	5	3	6	1.4
60	O	7	4	4	1.7

--------- SEX=M CHAMBER TEMPERATURE IN CENTIGRADE=30 ---------

OBS	FANCOND	SUBJCODE	NUMBER	DAY	PREVEL
61	F	1	1	8	0.8
62	F	3	2	8	0.4
63	F	5	3	2	1.3
64	F	7	4	2	1.5
65	N	1	1	9	1.2
66	N	3	2	7	0.4
67	N	5	3	1	1.4
68	N	7	4	3	1.4
69	O	1	1	7	0.9
70	O	3	2	9	1.2
71	O	5	3	3	1.4
72	O	7	4	1	1.4

APPENDIX L

ANOVA and Duncan Analyses for Explicitly Selected Fan Velocities

TEST OF THE NULL HYPOTHESIS THAT THE PREFERRED VELOCITY
IN M/SEC VARIES WITH NEITHER THE CHAMBER TEMPERATURE, SEX,
GROUP NUMBER, NOR WITH THE PREDETERMINED TWO HOUR FAN CONDITION
ERROR = CTEMP*FANCOND*SEX*NUMBER + FANCOND*SEX*NUMBER +
CTEMP*SEX*NUMBER + CTEMP*FANCOND*SEX + CTEMP*FANCOND*NUMBER

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
CTEMP	3	30 25.6 27.8
FANCOND	3	F N O
SEX	2	F M
NUMBER	4	1 2 3 4

NUMBER OF OBSERVATIONS IN DATA SET = 72

TEST OF THE NULL HYPOTHESIS THAT THE PREFERRED VELOCITY IN M/SEC VARIES WITH NEITHER THE CHAMBER TEMPERATURE, SEX, GROUP NUMBER, NOR WITH THE PREDETERMINED TWO HOUR FAN CONDITION
ERROR = CTEMP*FANCOND*SEX*NUMBER + FANCCND*SEX*NUMBER + CTEMP*SEX*NUMBER + CTEMP*FANCOND*SEX + CTEMP*FANCOND*NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: PREVEL

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	31	12.44024306	0.40129816
ERROR	40	3.74805556	0.09370139
CORRECTED TOTAL	71	16.18829861	

MODEL F =	4.28		PR > F = 0.0001
R-SQUARE	C.V.	STD DEV	PREVEL MEAN
0.768471	31.9647	0.30610683	0.95763889

SOURCE	DF	ANOVA SS	F VALUE	PR > F
CTEMP	2	3.38965278	18.09	0.0001
FANCOND	2	0.19090278	1.02	0.3702
SEX	1	0.18503472	1.97	0.1677
NUMBER	3	4.03538194	14.36	0.0001
CTEMP*FANCOND	4	0.47555556	1.27	0.2982
CTEMP*SEX	2	0.17381944	0.93	0.4039
FANCOND*SEX	2	0.01590278	0.08	0.9188
CTEMP*NUMBER	6	1.37118056	2.44	0.0420
FANCOND*NUMBER	6	0.53993056	0.96	0.4641
SEX*NUMBER	3	2.06288194	7.34	0.0005

TEST OF THE NULL HYPOTHESIS THAT THE PREFERRED VELOCITY
IN M/SEC VARIES WITH NEITHER THE CHAMBER TEMPERATURE, SEX,
GROUP NUMBER, NOR WITH THE PREDETERMINED TWO HOUR FAN CONDITION
ERROR = CTEMP*FANCOND*SEX*NUMBER + FANCCND*SEX*NUMBER +
CTEMP*SEX*NUMBER + CTEMP*FANCOND*SEX + CTEMP*FANCOND*NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE PREVEL

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=40 MS=.0937014

GROUPING	MEAN	N	CTEMP
A	1.191667	24	30
B	1.012500	24	27.8
C	0.668750	24	25.6

TEST OF THE NULL HYPOTHESIS THAT THE PREFERRED VELOCITY
IN M/SEC VARIES WITH NEITHER THE CHAMBER TEMPERATURE, SEX,
GROUP NUMBER, NOR WITH THE PREDETERMINED TWO HOUR FAN CONDITION
ERROR = CTEMP*FANCOND*SEX*NUMBER + FANCCND*SEX*NUMBER +
CTEMP*SEX*NUMBER + CTEMP*FANCOND*SEX + CTEMP*FANCOND*NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE PREVEL

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=40 MS=.0937014

GROUPING	MEAN	N	FANCOND
A	1.025000	24	O
A			
A	0.947917	24	N
A			
A	0.900000	24	F

TEST OF THE NULL HYPOTHESIS THAT THE PREFERRED VELOCITY
IN M/SEC VARIES WITH NEITHER THE CHAMBER TEMPERATURE, SEX,
GROUP NUMBER, NOR WITH THE PREDETERMINED TWO HOUR FAN CONDITION
ERROR = CTEMP*FANCOND*SEX*NUMBER + FANCOND*SEX*NUMBER +
CTEMP*SEX*NUMBER + CTEMP*FANCOND*SEX + CTEMP*FANCOND*NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE PREVEL

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=40 MS=.0937014

GROUPING	MEAN	N	SEX
A	1.008333	36	F
A			
A	0.906944	36	M

TEST OF THE NULL HYPOTHESIS THAT THE PREFERRED VELOCITY
IN M/SEC VARIES WITH NEITHER THE CHAMBER TEMPERATURE, SEX,
GROUP NUMBER, NOR WITH THE PREDETERMINED TWO HOUR FAN CONDITION
ERROR = CTEMP*FANCOND*SEX*NUMBER + FANCOND*SEX*NUMBER +
CTEMP*SEX*NUMBER + CTEMP*FANCOND*SEX + CTEMP*FANCOND*NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE PREVEL

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=40 MS=.0937014

GROUPING	MEAN	N	NUMBER
A	1.355556	18	4
B	0.886111	18	3
B			
B	0.855556	18	1
B			
B	0.733333	18	2

TEST OF THE NULL HYPOTHESIS THAT THE PREFERRED VELOCITY
IN M/SEC VARIES WITH NEITHER THE DAY OF EXPOSURE, SEX, NOR
THE GROUP NUMBER
ERROR = DAY*SEX*NUMBER = CTEMP*FANCOND*SEX*NUMBER +
CTEMP*SEX*NUMBER + FANCOND*SEX*NUMBER

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
DAY	9	1 2 3 4 5 6 7 8 9
SEX	2	F M
NUMBER	4	1 2 3 4

NUMBER OF OBSERVATIONS IN DATA SET = 72

TEST OF THE NULL HYPOTHESIS THAT THE PREFERRED VELOCITY IN M/SEC VARIES WITH NEITHER THE DAY OF EXPOSURE, SEX, NOR THE GROUP NUMBER
ERROR = DAY*SEX*NUMBER = CTEMP*FANCOND*SEX*NUMBER + CTEMP*SEX*NUMBER + FANCOND*SEX*NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: PREVEL

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	47	13.67336806	0.29092272
ERROR	24	2.51493056	0.10478877
CORRECTED TOTAL	71	16.18829861	

MODEL F = 2.78 PR > F = 0.0043

R-SQUARE	C.V.	STD DEV	PREVEL MEAN
0.844645	33.8030	0.32371094	0.95763889

SOURCE	DF	ANOVA SS	F VALUE	PR > F
DAY	8	1.72298611	2.06	0.0825
SEX	1	0.18503472	1.77	0.1964
NUMBER	3	4.03538194	12.84	0.0001
DAY*SEX	8	0.75590278	0.90	0.5308
DAY*NUMBER	24	4.91118056	1.95	0.0539
SEX*NUMBER	3	2.06288194	6.56	0.0021

TEST OF THE NULL HYPOTHESIS THAT THE PREFERRED VELOCITY
IN M/SEC VARIES WITH NEITHER THE TEMPERATURE-FAN CONDITION,
SEX, NOR THE GROUP NUMBER
ERROR = TCOND*SEX*NUMBER = CTEMP*FANCOND*SEX*NUMBER +
CTEMP*SEX*NUMBER + FANCOND*SEX*NUMBER

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
TCOND	9	F78FAR F78NEA F78OFF F82FAR F82NEA F82OFF F86FAR F86NEA F86OFF
SEX	2	F M
NUMBER	4	1 2 3 4

NUMBER OF OBSERVATIONS IN DATA SET = 72

TEST OF THE NULL HYPOTHESIS THAT THE PREFERRED VELOCITY
IN M/SEC VARIES WITH NEITHER THE TEMPERATURE-FAN CONDITION,
SEX, NOR THE GROUP NUMBER
ERROR = TCOND*SEX*NUMBER = CTEMP*FANCOND*SEX*NUMBER +
CTEMP*SEX*NUMBER + FANCOND*SEX*NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: PREVEL

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	47	13.77024306	0.29298389
ERROR	24	2.41805556	0.10075231
CORRECTED TOTAL	71	16.18829861	

MODEL F =	2.91		PR > F = 0.0031
R-SQUARE	C.V.	STD DEV	PREVEL MEAN
0.850629	33.1456	0.31741505	0.95763889

SOURCE	DF	ANOVA SS	F VALUE	PR > F
TCOND	8	4.05611111	5.03	0.0009
SEX	1	0.18503472	1.84	0.1880
NUMBER	3	4.03538194	13.35	0.0001
TCOND*SEX	8	0.61277778	0.76	0.6400
TCOND*NUMBER	24	2.81805556	1.17	0.3554
SEX*NUMBER	3	2.06288194	6.82	0.0017

TEST OF THE NULL HYPOTHESIS THAT THE PREFERRED VELOCITY IN M/SEC VARIES WITH NEITHER THE TEMPERATURE-FAN CONDITION, SEX, NOR THE GROUP NUMBER
ERROR = TCOND*SEX*NUMBER = CTEMP*FANCOND*SEX*NUMBER + CTEMP*SEX*NUMBER + FANCOND*SEX*NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE PREVEL

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=24 MS=0.100752

GROUPING			MEAN	N	TCOND
	A		1.262500	8	F86OFF
	A				
	A		1.250000	8	F86NEA
	A				
B	A		1.162500	8	F82OFF
B	A				
B	A	C	1.062500	8	F86FAR
B	A	C			
B	A	C	1.025000	8	F82FAR
B		C			
B	D	C	0.850000	8	F82NEA
	D	C			
	D	C	0.743750	8	F78NEA
	D				
	D		0.650000	8	F78OFF
	D				
	D		0.612500	8	F78FAR

APPENDIX M

<u>Average Daily Outside Environment at Time of Test</u>

Variable Description	Label	N	Mean	Std. Error of Mean	Standard Deviation	Minimum Value	Maximum Value
Temperature (C) for Previous Hour	PRHRCTEM	72	18.981	0.64	5.47	8.33	28.89
Daily Maximum Temperature (C)	MAXCTEMP	72	24.48	0.47	4.00	15.56	30.00
Daily Minimum Temperature (C)	MINCTEMP	72	12.34	0.65	5.54	0.56	18.33
Relative Humidity for Previous Hour	PRHRRH	72	77.57	2.73	23.13	33.00	99.00
Total Daily Precipitation (Inches)	INCHESPR	72	0.24	0.04	0.35	0.00	1.25
Solar Radiation (Langleys) for Prev Hr	PRRHSRAD	72	31.35	3.81	32.31	0.20	82.60
Total Daily Solar Radiation (Langleys)	TOTRAD	72	488.88	23.97	203.43	33.00	692.00

APPENDIX N

Duncan Analyses for the Thermal Sensation Variable Group

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MTHERML

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=24 MS=0.31939

GROUPING		MEAN	N	TCOND
	A	7.015625	8	F86_OFF
	A			
B	A	6.437500	8	F82_OFF
B				
B	C	5.906250	8	F86_FAR
	C			
	C	5.640625	8	F78_OFF
	C			
	C	5.578125	8	F86NEAR
	C			
D	C	5.296875	8	F82_FAR
D				
D	E	4.921875	8	F78_FAR
D	E			
D	E	4.828125	8	F82NEAR
	E			
	E	4.406250	8	F78NEAR

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MPREFTM

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=24 MS=0.29192

GROUPING		MEAN	N	TCOND
	A	7.015625	8	F86_OFF
	B	6.437500	8	F82_OFF
	B			
C	B	6.078125	8	F86_FAR
C				
C		5.671875	8	F78_OFF
C				
C		5.671875	8	F86NEAR
C				
C	D	5.609375	8	F82_FAR
	D			
E	D	5.062500	8	F78_FAR
E				
E		4.875000	8	F82NEAR
E				
E		4.562500	8	F78NEAR

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MESTTM

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=24 MS=14.8254

GROUPING			MEAN	N	TCOND
	A		82.484375	8	F86_OFF
	A				
B	A		79.593750	8	F82_OFF
B					
B	C		77.609375	8	F86_FAR
B	C				
B	C		76.890625	8	F86NEAR
B	C				
B	C	D	76.078125	8	F78_OFF
	C	D			
	C	D	75.078125	8	F82_FAR
		D			
	E	D	72.140625	8	F82NEAR
	E	D			
	E	D	72.031250	8	F78_FAR
	E				
	E		70.296875	8	F78NEAR

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MTHERML

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=24 MS=0.31939

GROUPING	MEAN	N	SEX
A	5.843750	36	M
B	5.274306	36	F

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MPREFTM

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=24 MS=0.29192

GROUPING	MEAN	N	SEX
A	5.725694	36	M
A			
A	5.604167	36	F

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MESTTM

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05　　DF=24　　MS=14.8254

GROUPING	MEAN	N	SEX
A	77.954861	36	M
B	73.645833	36	F

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MTHERML

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=24 MS=0.31939

GROUPING		MEAN	N	NUMBER
	A	5.777778	18	4
	A			
B	A	5.743056	18	2
B				
B		5.361111	18	3
B				
B		5.354167	18	1

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MPREFTM

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=24 MS=0.29192

GROUPING	MEAN	N	NUMBER
A	6.194444	18	4
B	5.590278	18	1
B			
B	5.444444	18	2
B			
B	5.430556	18	3

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MESTTM

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=24 MS=14.8254

GROUPING	MEAN	N	NUMBER
A	76.937500	18	2
A			
A	76.215278	18	1
A			
A	75.138889	18	3
A			
A	74.909722	18	4

APPENDIX O

Duncan Analyses for the Thermal Comfort Variable Group

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MSTCV

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=24 MS=46.9117

GROUPING			MEAN	N	TCOND
	A		45.828125	8	F78_FAR
	A				
B	A		44.640625	8	F78NEAR
B	A				
B	A	C	41.093750	8	F86NEAR
B	A	C			
B	A	C	40.578125	8	F82NEAR
B	A	C			
B	A	C	40.406250	8	F82_FAR
B		C			
B	D	C	37.093750	8	F86_FAR
	D	C			
	D	C	34.687500	8	F78_OFF
	D				
E	D		29.875000	8	F82_OFF
E					
E			25.187500	8	F86_OFF

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MLAPC_R

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=24 MS=91.5568

GROUPING			MEAN	N	TCOND
	A		65.159028	8	F78_FAR
	A				
B	A		60.970330	8	F78NEAR
B	A				
B	A		57.921626	8	F86NEAR
B	A				
B	A		56.365759	8	F82_FAR
B	A				
B	A	C	55.228052	8	F82NEAR
B		C			
B		C	52.299280	8	F86_FAR
B		C			
B		C	51.715812	8	F78_OFF
		C			
	D	C	44.707754	8	F82_OFF
	D				
	D		38.362980	8	F86_OFF

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MLAPC_A

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=24 MS=148.915

GROUPING			MEAN	N	TCOND
	A		69.153222	8	F78_FAR
	A				
B	A		66.758350	8	F78NEAR
B	A				
B	A	C	60.568123	8	F86NEAR
B	A	C			
B	A	C	59.472985	8	F82NEAR
B	A	C			
B	A	C	59.356841	8	F82_FAR
B		C			
B	D	C	53.397857	8	F86_FAR
	D	C			
	D	C	49.740055	8	F78_OFF
	D				
E	D		41.014371	8	F82_OFF
E					
E			32.541366	8	F86_OFF

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MLAPC_B

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=24 MS=134.093

GROUPING		MEAN	N	TCOND
	A	55.012438	8	F78_FAR
	A			
	A	52.778595	8	F78NEAR
	A			
B	A	46.290181	8	F86NEAR
B	A			
B	A	45.700489	8	F82_FAR
B	A			
B	A	45.638616	8	F82NEAR
B				
B	C	39.326582	8	F86_FAR
B	C			
B	C	38.541437	8	F78_OFF
	C			
D	C	29.361941	8	F82_OFF
D				
D		20.227388	8	F86_OFF

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MSTCV

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=24 MS=46.9117

GROUPING	MEAN	N	SEX
A	38.246528	36	F
A			
A	37.173611	36	M

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MLAPC_R

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=24 MS=91.5568

GROUPING	MEAN	N	SEX
A	54.285155	36	F
A			
A	52.988317	36	M

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MLAPC_A

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=24 MS=148.915

GROUPING	MEAN	N	SEX
A	55.670097	36	F
A			
A	53.663941	36	M

TEST CF THE NULL HYPOTHESIS THAT THE DAILY MEAN CF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HCUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MLAPC_B

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=24 MS=134.093

GROUPING	MEAN	N	SEX
A	42.803981	36	F
A			
A	40.057723	36	M

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MSTCV

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=24 MS=46.9117

GROUPING		MEAN	N	NUMBER
	A	40.798611	18	3
	A			
B	A	38.354167	18	4
B	A			
B	A	36.159722	18	2
B				
B		35.527778	18	1

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MLAPC_R

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=24 MS=91.5568

GROUPING		MEAN	N	NUMBER
	A	59.820319	18	3
	A			
B	A	55.151889	18	4
B				
B		49.901292	18	2
B				
B		49.673443	18	1

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MLAPC_A

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05   DF=24   MS=148.915

GROUPING		MEAN	N	NUMBER
	A	60.436715	18	3
	A			
B	A	55.915449	18	4
B				
B		51.611696	18	2
B				
B		50.704214	18	1

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE MLAPC_B

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=24 MS=134.093

GROUPING		MEAN	N	NUMBER
	A	47.363303	18	3
	A			
B	A	42.866813	18	4
B				
B		37.922299	18	1
B				
B		37.570993	18	2

APPENDIX P

ANOVA Analyses for both the Thermal Sensation and Thermal Comfort Variable Groups

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
CTEMP	3	30 25.6 27.8
FANCOND	3	F N O
SEX	2	F M
NUMBER	4	1 2 3 4

NUMBER OF OBSERVATIONS IN DATA SET = 72

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MTHERML

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	31	68.78949653	2.21901602
ERROR	40	9.45963542	0.23649089
CORRECTED TOTAL	71	78.24913194	
MODEL F =	9.38		PR > F = 0.0001

R-SQUARE	C.V.	STD DEV	MTHERML MEAN
0.879109	8.7480	0.48630329	5.55902778

SOURCE	DF	ANOVA SS	F VALUE	PR > F
CTEMP	2	16.67881944	35.26	0.0001
FANCOND	2	25.65798611	54.25	0.0001
SEX	1	5.83680556	24.68	0.0001
NUMBER	3	2.93142361	4.13	0.0121
CTEMP*FANCOND	4	0.53342014	0.56	0.6902
CTEMP*SEX	2	0.46527778	0.98	0.3828
FANCOND*SEX	2	1.32465278	2.80	0.0727
CTEMP*NUMBER	6	2.08159722	1.47	0.2142
FANCOND*NUMBER	6	2.37847222	1.68	0.1521
SEX*NUMBER	3	10.90104167	15.36	0.0001

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MPREFTM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	31	66.92773437	2.15895917
ERROR	40	11.47309028	0.28682726
CORRECTED TOTAL	71	78.40082465	
MODEL F =	7.53		PR > F = 0.0001

R-SQUARE	C.V.	STD DEV	MPREFTM MEAN
0.853661	9.4540	0.53556256	5.66493056

SOURCE	DF	ANOVA SS	F VALUE	PR > F
CTEMP	2	16.06423611	28.00	0.0001
FANCOND	2	21.74001736	37.90	0.0001
SEX	1	0.26584201	0.93	0.3415
NUMBER	3	7.01106771	8.15	0.0002
CTEMP*FANCOND	4	0.57508681	0.50	0.7349
CTEMP*SEX	2	0.29861111	0.52	0.5982
FANCOND*SEX	2	1.51085069	2.63	0.0842
CTEMP*NUMBER	6	3.96875000	2.31	0.0526
FANCOND*NUMBER	6	1.22005208	0.71	0.6443
SEX*NUMBER	3	14.27322049	16.59	0.0001

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MESTTM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	31	2040.80403646	65.83238827
ERROR	40	486.59157986	12.16478950
CORRECTED TOTAL	71	2527.39561632	

MODEL F =	5.41		PR > F = 0.0001
R-SQUARE	C.V.	STD DEV	MESTTM MEAN
0.807473	4.6013	3.48780583	75.80034722

SOURCE	DF	ANOVA SS	F VALUE	PR > F
CTEMP	2	461.58116319	18.97	0.0001
FANCOND	2	501.44314236	20.61	0.0001
SEX	1	334.21896701	27.47	0.0001
NUMBER	3	48.52842882	1.33	0.2782
CTEMP*FANCOND	4	13.08810764	0.27	0.8962
CTEMP*SEX	2	1.93012153	0.08	0.9239
FANCOND*SEX	2	26.47178819	1.09	0.3466
CTEMP*NUMBER	6	82.75217014	1.13	0.3607
FANCOND*NUMBER	6	128.23914931	1.76	0.1330
SEX*NUMBER	3	442.55099826	12.13	0.0001

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MSTCV

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	31	4112.60264757	132.66460153
ERROR	40	1605.89192708	40.14729818
CORRECTED TOTAL	71	5718.49457465	
MODEL F =	3.30		PR > F = 0.0002

R-SQUARE	C.V.	STD DEV	MSTCV MEAN
0.719176	16.8024	6.33618956	37.71006944

SOURCE	DF	ANOVA SS	F VALUE	PR > F
CTEMP	2	653.19053819	8.13	0.0011
FANCOND	2	2198.41189236	27.38	0.0001
SEX	1	20.72070313	0.52	0.4767
NUMBER	3	308.15863715	2.56	0.0686
CTEMP*FANCOND	4	97.18706597	0.61	0.6612
CTEMP*SEX	2	1.07942708	0.01	0.9867
FANCOND*SEX	2	14.14192708	0.18	0.8392
CTEMP*NUMBER	6	83.88758681	0.35	0.9067
FANCOND*NUMBER	6	195.85894097	0.81	0.5661
SEX*NUMBER	3	539.96592882	4.48	0.0084

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MLAPC_R

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	31	7098.40903099	228.98093648
ERROR	40	3278.98948001	81.97473700
CORRECTED TOTAL	71	10377.39851100	
MODEL F =	2.79		PR > F = 0.0012

R-SQUARE	C.V.	STD DEV	MLAPC_R MEAN
0.684026	16.8802	9.05399011	53.63673561

SOURCE	DF	ANOVA SS	F VALUE	PR > F
CTEMP	2	1226.58866961	7.48	0.0017
FANCOND	2	2729.89926311	16.65	0.0001
SEX	1	30.27220771	0.37	0.5468
NUMBER	3	1263.48527824	5.14	0.0042
CTEMP*FANCOND	4	310.53613672	0.95	0.4470
CTEMP*SEX	2	7.95100013	0.05	0.9527
FANCOND*SEX	2	26.59487579	0.16	0.8508
CTEMP*NUMBER	6	167.18873645	0.34	0.9116
FANCOND*NUMBER	6	453.29580284	0.92	0.4898
SEX*NUMBER	3	882.59706040	3.59	0.0218

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MLAPC_A

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	31	12919.88158509	416.77037371
ERROR	40	5125.19654985	128.12991375
CORRECTED TOTAL	71	18045.07813493	

MODEL F =	3.25		PR > F = 0.0003
R-SQUARE	C.V.	STD DEV	MLAPC_A MEAN
0.715978	20.7062	11.31944847	54.66701879

SOURCE	DF	ANOVA SS	F VALUE	PR > F
CTEMP	2	2112.15088245	8.24	0.0010
FANCOND	2	6659.57716413	25.99	0.0001
SEX	1	72.44392346	0.57	0.4565
NUMBER	3	1077.96220806	2.80	0.0520
CTEMP*FANCOND	4	330.59350751	0.65	0.6336
CTEMP*SEX	2	2.92936744	0.01	0.9886
FANCOND*SEX	2	48.96476633	0.19	0.8268
CTEMP*NUMBER	6	266.42048767	0.35	0.9077
FANCOND*NUMBER	6	619.30387069	0.81	0.5716
SEX*NUMBER	3	1729.53540735	4.50	0.0082

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MLAPC_B

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	31	11775.33171862	379.84941028
ERROR	40	4662.90747092	116.57268677
CORRECTED TOTAL	71	16438.23918954	

MODEL F = 3.26 PR > F = 0.0003

R-SQUARE	C.V.	STD DEV	MLAPC_B MEAN
0.716338	26.0600	10.79688320	41.43085194

SOURCE	DF	ANOVA SS	F VALUE	PR > F
CTEMP	2	2237.33450727	9.60	0.0004
FANCOND	2	5259.75235104	22.56	0.0001
SEX	1	135.75483483	1.16	0.2870
NUMBER	3	1160.35941059	3.32	0.0293
CTEMP*FANCOND	4	349.32193307	0.75	0.5644
CTEMP*SEX	2	3.77996843	0.02	0.9839
FANCOND*SEX	2	96.29031705	0.41	0.6644
CTEMP*NUMBER	6	235.75992237	0.34	0.9132
FANCOND*NUMBER	6	499.64038134	0.71	0.6402
SEX*NUMBER	3	1797.33809264	5.14	0.0042

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE FINAL FAN CONDITION SELECTED BY THE SUBJECT, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
CTEMP	3	30 25.6 27.8
FANCOND	3	F N O
SEX	2	F M
NUMBER	4	1 2 3 4

NUMBER OF OBSERVATIONS IN DATA SET = 72

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE FINAL FAN CONDITION SELECTED BY THE SUBJECT, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MTHERML

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	31	23.16319444	0.74719982
ERROR	40	11.08333333	0.27708333
CORRECTED TOTAL	71	34.24652778	

MODEL F =	2.70		PR > F = 0.0017
R-SQUARE	C.V.	STD DEV	MTHERML MEAN
0.676366	10.2849	0.52638706	5.11805556

SOURCE	DF	ANOVA SS	F VALUE	PR > F
CTEMP	2	2.75694444	4.97	0.0118
FANCOND	2	0.09027778	0.16	0.8502
SEX	1	4.75347222	17.16	0.0002
NUMBER	3	1.76041667	2.12	0.1131
CTEMP*FANCOND	4	0.55555556	0.50	0.7349
CTEMP*SEX	2	0.71527778	1.29	0.2863
FANCOND*SEX	2	0.67361111	1.22	0.3073
CTEMP*NUMBER	6	3.93750000	2.37	0.0473
FANCOND*NUMBER	6	0.85416667	0.51	0.7943
SEX*NUMBER	3	7.06597222	8.50	0.0002

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE FINAL FAN CONDITION SELECTED BY THE SUBJECT, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MPREFTM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	31	17.74652778	0.57246864
ERROR	40	9.47222222	0.23680556
CORRECTED TOTAL	71	27.21875000	
MODEL F =	2.42		PR > F = 0.0045

R-SQUARE	C.V.	STD DEV	MPREFTM MEAN
0.651996	9.0887	0.48662671	5.35416667

SOURCE	DF	ANOVA SS	F VALUE	PR > F
CTEMP	2	4.52083333	9.55	0.0004
FANCOND	2	0.43750000	0.92	0.4053
SEX	1	0.03125000	0.13	0.7183
NUMBER	3	2.39930556	3.38	0.0275
CTEMP*FANCOND	4	0.66666667	0.70	0.5940
CTEMP*SEX	2	0.02083333	0.04	0.9570
FANCOND*SEX	2	0.14583333	0.31	0.7367
CTEMP*NUMBER	6	4.42361111	3.11	0.0134
FANCOND*NUMBER	6	0.25694444	0.18	0.9805
SEX*NUMBER	3	4.84375000	6.82	0.0008

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE FINAL FAN CONDITION SELECTED BY THE SUBJECT, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MESTTM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	31	1071.12152778	34.55230735
ERROR	40	449.09722222	11.22743056
CORRECTED TOTAL	71	1520.21875000	

MODEL F =	3.08		PR > F = 0.0005
R-SQUARE	C.V.	STD DEV	MESTTM MEAN
0.704584	4.5267	3.35073582	74.02083333

SOURCE	DF	ANOVA SS	F VALUE	PR > F
CTEMP	2	159.14583333	7.09	0.0023
FANCOND	2	12.02083333	0.54	0.5896
SEX	1	229.33680556	20.43	0.0001
NUMBER	3	55.76041667	1.66	0.1920
CTEMP*FANCOND	4	28.70833333	0.64	0.6376
CTEMP*SEX	2	12.00694444	0.53	0.5900
FANCOND*SEX	2	9.88194444	0.44	0.6471
CTEMP*NUMBER	6	54.93750000	0.82	0.5643
FANCOND*NUMBER	6	67.97916667	1.01	0.4331
SEX*NUMBER	3	441.34375000	13.10	0.0001

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE FINAL FAN CONDITION SELECTED BY THE SUBJECT, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MSTCV

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	31	2033.66666667	65.60215054
ERROR	40	1101.61111111	27.54027778
CORRECTED TOTAL	71	3135.27777778	

MODEL F =	2.38	PR > F = 0.0051

R-SQUARE	C.V.	STD DEV	MSTCV MEAN
0.648640	12.0487	5.24788317	43.55555556

SOURCE	DF	ANOVA SS	F VALUE	PR > F
CTEMP	2	171.54861111	3.11	0.0553
FANCOND	2	32.13194444	0.58	0.5627
SEX	1	224.01388889	8.13	0.0068
NUMBER	3	375.36111111	4.54	0.0078
CTEMP*FANCOND	4	97.59722222	0.89	0.4811
CTEMP*SEX	2	30.21527778	0.55	0.5821
FANCOND*SEX	2	25.46527778	0.46	0.6331
CTEMP*NUMBER	6	353.36805556	2.14	0.0699
FANCOND*NUMBER	6	84.61805556	0.51	0.7956
SEX*NUMBER	3	639.34722222	7.74	0.0003

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE FINAL FAN CONDITION SELECTED BY THE SUBJECT, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MLAPC_R

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	31	4632.34725438	149.43055659
ERROR	40	2338.84446357	58.47111159
CORRECTED TOTAL	71	6971.19171795	

MODEL F = 2.56 PR > F = 0.0028

R-SQUARE	C.V.	STD DEV	MLAPC_R MEAN
0.664499	12.4457	7.64664054	61.43992360

SOURCE	DF	ANOVA SS	F VALUE	PR > F
CTEMP	2	507.32469758	4.34	0.0197
FANCOND	2	88.19863268	0.75	0.4770
SEX	1	589.16927959	10.08	0.0029
NUMBER	3	1170.58996098	6.67	0.0009
CTEMP*FANCOND	4	174.62808361	0.75	0.5661
CTEMP*SEX	2	63.09131519	0.54	0.5872
FANCOND*SEX	2	91.85966780	0.79	0.4628
CTEMP*NUMBER	6	597.21737082	1.70	0.1456
FANCOND*NUMBER	6	148.12316441	0.42	0.8598
SEX*NUMBER	3	1202.14508173	6.85	0.0008

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE FINAL FAN CONDITION SELECTED BY THE SUBJECT, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MLAPC_A

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	31	6631.38605303	213.91567913
ERROR	40	3537.33305702	88.43332643
CORRECTED TOTAL	71	10168.71911005	

MODEL F = 2.42 PR > F = 0.0045

R-SQUARE	C.V.	STD DEV	MLAPC_A MEAN
0.652136	14.4652	9.40389953	65.01045316

SOURCE	DF	ANOVA SS	F VALUE	PR > F
CTEMP	2	582.20291445	3.29	0.0475
FANCOND	2	100.39547257	0.57	0.5714
SEX	1	760.89172249	8.60	0.0055
NUMBER	3	1247.64795959	4.70	0.0066
CTEMP*FANCOND	4	302.83785021	0.86	0.4985
CTEMP*SEX	2	97.69865705	0.55	0.5799
FANCOND*SEX	2	82.57582428	0.47	0.6303
CTEMP*NUMBER	6	1105.47229437	2.08	0.0768
FANCOND*NUMBER	6	270.38012279	0.51	0.7974
SEX*NUMBER	3	2081.28323523	7.85	0.0003

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE FINAL FAN CCNDITION SELECTED BY THE SUBJECT, THE SEX OF THE SUBJECT, NOR WITH THE GRCUP NUMBER

ANALYSIS OF VARIANCE PRCCEDURE

DEPENDENT VARIABLE: MLAPC_B

SCURCE	DF	SUM OF SQUARES	MEAN SQUARE
MCDEL	31	6805.88080142	219.54454198
ERROR	40	3350.60752141	83.76518804
CORRECTED TCTAL	71	10156.48832284	

MOCEL F =	2.62		PR > F = 0.0022
R-SQUARE	C.V.	STD DEV	MLAPC_B MEAN
0.670102	18.0040	9.15233238	50.83486354

SCURCE	DF	ANOVA SS	F VALUE	PR > F
CTEMP	2	653.69910165	3.90	0.0283
FANCCNC	2	61.38456077	C.37	C.6955
SEX	1	888.05810934	10.60	0.0023
NUMBER	3	1310.34550988	5.21	0.0039
CTEMP*FANCCND	4	226.97566604	C.68	C.6116
CTEMP*SEX	2	92.42938448	0.55	0.5803
FANCOND*SEX	2	49.22258529	0.29	C.7470
CTEMP*NUMBER	6	989.56638393	1.97	0.0932
FANCCNC*NUMBER	6	267.86967640	C.53	0.7799
SEX*NUMBER	3	2266.32982365	9.02	0.0001

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
TCOND	9	F78_FAR F78_OFF F78NEAR F82_FAR F82_OFF F82NEAR F86_FAR F86_OFF F86NEAR
SEX	2	F M
NUMBER	4	1 2 3 4

NUMBER OF OBSERVATIONS IN DATA SET = 72

TEST OF THE NULL HYPCTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MTHERML

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	47	70.58376736	1.50178228
ERROR	24	7.66536458	0.31939019
CORRECTED TOTAL	71	78.24913194	
MODEL F =	4.70		PR > F = 0.0001

R-SQUARE	C.V.	STD DEV	MTHERML MEAN
0.902039	10.1663	0.56514617	5.55902778

SOURCE	DF	ANOVA SS	F VALUE	PR > F
TCOND	8	42.87022569	16.78	0.0001
SEX	1	5.83680556	18.27	0.0003
NUMBER	3	2.93142361	3.06	0.0475
TCOND*SEX	8	2.08116319	0.81	0.5971
TCOND*NUMBER	24	5.96310764	0.78	0.7284
SEX*NUMBER	3	10.90104167	11.38	0.0001

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MPREFTM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	47	71.39474826	1.51903720
ERROR	24	7.00607639	0.29191985
CORRECTED TOTAL	71	78.40082465	
MODEL F =	5.20		PR > F = 0.0001

R-SQUARE	C.V.	STD DEV	MPREFTM MEAN
0.910638	9.5376	0.54029608	5.66493056

SOURCE	DF	ANOVA SS	F VALUE	PR > F
TCOND	8	38.37934028	16.43	0.0001
SEX	1	0.26584201	0.91	0.3495
NUMBER	3	7.01106771	8.01	0.0007
TCOND*SEX	8	2.40017361	1.03	0.4428
TCOND*NUMBER	24	9.06510417	1.29	0.2664
SEX*NUMBER	3	14.27322049	16.30	0.0001

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MESTTM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	47	2171.58528646	46.20394227
ERROR	24	355.81032986	14.82543041
CORRECTED TOTAL	71	2527.39561632	

MODEL F = 3.12 PR > F = 0.0019

R-SQUARE	C.V.	STD DEV	MESTTM MEAN
0.859219	5.0796	3.85038055	75.80034722

SOURCE	DF	ANOVA SS	F VALUE	PR > F
TCOND	8	976.11241319	8.23	0.0001
SEX	1	334.21896701	22.54	0.0001
NUMBER	3	48.52842882	1.09	0.3719
TCOND*SEX	8	51.92751736	0.44	0.8864
TCOND*NUMBER	24	318.24696181	0.89	0.6066
SEX*NUMBER	3	442.55099826	9.95	0.0002

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN CF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWC HOUR FAN CCNDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MSTCV

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MCDEL	47	4592.61480035	97.7152C852
ERRCR	24	1125.87977431	46.91165726
CORRECTED TOTAL	71	5718.49457465	

MODEL F =	2.08		PR > F = 0.0275
R-SQUARE	C.V.	STD DEV	MSTCV MEAN
0.803116	18.1628	6.84920851	37.71CC6944

SCURCE	DF	ANOVA SS	F VALUE	PR > F
TCCND	8	2948.78949653	7.86	0.0001
SEX	1	20.72070313	0.44	0.5126
NUMBER	3	308.15863715	2.19	0.1154
TCCND*SEX	8	102.23828125	C.27	C.9689
TCOND*NUMBER	24	672.74175347	0.60	0.8928
SEX*NUMBER	3	539.96592882	3.84	0.0224

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MLAPC_R

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	47	8180.03495236	174.04329686
ERROR	24	2197.36355864	91.55681494
CORRECTED TOTAL	71	10377.39851100	

MODEL F = 1.90 PR > F = 0.0458

R-SQUARE	C.V.	STD DEV	MLAPC_R MEAN
0.788255	17.8395	9.56853254	53.63673561

SOURCE	DF	ANOVA SS	F VALUE	PR > F
TCOND	8	4267.02406944	5.83	0.0004
SEX	1	30.27220771	0.33	0.5706
NUMBER	3	1263.48527824	4.60	0.0111
TCOND*SEX	8	260.26962651	0.36	0.9338
TCOND*NUMBER	24	1476.38671007	0.67	0.8317
SEX*NUMBER	3	882.59706040	3.21	0.0408

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PREDETERMINED TWC HCUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MLAPC_A

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MCDEL	47	14471.12323135	307.89623896
ERROR	24	3573.95490358	148.91478765
CORRECTED TOTAL	71	18045.07813493	

MODEL F = 2.07 PR > F = 0.0287

R-SQUARE	C.V.	STD DEV	MLAPC_A MEAN
0.801943	22.3225	12.20306468	54.66701879

SCURCE	DF	ANOVA SS	F VALUE	PR > F
TCCND	8	9102.32155409	7.64	0.0001
SEX	1	72.44392346	0.49	0.4922
NUMBER	3	1077.96220806	2.41	0.0915
TCCND*SEX	8	335.07675837	0.28	0.9658
TCOND*NUMBER	24	2153.78338002	0.60	0.8890
SEX*NUMBER	3	1729.53540735	3.87	0.0217

TEST CF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE PRECETERMINED TWO HOUR FAN CONDITION, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MLAPC_B

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	47	13220.01374227	281.27688813
ERROR	24	3218.22544727	134.09272697
CORRECTED TOTAL	71	16438.23918954	

MODEL F =	2.10		PR > F = 0.0264
R-SQUARE	C.V.	STD DEV	MLAPC_B MEAN
0.804223	27.9498	11.57984141	41.43085194

SOURCE	DF	ANOVA SS	F VALUE	PR > F
TCOND	8	7846.40879138	7.31	0.0001
SEX	1	135.75483483	1.01	0.3244
NUMBER	3	1160.35941059	2.88	0.0566
TCOND*SEX	8	343.65745808	0.32	0.9503
TCOND*NUMBER	24	1936.49515474	0.60	0.8897
SEX*NUMBER	3	1797.33809264	4.47	0.0125

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE FINAL FAN CONDITION SELECTED BY THE SUBJECT, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
TCOND	9	F78_FAR F78_OFF F78NEAR F82_FAR F82_OFF F82NEAR F86_FAR F86_OFF F86NEAR
SEX	2	F M
NUMBER	4	1 2 3 4

NUMBER OF OBSERVATIONS IN DATA SET = 72

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE FINAL FAN CONDITION SELECTED BY THE SUBJECT, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MTHERML

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	47	27.84375000	0.59242021
ERROR	24	6.40277778	0.26678241
CORRECTED TOTAL	71	34.24652778	

MODEL F =	2.22		PR > F = 0.0188
R-SQUARE	C.V.	STD DEV	MTHERML MEAN
0.813039	10.0919	0.51650983	5.11805556

SOURCE	DF	ANOVA SS	F VALUE	PR > F
TCOND	8	3.40277778	1.59	0.1789
SEX	1	4.75347222	17.82	0.0003
NUMBER	3	1.76041667	2.20	0.1142
TCOND*SEX	8	2.15277778	1.01	0.4555
TCOND*NUMBER	24	8.70833333	1.36	0.2284
SEX*NUMBER	3	7.06597222	8.83	0.0004

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE FINAL FAN CONDITION SELECTED BY THE SUBJECT, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MPREFTM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	47	20.09375000	0.42752660
ERROR	24	7.12500000	0.29687500
CORRECTED TOTAL	71	27.21875000	

MODEL F =	1.44		PR > F = 0.1686
R-SQUARE	C.V.	STD DEV	MPREFTM MEAN
0.738232	10.1764	0.54486237	5.35416667

SOURCE	DF	ANOVA SS	F VALUE	PR > F
TCOND	8	5.62500000	2.37	0.0489
SEX	1	0.03125000	0.11	0.7484
NUMBER	3	2.39930556	2.69	0.0686
TCOND*SEX	8	0.37500000	0.16	0.9945
TCOND*NUMBER	24	6.81944444	0.96	0.5423
SEX*NUMBER	3	4.84375000	5.44	0.0054

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE FINAL FAN CONDITION SELECTED BY THE SUBJECT, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MESTTM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	47	1286.59375000	27.37433511
ERROR	24	233.62500000	9.73437500
CORRECTED TOTAL	71	1520.21875000	

MODEL F =	2.81		PR > F = 0.0039
R-SQUARE	C.V.	STD DEV	MESTTM MEAN
0.846321	4.2150	3.11999599	74.02083333

SOURCE	DF	ANOVA SS	F VALUE	PR > F
TCOND	8	199.87500000	2.57	0.0353
SEX	1	229.33680556	23.56	0.0001
NUMBER	3	55.76041667	1.91	0.1550
TCOND*SEX	8	86.81944444	1.11	0.3883
TCOND*NUMBER	24	273.45833333	1.17	0.3514
SEX*NUMBER	3	441.34375000	15.11	0.0001

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE FINAL FAN CONDITION SELECTED BY THE SUBJECT, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MSTCV

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	47	2435.37500000	51.81648936
ERROR	24	699.90277778	29.16261574
CORRECTED TOTAL	71	3135.27777778	

MODEL F = 1.78 PR > F = 0.0652

R-SQUARE	C.V.	STD DEV	MSTCV MEAN
0.776765	12.3985	5.40024219	43.55555556

SOURCE	DF	ANOVA SS	F VALUE	PR > F
TCOND	8	301.27777778	1.29	0.2942
SEX	1	224.01388889	7.68	0.0106
NUMBER	3	375.36111111	4.29	0.0147
TCOND*SEX	8	147.23611111	0.63	0.7438
TCOND*NUMBER	24	748.13888889	1.07	0.4358
SEX*NUMBER	3	639.34722222	7.31	0.0012

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE FINAL FAN CONDITION SELECTED BY THE SUBJECT, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MLAPC_R

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	47	5426.32220705	115.45366398
ERROR	24	1544.86951091	64.36956295
CORRECTED TOTAL	71	6971.19171795	

MODEL F = 1.79 PR > F = 0.0621

R-SQUARE	C.V.	STD DEV	MLAPC_R MEAN
0.778392	13.0584	8.02306444	61.43992360

SOURCE	DF	ANOVA SS	F VALUE	PR > F
TCOND	8	770.15141387	1.50	0.2108
SEX	1	589.16927959	9.15	0.0059
NUMBER	3	1170.58996098	6.06	0.0032
TCOND*SEX	8	299.54188497	0.58	0.7828
TCOND*NUMBER	24	1394.72458591	0.90	0.5979
SEX*NUMBER	3	1202.14508173	6.23	0.0028

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE FINAL FAN CONDITION SELECTED BY THE SUBJECT, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MLAPC_A

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	47	7920.30808023	168.51719320
ERROR	24	2248.41102982	93.68379291
CORRECTED TOTAL	71	10168.71911005	

MODEL F = 1.80 PR > F = 0.0612

R-SQUARE	C.V.	STD DEV	MLAPC_A MEAN
0.778889	14.8884	9.67903884	65.01045316

SOURCE	DF	ANOVA SS	F VALUE	PR > F
TCOND	8	985.43623723	1.31	0.2833
SEX	1	760.89172249	8.12	0.0088
NUMBER	3	1247.64795959	4.44	0.0128
TCOND*SEX	8	467.35840523	0.62	0.7498
TCOND*NUMBER	24	2377.69052046	1.06	0.4461
SEX*NUMBER	3	2081.28323523	7.41	0.0011

TEST OF THE NULL HYPOTHESIS THAT THE DAILY MEAN OF THE DEPENDENT VARIABLE SHOWN VARIES WITH NEITHER THE CHAMBER TEMPERATURE, THE FINAL FAN CONDITION SELECTED BY THE SUBJECT, THE SEX OF THE SUBJECT, NOR WITH THE GROUP NUMBER

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: MLAPC_B

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	47	8084.27808616	172.00591673
ERROR	24	2072.21023668	86.34209319
CORRECTED TOTAL	71	10156.48832284	

MODEL F = 1.99 PR > F = 0.0354

R-SQUARE	C.V.	STD DEV	MLAPC_B MEAN
0.795972	18.2789	9.29204462	50.83486354

SOURCE	DF	ANOVA SS	F VALUE	PR > F
TCOND	8	942.05932846	1.36	0.2617
SEX	1	888.05810934	10.29	0.0038
NUMBER	3	1310.34550988	5.06	0.0074
TCOND*SEX	8	418.84533406	0.61	0.7635
TCOND*NUMBER	24	2258.63998076	1.09	0.4173
SEX*NUMBER	3	2266.32982365	8.75	0.0004

APPENDIX Q

Values for PPC and for PPD

Values for Predicted Percent Comfortable and for Predicted Percent Dissatisfied taken at quarter hour intervals by temperature - fan velocity (≤0.35 m/s represents "still air", 0.8 m/s represents 3.0 m distance, 1.3 m/s represents 1.5 m distance)

Time in Chamber (hrs)	DBT (C)	PPC for Velocity (m/s)			PPD for Velocity (m/s)		
		≤0.35	0.8	1.3	≤0.35	0.8	1.3
0.75	25.6	37.5	75.0	100	12.5	0.0	0.0
	27.8	0.0	50.0	62.5	50.0	12.5	12.5
	30.0	0.0	12.5	25.0	62.5	25.0	25.0
1.00	25.6	25.0	75.0	100	12.5	12.5	0.0
	27.8	0.0	50.0	75.0	37.5	12.5	12.5
	30.0	0.0	0.0	37.5	75.0	12.5	12.5
1.25	25.6	37.5	87.5	100	25.0	0.0	0.0
	27.8	0.0	62.5	87.5	50.0	12.5	12.5
	30.0	0.0	25.0	50.0	75.0	25.0	12.5
1.50	25.6	37.5	75.0	100	12.5	0.0	0.0
	27.8	0.0	62.5	87.5	50.0	0.0	12.5
	30.0	0.0	37.5	50.0	75.0	25.0	12.5
1.75	25.6	25.0	87.5	100	12.5	0.0	12.5
	27.8	0.0	62.5	87.5	62.5	0.0	12.5
	30.0	0.0	37.5	50.0	75.0	12.5	12.5
2.00	25.6	50.0	87.5	100	12.5	0.0	25.0
	27.8	12.5	62.5	87.5	37.5	12.5	12.5
	30.0	0.0	12.5	50.0	87.5	12.5	12.5
2.25	25.6	50.0	87.5	100	12.5	0.0	25.0
	27.8	0.0	62.5	87.5	37.5	0.0	12.5
	30.0	12.5	50.0	50.0	87.5	12.5	12.5
2.50	25.6	37.5	87.5	100	12.5	0.0	25.0
	27.8	12.5	50.0	75.0	50.0	0.0	12.5
	30.0	0.0	50.0	50.0	87.5	25.0	25.0
End Predetermined Experimental Condition; Start Subject's Choice							
2.75	25.6	75.0	100	100	0.0	0.0	0.0
	27.8	75.0	50.0	75.0	0.0	0.0	0.0
	30.0	62.5	87.5	50.0	25.0	12.5	25.0
3.00	25.6	87.5	87.5	100	0.0	0.0	0.0
	27.8	87.5	62.5	87.5	0.0	0.0	0.0
	30.0	50.0	75.0	50.0	12.5	12.5	12.5

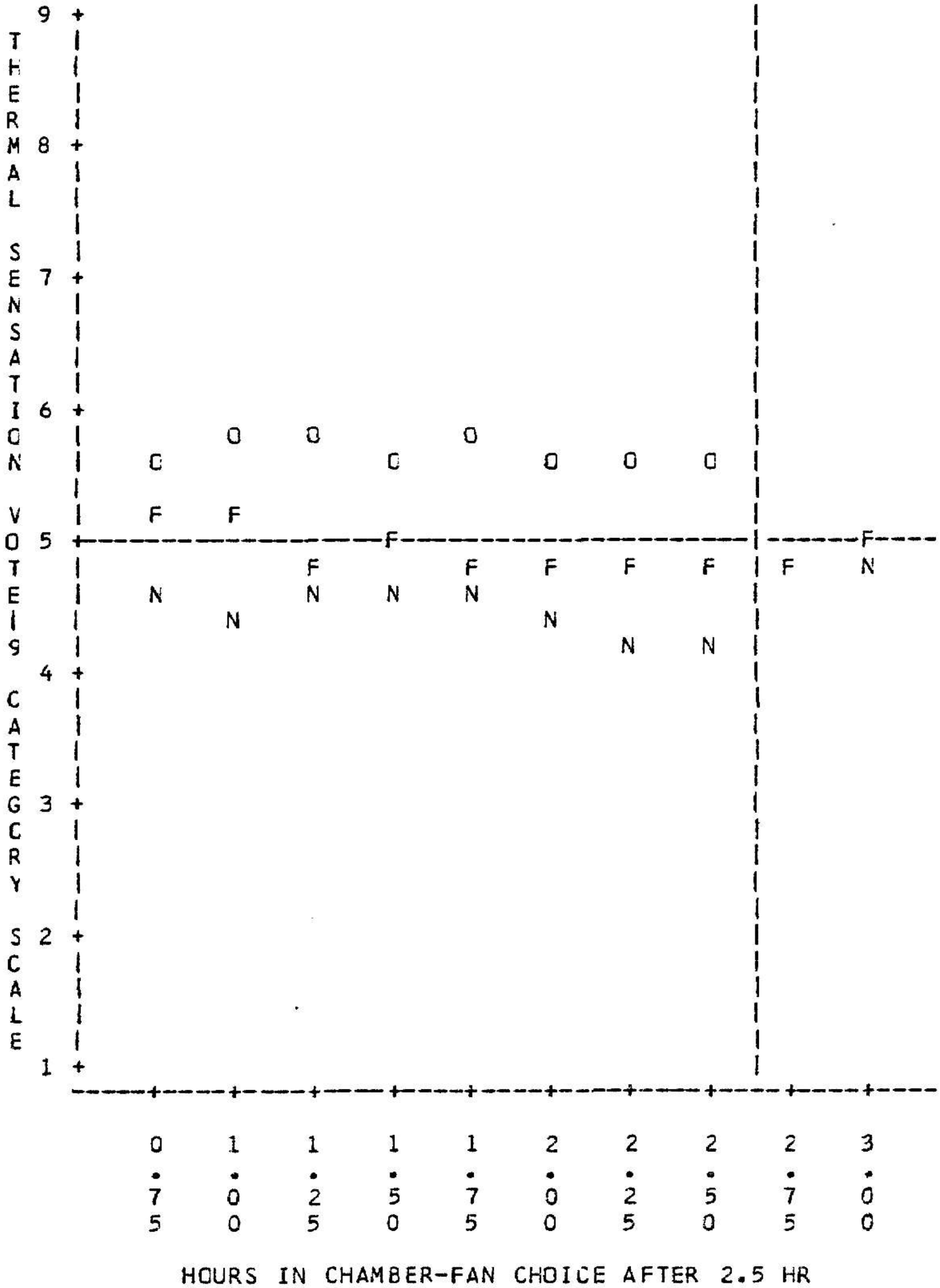
APPENDIX R

Plots of Relationship of Dependent Variables to Exposure Time

RELATICNSHIP CF DEP VAR SHOWN TO EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITICN: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=25.6

PLOT OF MTHERML*EXPINT   SYMBOL IS VALUE OF FANCOND

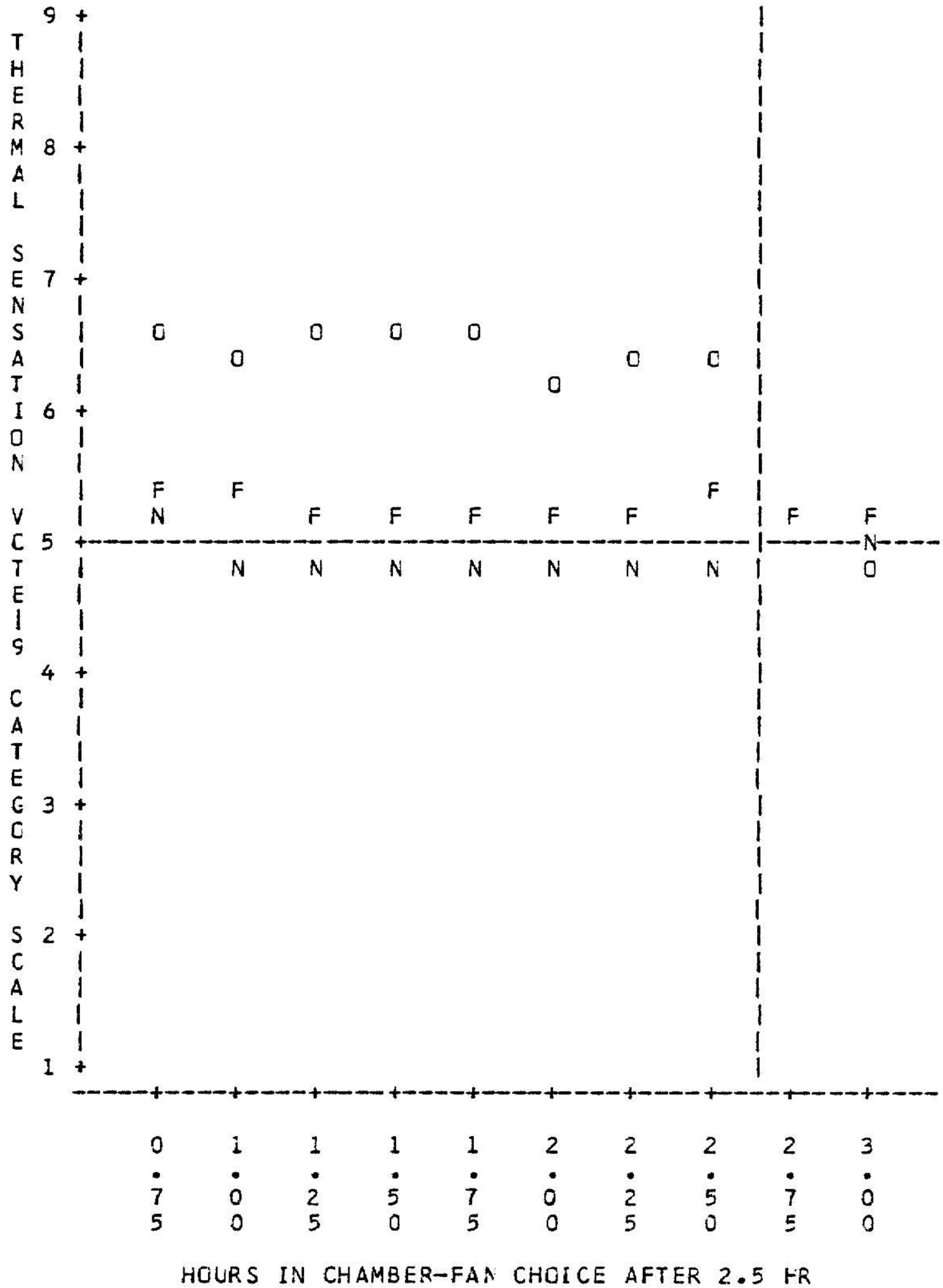


NOTE: 3 OBS HIDDEN

RELATIONSHIP OF DEP VAR SHCWN TC EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CCNDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=27.8

PLOT OF MTHERML*EXPINT   SYMBOL IS VALUE OF FANCCND

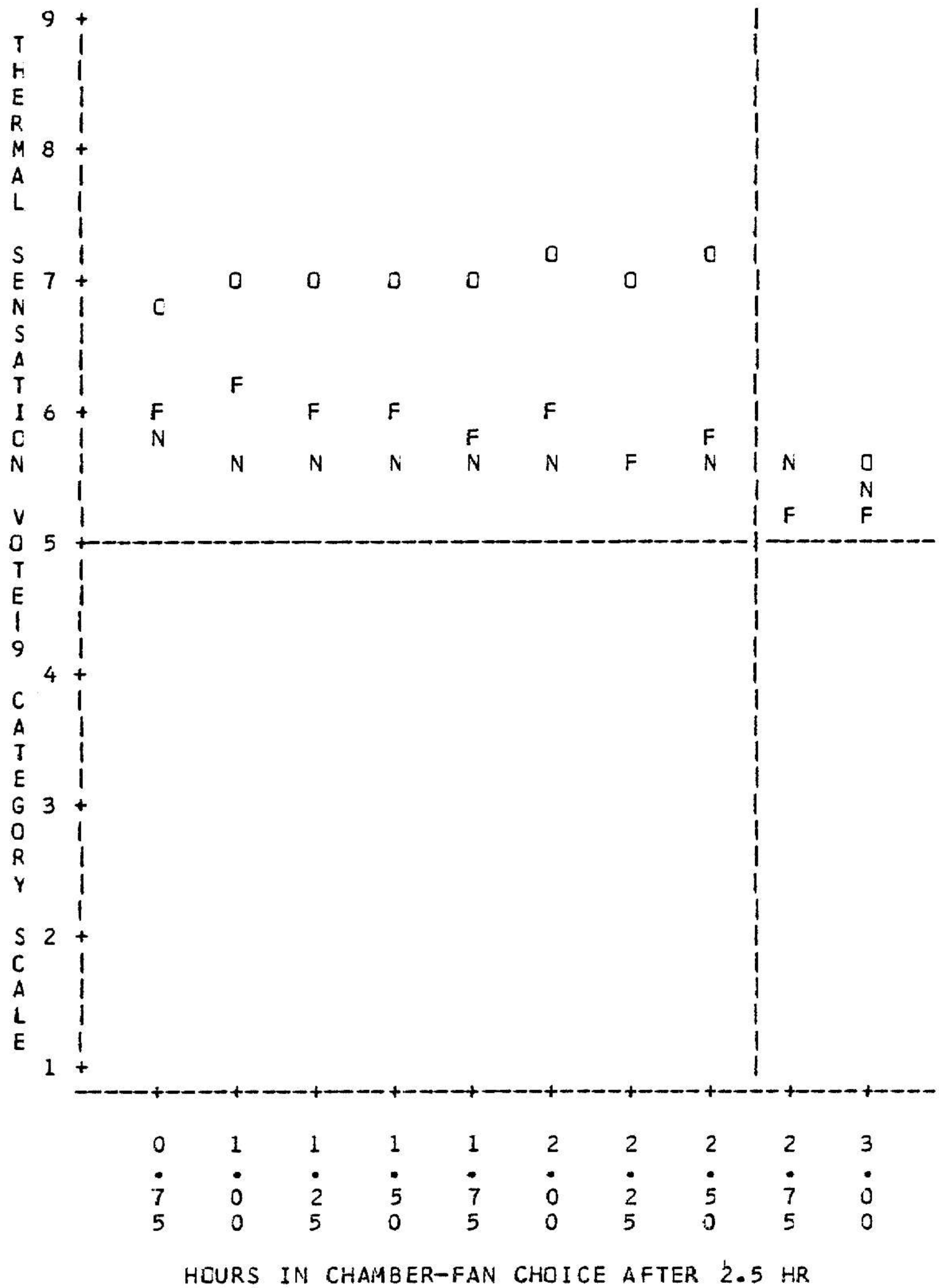


NCTE: 2 OBS HIDDEN

RELATIONSHIP OF DEP VAR SHOWN TO EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITION: O=OFF—LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=30

PLOT OF MTHERML*EXPINT SYMBOL IS VALUE OF FANCOND

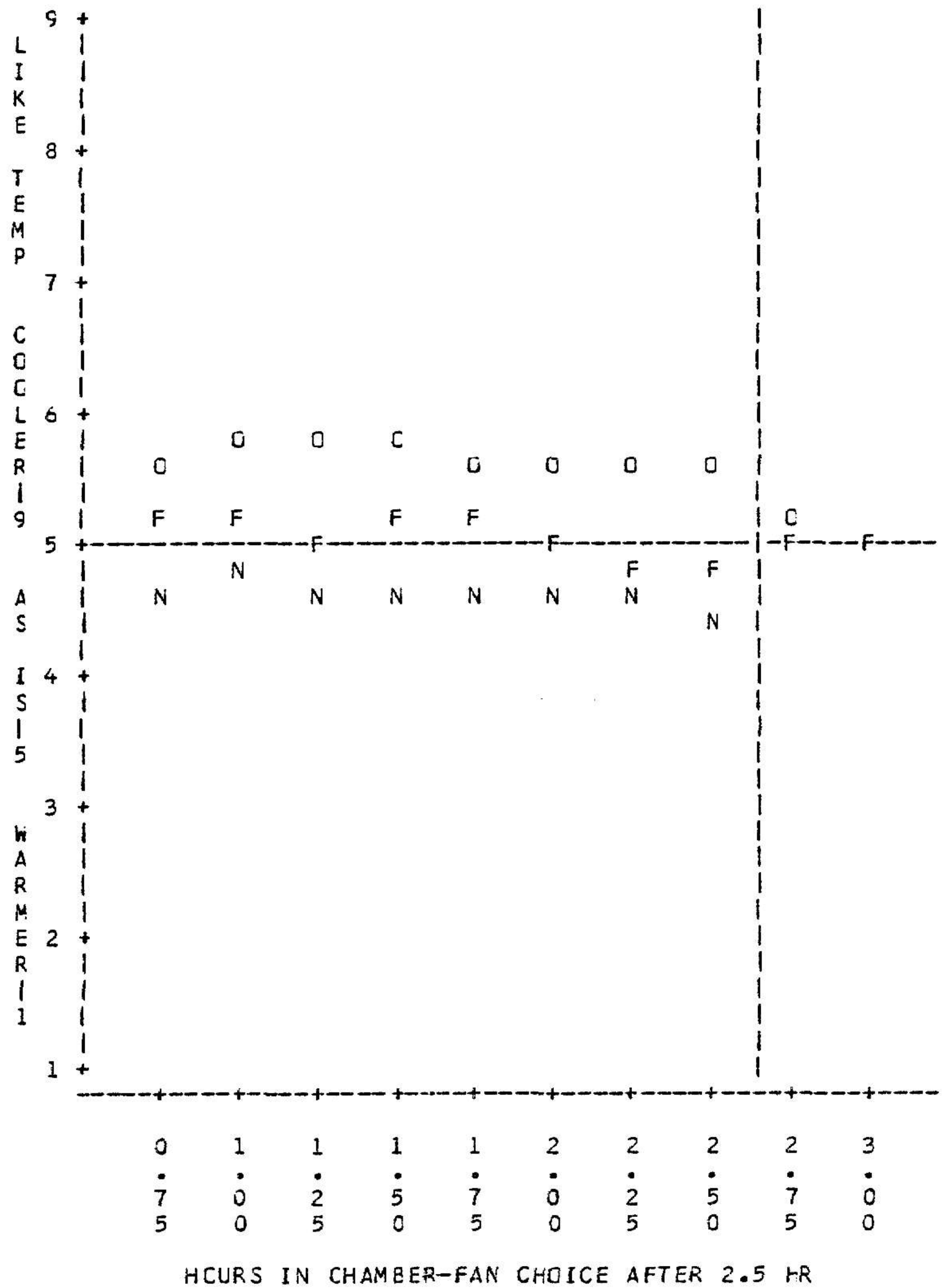


NOTE: 2 OBS HIDDEN

RELATIONSHIP OF DEP VAR SHOWN TO EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=25.6

PLOT OF MPREFTM*EXPINT   SYMBOL IS VALUE OF FANCOND

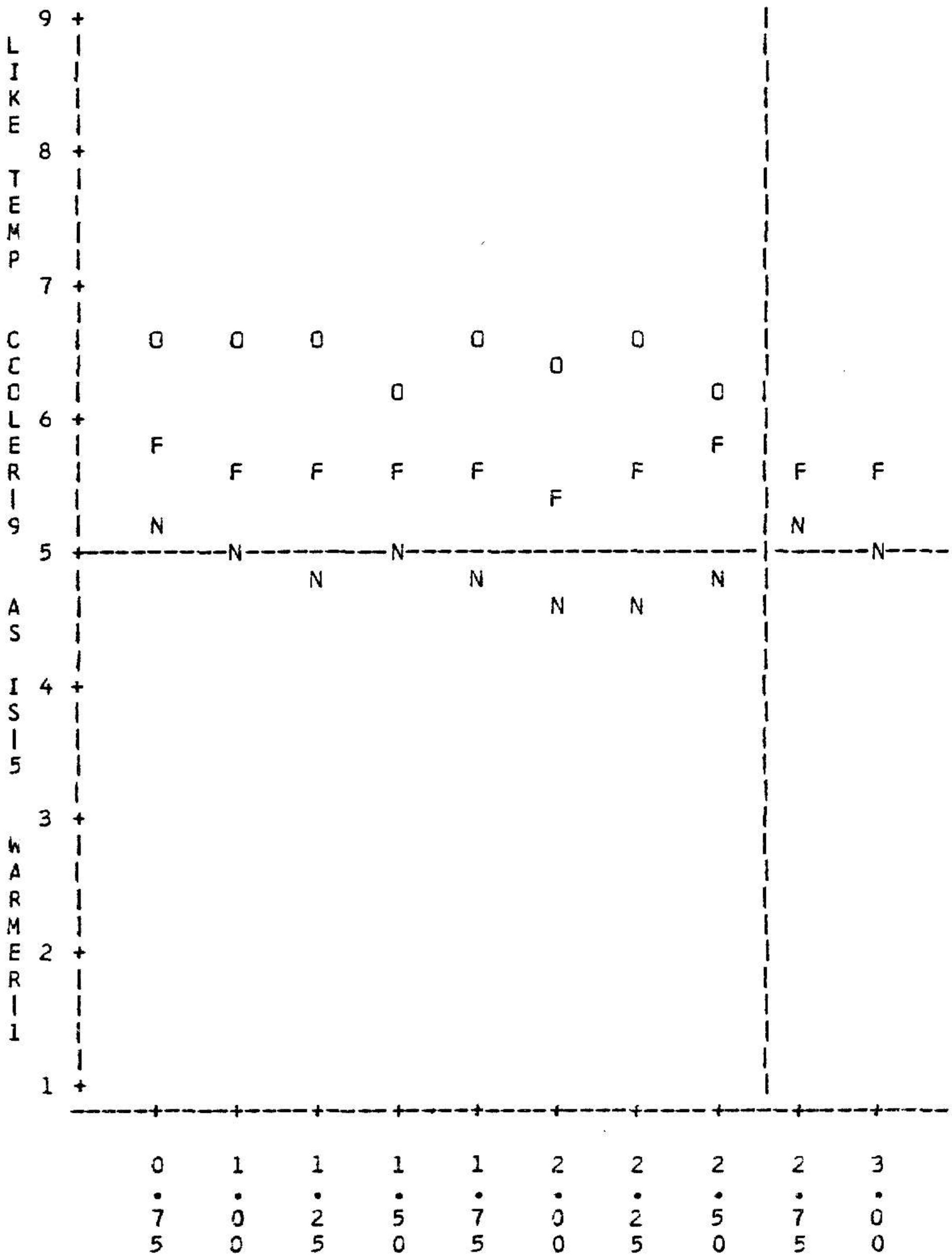


NOTE: 3 OBS HIDDEN

RELATIONSHIP OF DEP VAR SHOWN TO EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=27.8

PLOT OF MPREFTM*EXPINT SYMBOL IS VALUE OF FANCOND



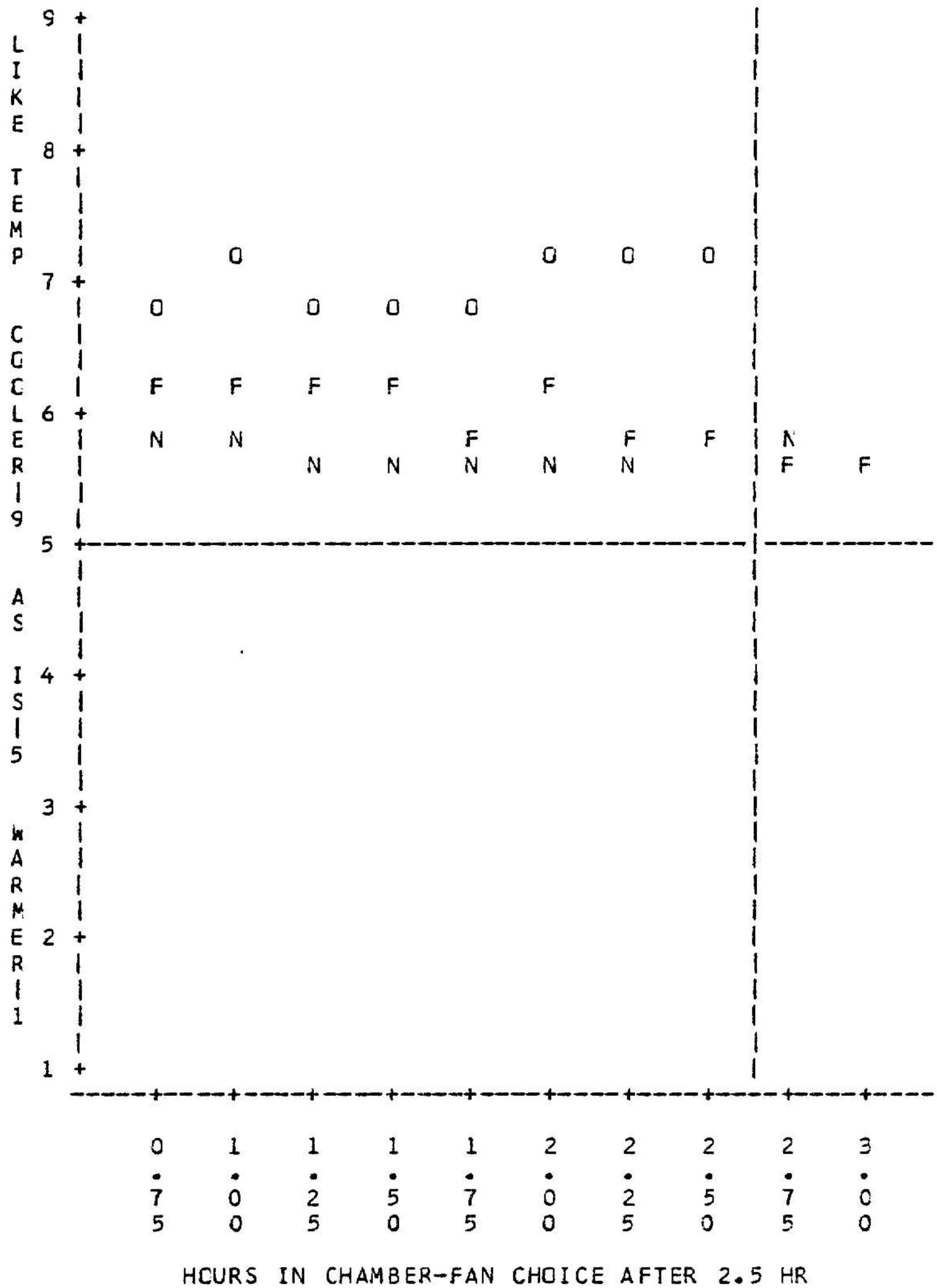
HOURS IN CHAMBER-FAN CHOICE AFTER 2.5 HR

NOTE: 2 OBS HIDDEN

RELATIONSHIP OF DEP VAR SHCWN TC EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=30

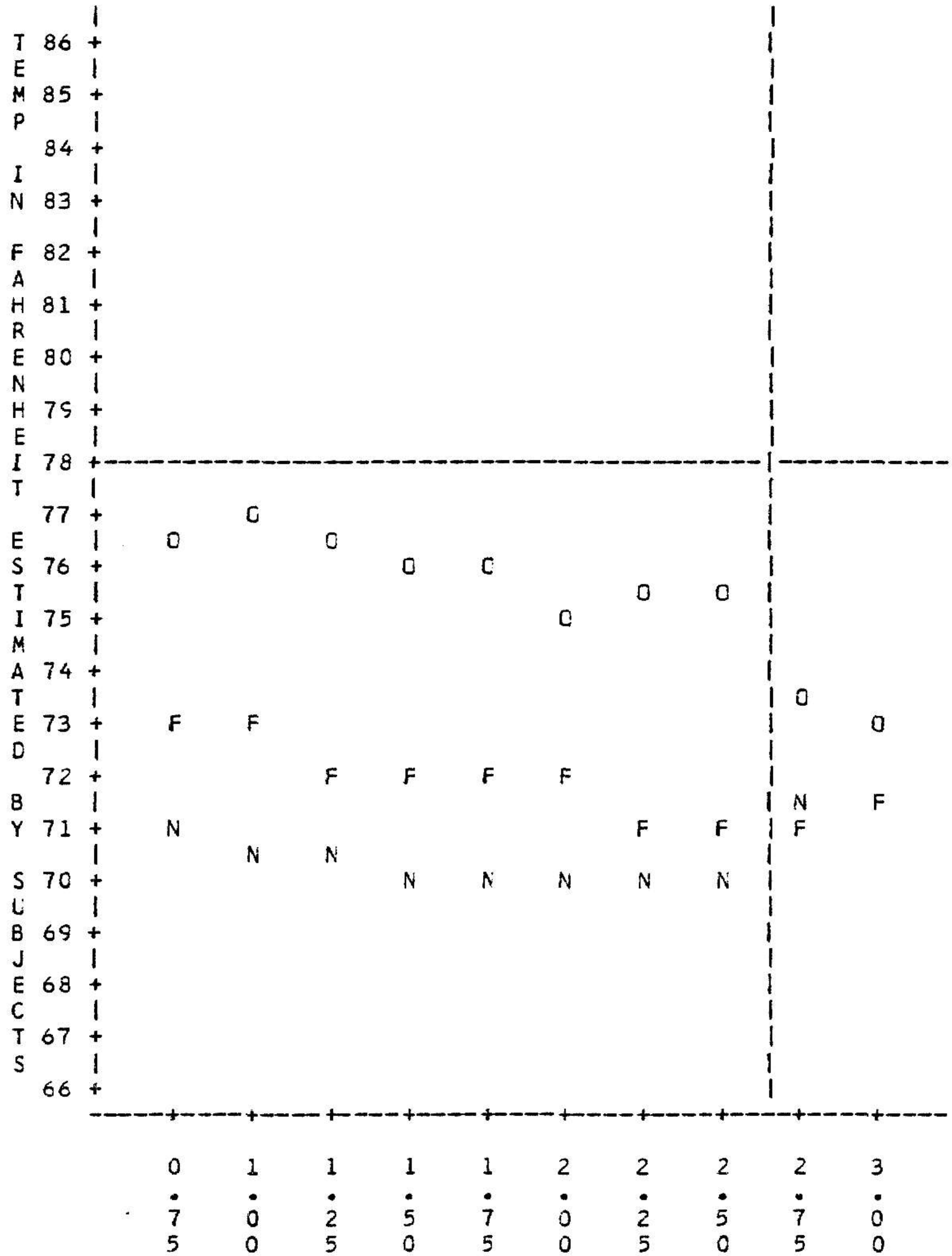
PLOT OF MPREFTM*EXPINT SYMBOL IS VALUE OF FANCOND



NCTE: 4 OBS HIDDEN

RELATICNSHIP OF DEP VAR SHOWN TO EXPCSURE TIME AT 25.6 C (78 F)
FOR EACH FAN CONDITION: O=OFF—LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

PLOT OF MESTTM*EXPINT   SYMBOL IS VALUE OF FANCOND

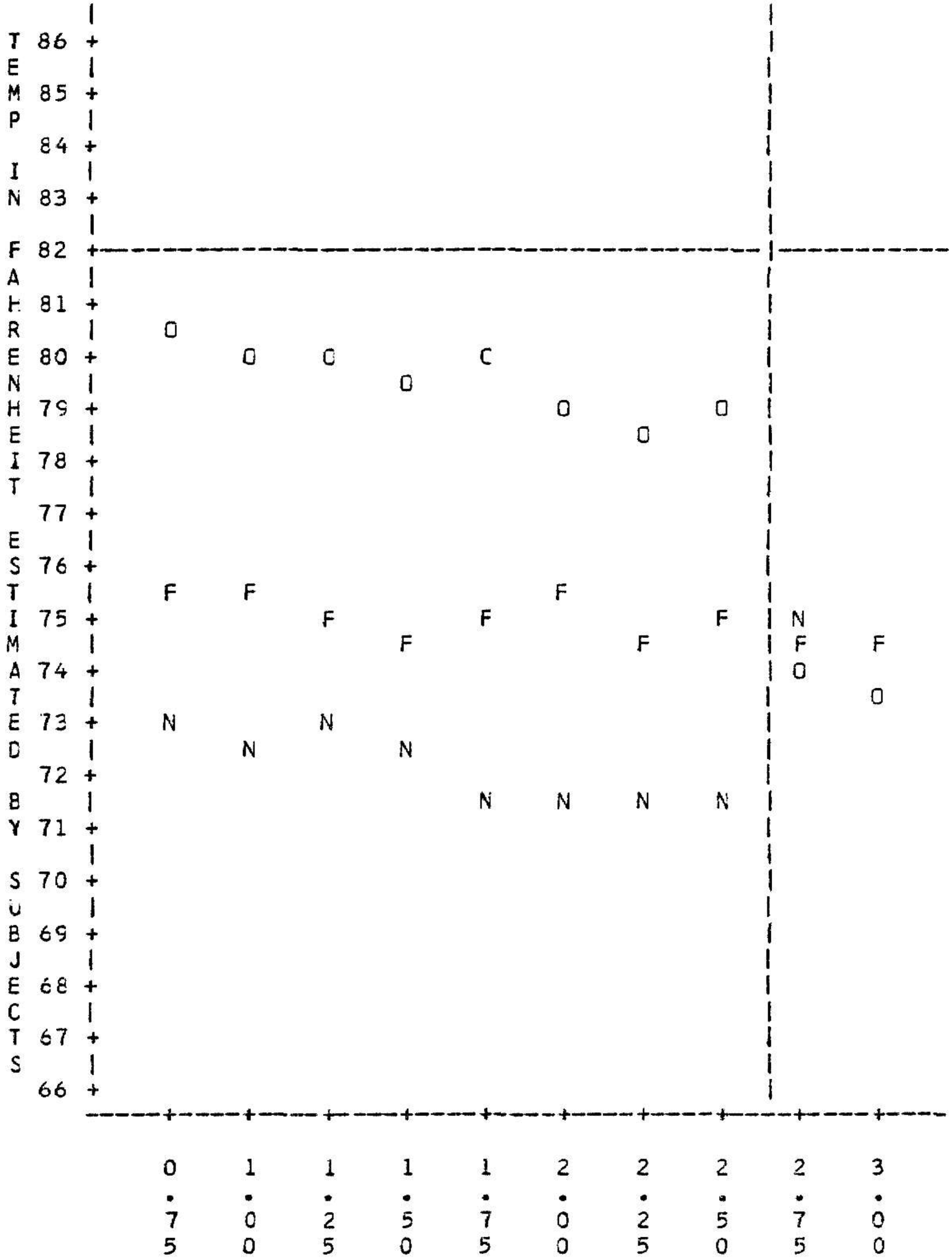


HOURS IN CHAMBER-FAN CHOICE AFTER 2.5 HR

NOTE: 1 OBS HIDDEN

RELATICNSHIP OF DEP VAR SHOWN TO EXPOSURE TIME AT 27.8 C (82 F)
FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

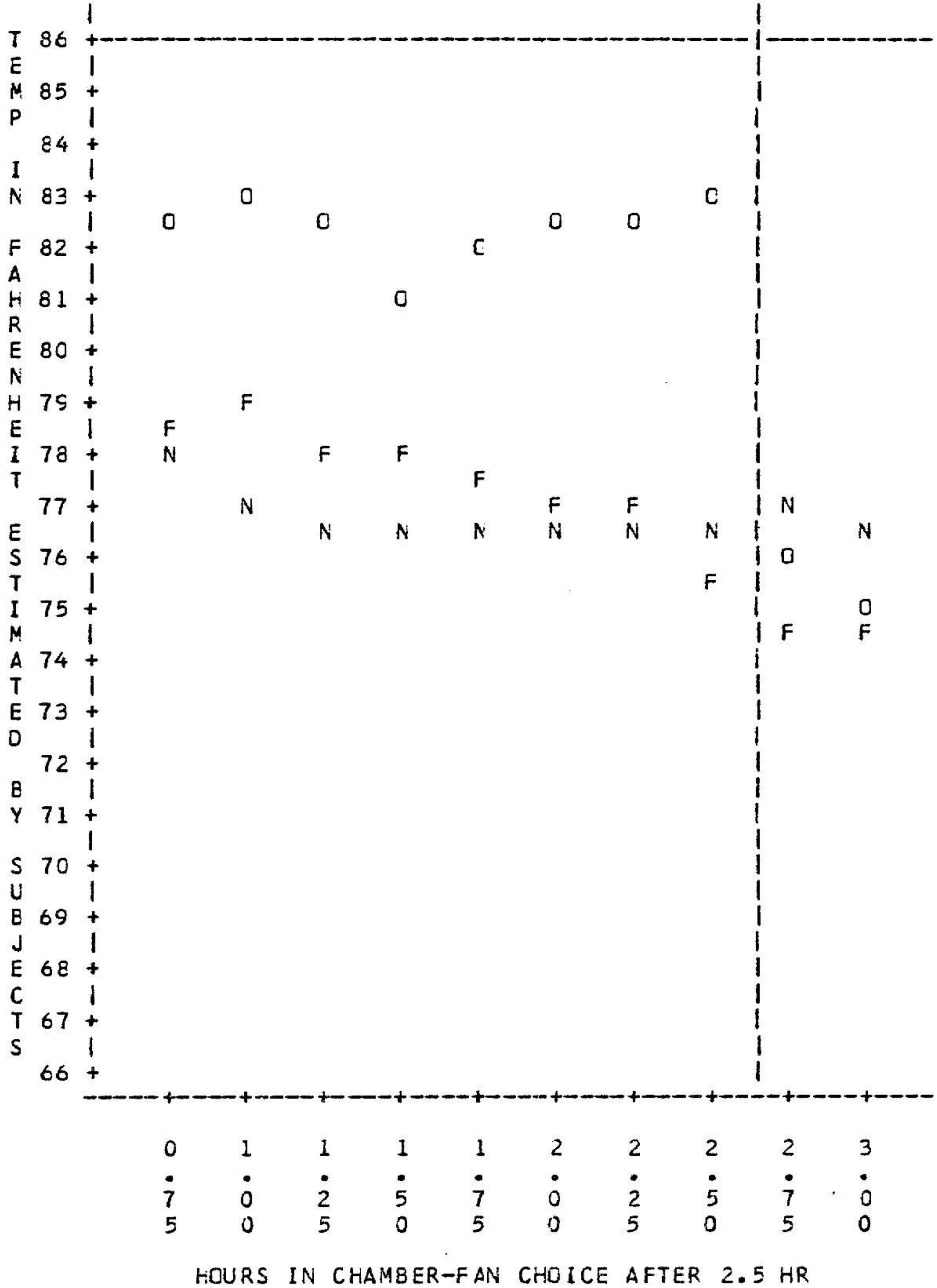
PLOT OF MESTTM*EXPINT SYMBOL IS VALUE OF FANCCND



NOTE: 1 OBS HIDDEN

RELATIONSHIP OF DEP VAR SHOWN TO EXPOSURE TIME AT 30.0 C (86 F)
FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

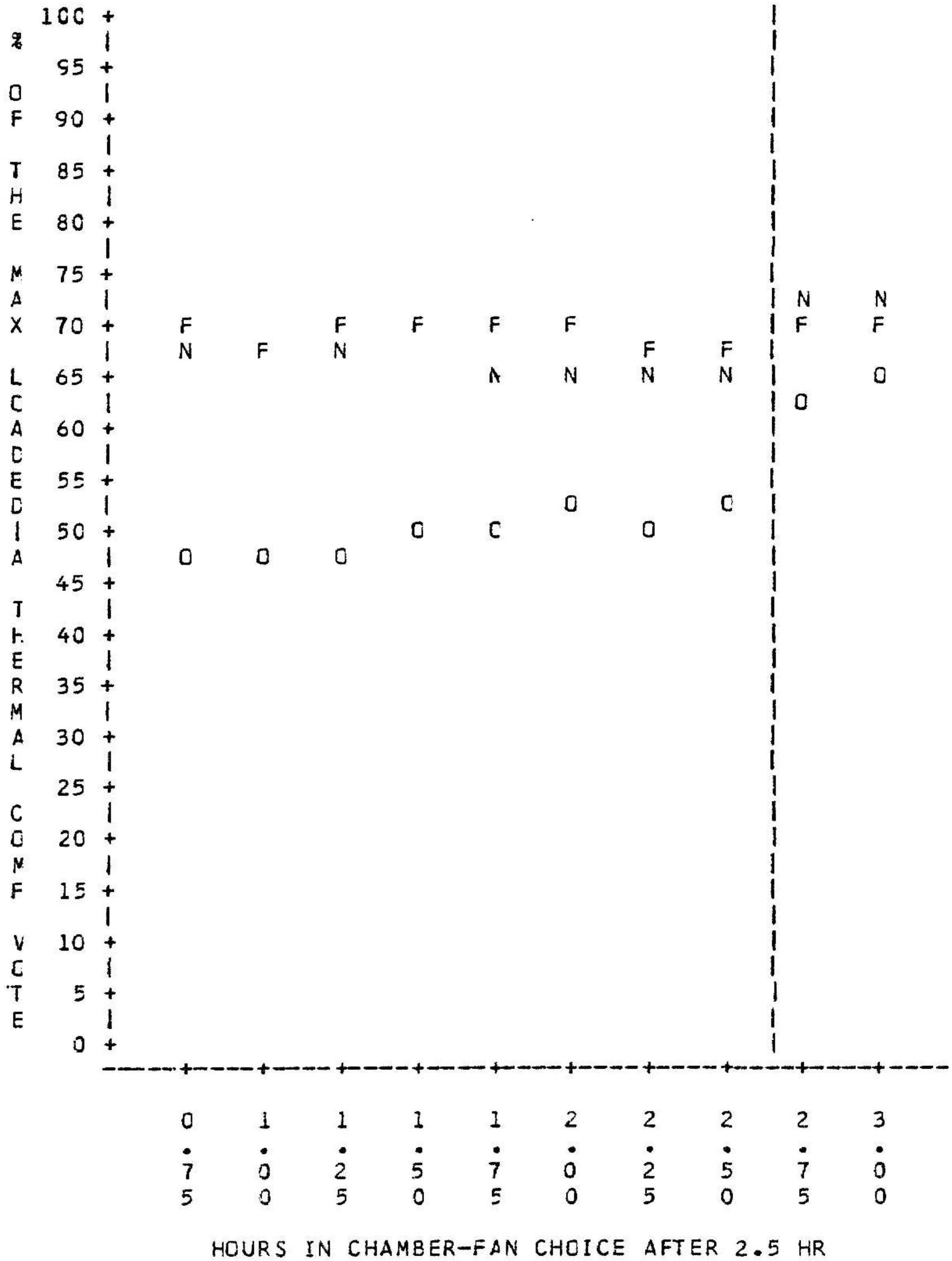
PLOT OF MESTTM*EXPINT   SYMBOL IS VALUE OF FANCOND



RELATIONSHIP OF DEP VAR SHOWN TO EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=25.6

PLOT OF MLAPC_A*EXPINT   SYMBOL IS VALUE OF FANCOND

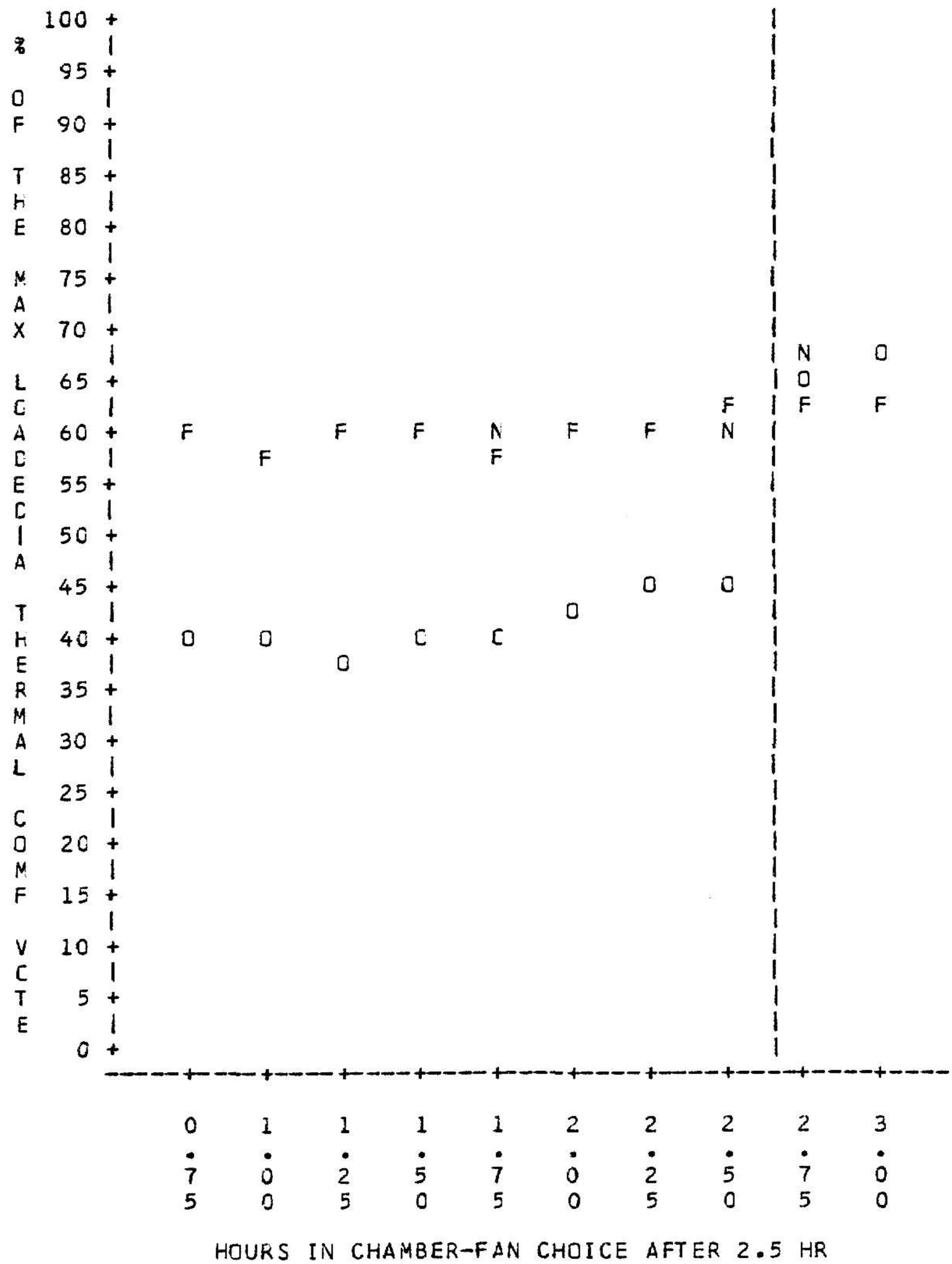


NOTE: 2 OBS HIDDEN

RELATIONSHIP OF DEP VAR SHCWN TC EXPOSURE TIME BY TEMPERATURE
FCR EACH FAN CCNDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=27.8

PLOT OF MLAPC_A*EXPINT SYMBOL IS VALUE OF FANCOND

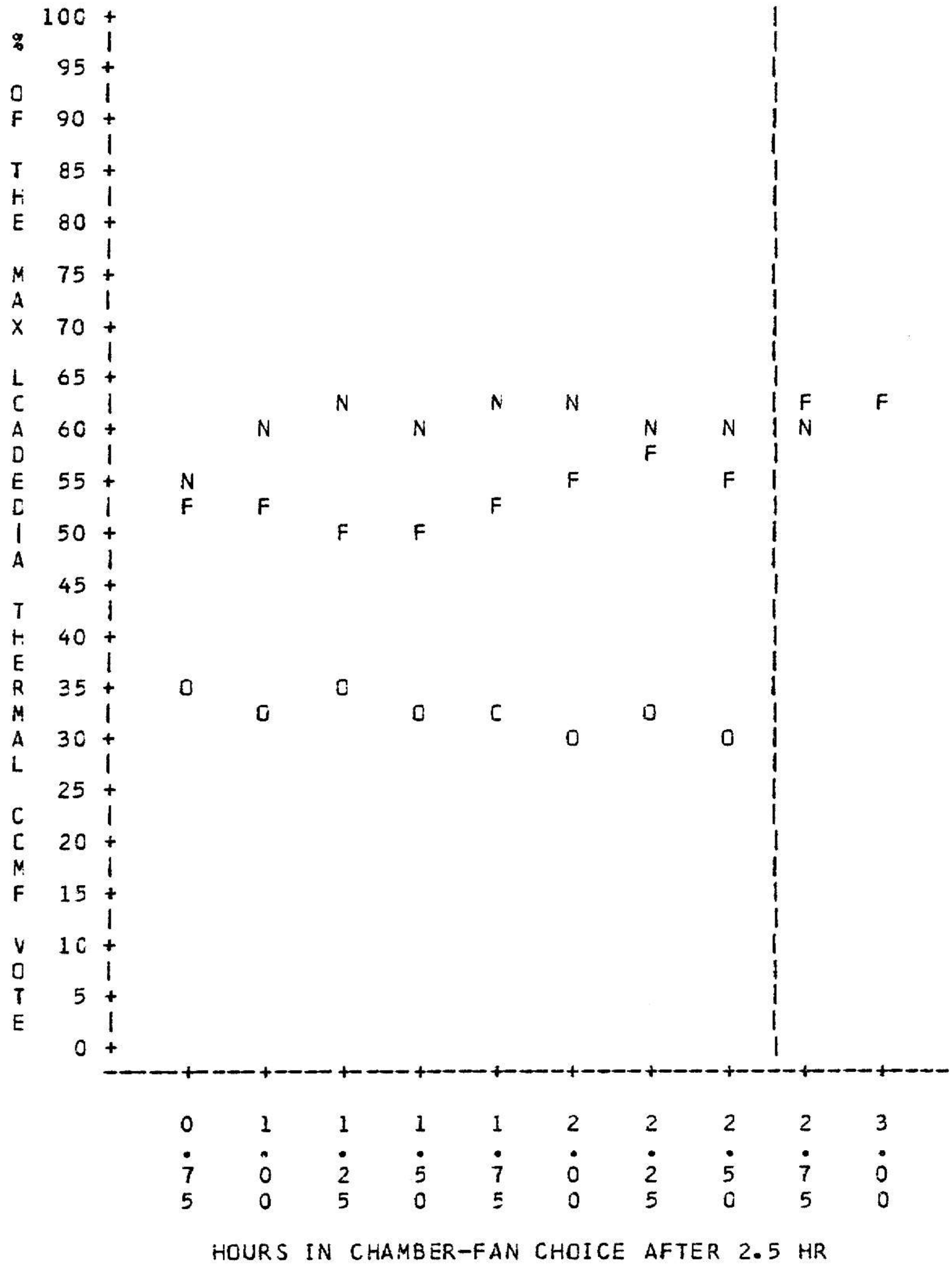


NCTE: 7 CBS HIDDEN

RELATIONSHIP OF DEP VAR SHOWN TC EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=30

PLOT OF MLAPC_A*EXPINT   SYMBOL IS VALUE OF FANCOND

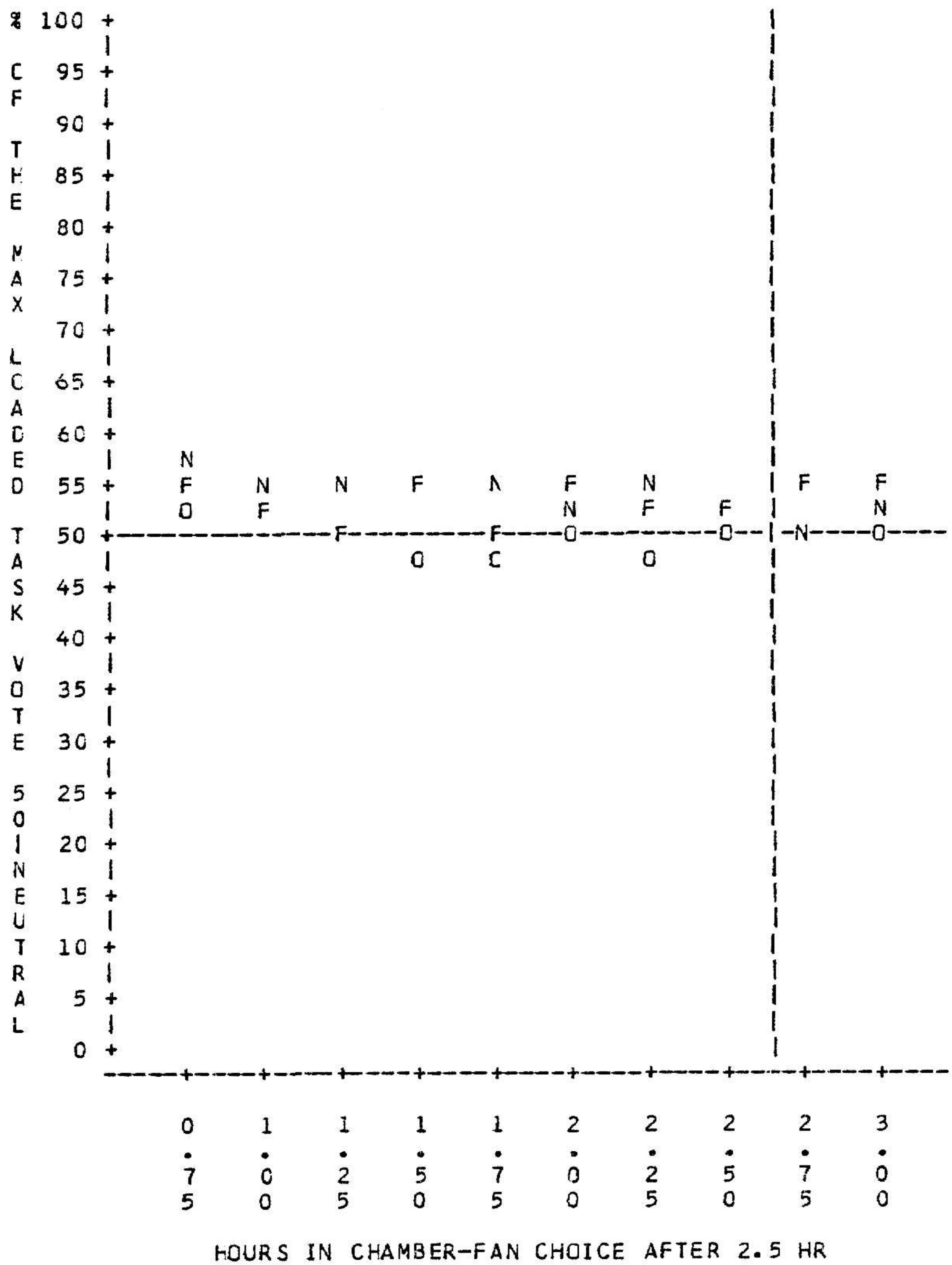


NCTE: 3 OBS HIDDEN

RELATIONSHIP OF DEP VAR SHCWN TC EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=25.6

PLOT OF MLAPTV*EXPINT   SYMBOL IS VALUE OF FANCCND

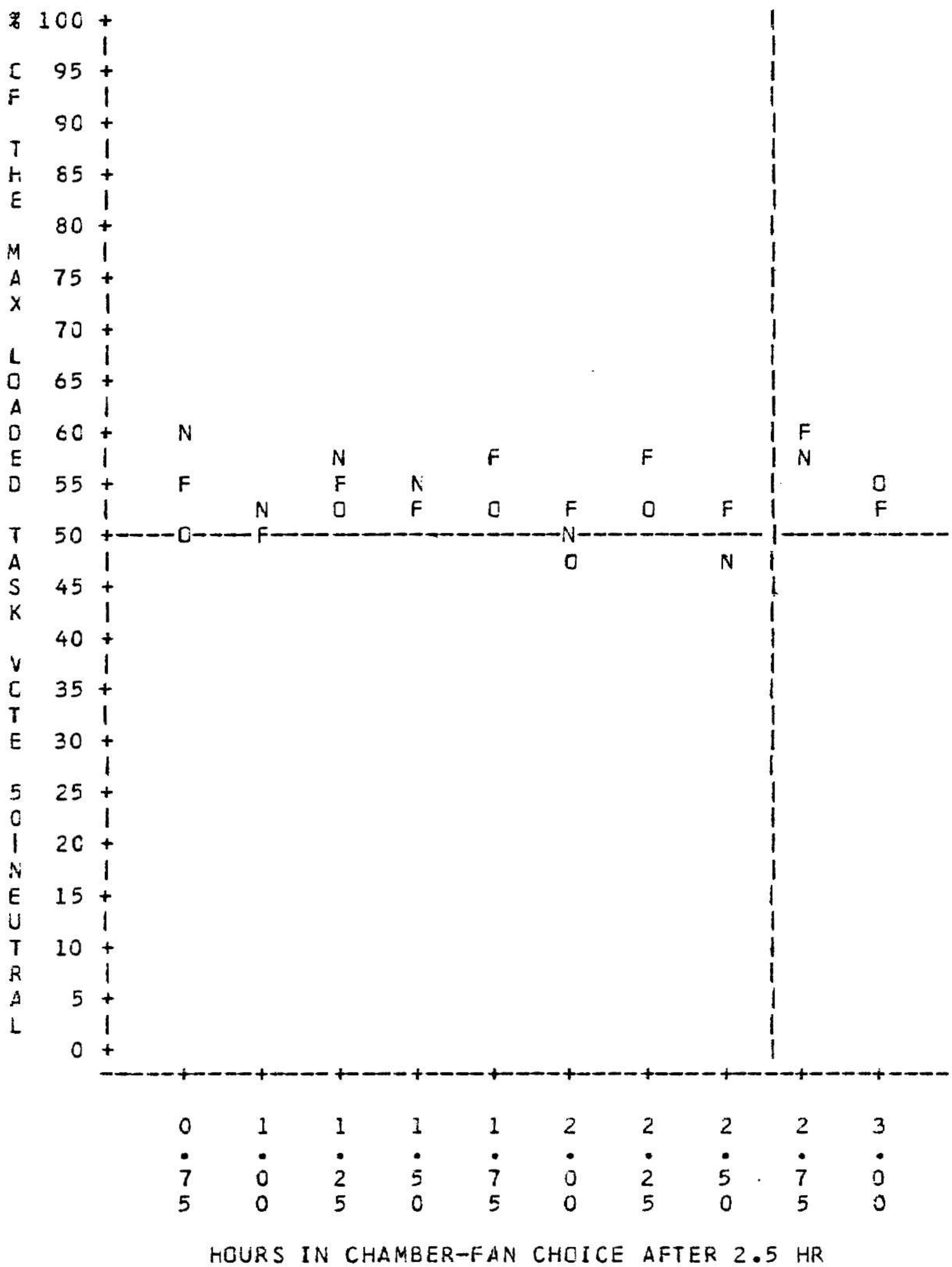


NOTE: 5 OBS HIDDEN

RELATICNSHIP CF DEP VAR SHCWN TC EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=27.8

PLOT OF MLAPTV*EXPINT SYMBOL IS VALUE OF FANCCND

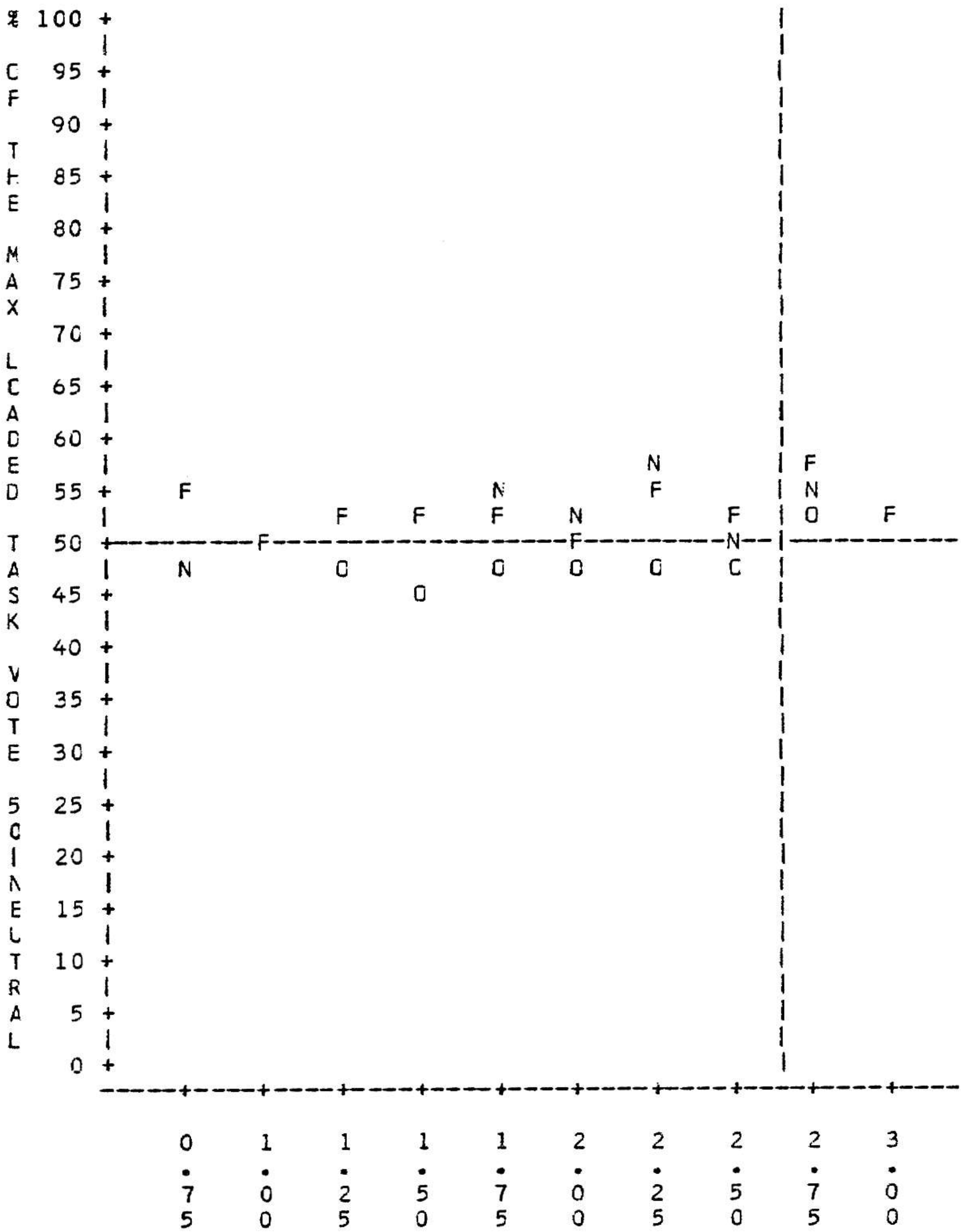


NOTE: 7 OBS HIDDEN

RELATIONSHIP OF DEP VAR SHOWN TO EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=30

PLOT OF MLAPTV*EXPINT   SYMBOL IS VALUE OF FANCOND

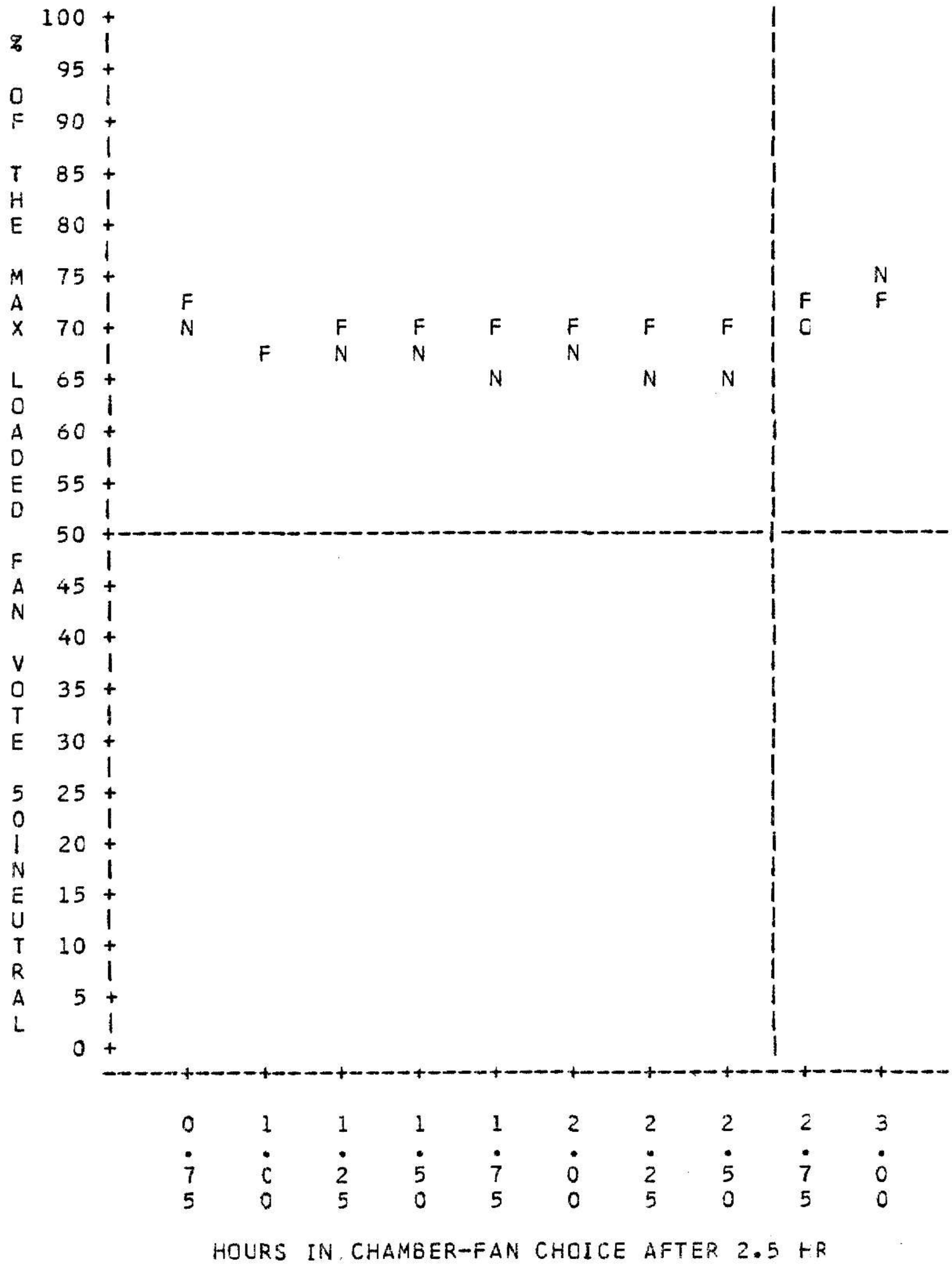


NOTE: 7 OBS HIDDEN

RELATIONSHIP OF DEP VAR SHOWN TO EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=25.6

PLOT OF MLAPFV*EXPINT   SYMBOL IS VALUE OF FANCOND

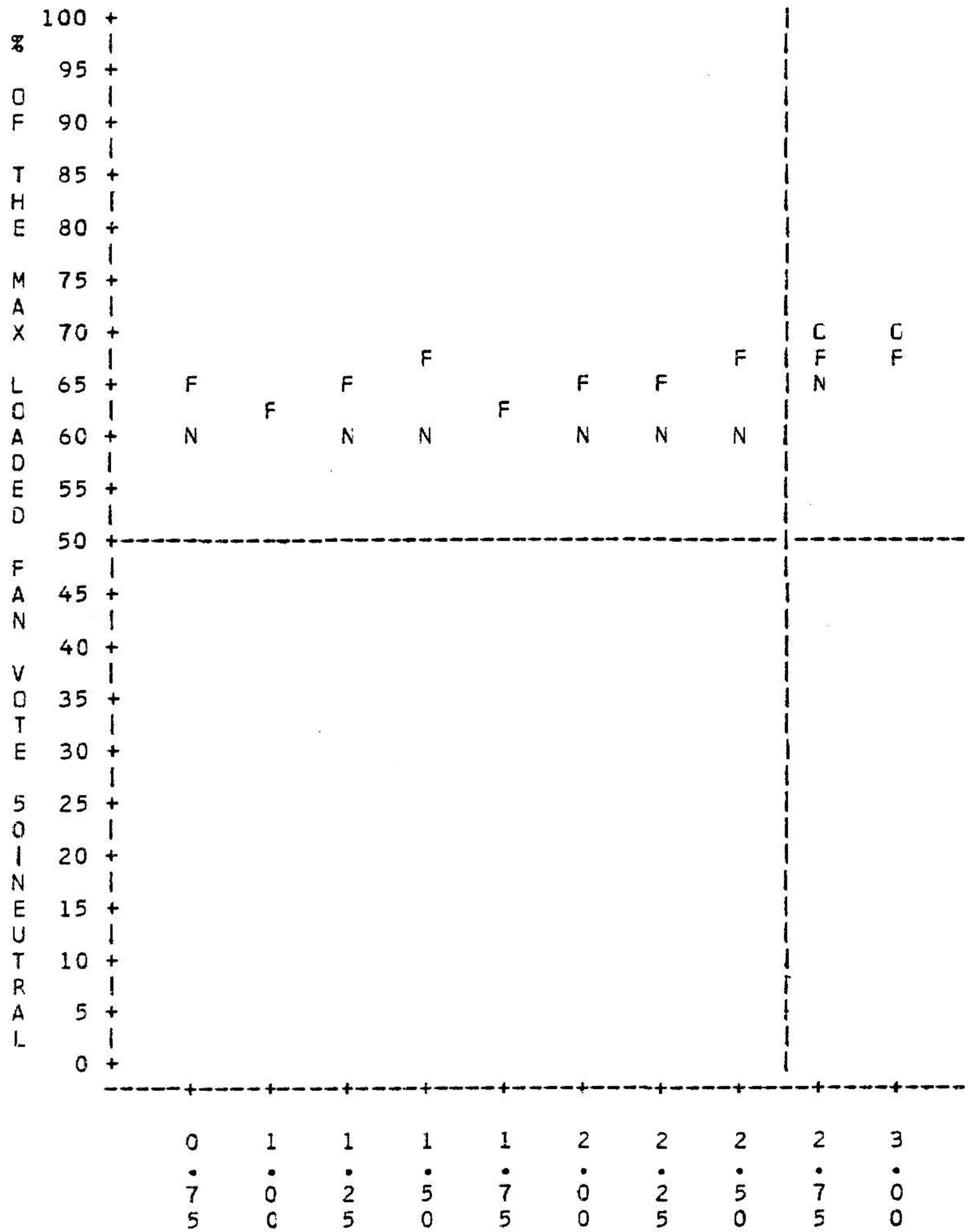


3 OBS HIDDEN

RELATIONSHIP OF DEP VAR SHOWN TO EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=27.8

PLOT OF MLAPFV*EXPINT   SYMBOL IS VALUE OF FANCOND



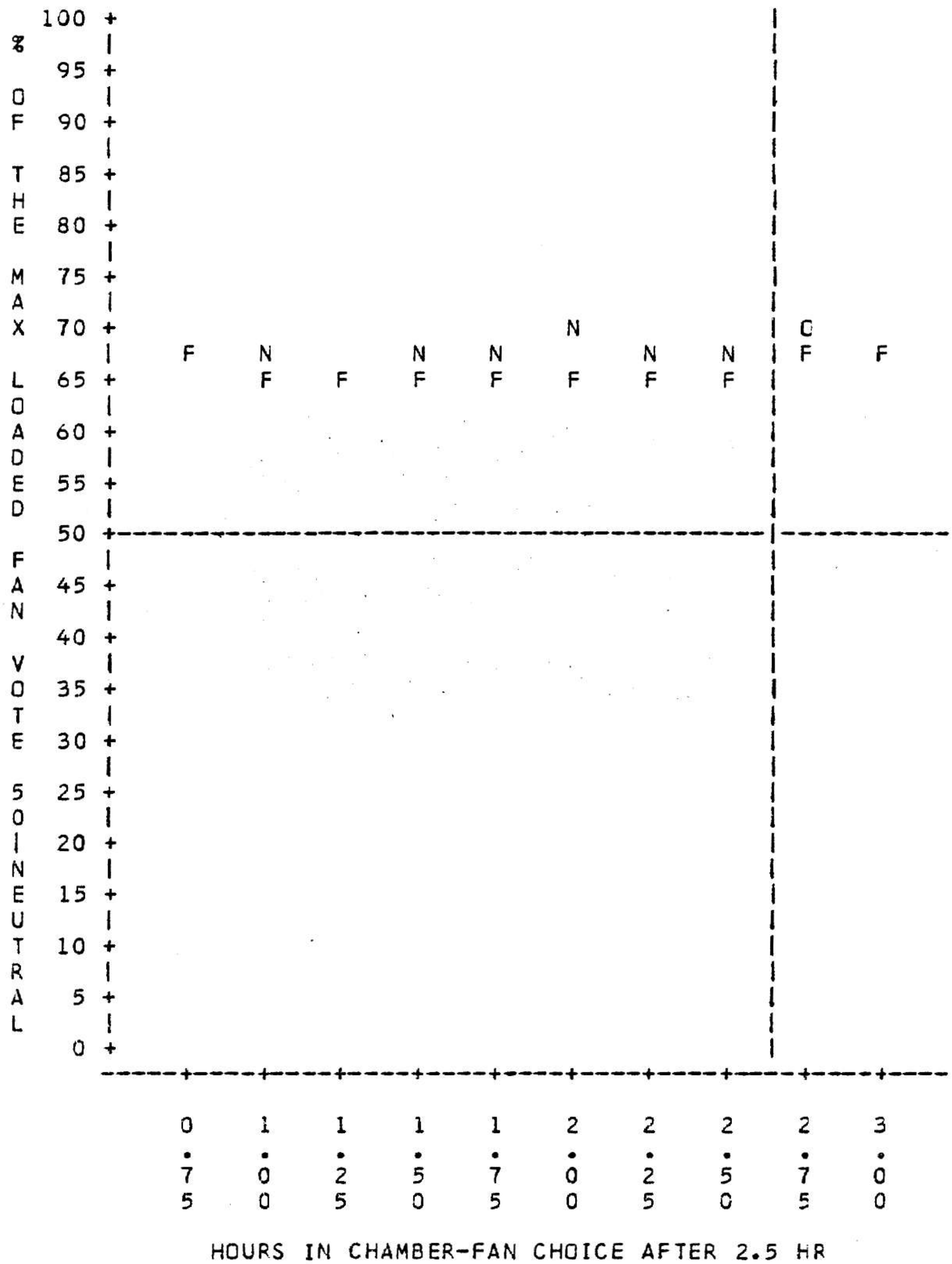
HOURS IN CHAMBER-FAN CHOICE AFTER 2.5 HR

3 OBS HIDDEN

RELATIONSHIP OF DEP VAR SHOWN TO EXPOSURE TIME BY TEMPERATURE FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S), F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=30

PLOT OF MLAPFV*EXPINT SYMBOL IS VALUE OF FANCOND

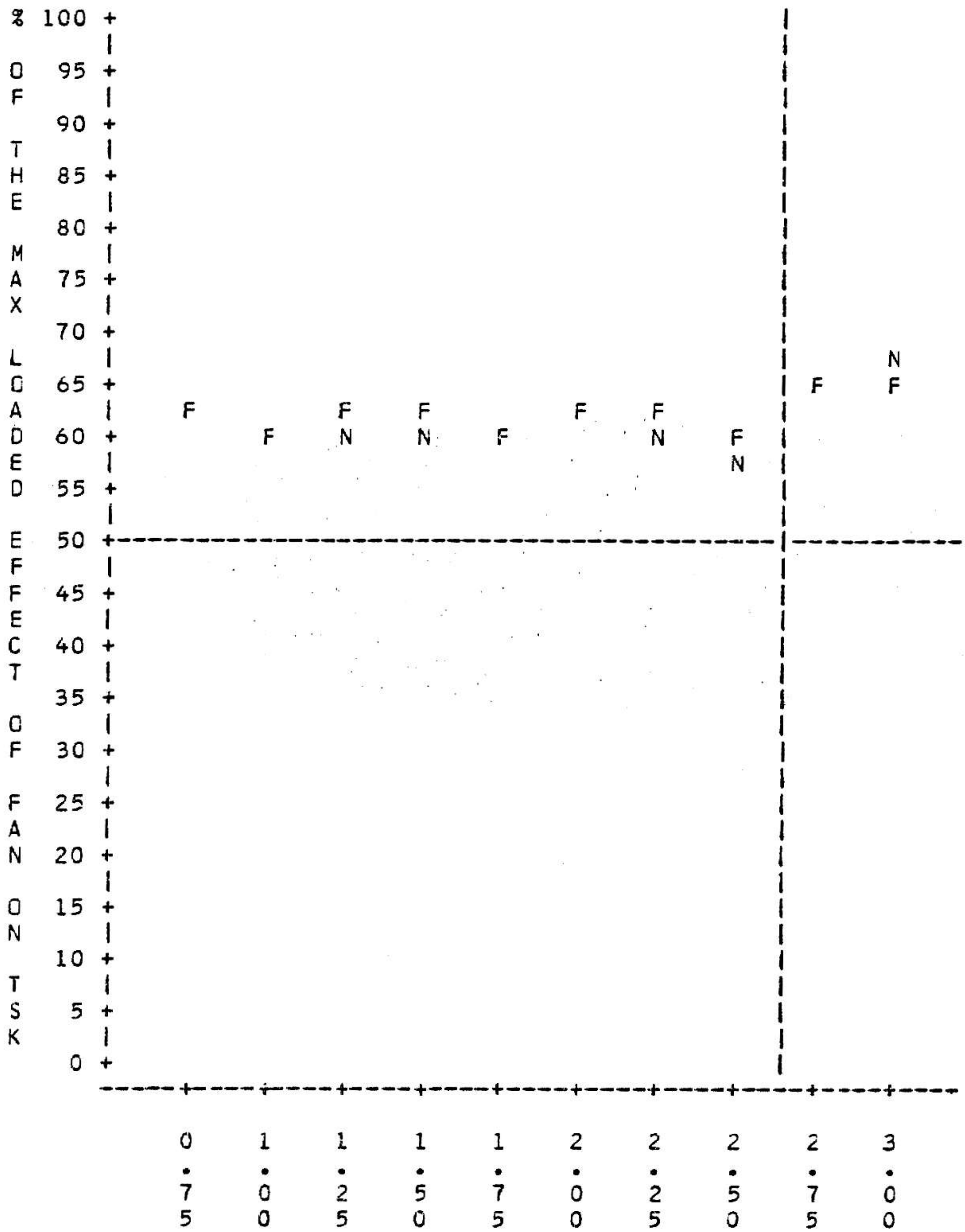


5 OBS HIDDEN

RELATIONSHIP OF DEP VAR SHOWN TO EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=25.6

PLOT OF MLAPIV*EXPINT SYMBOL IS VALUE OF FANCOND



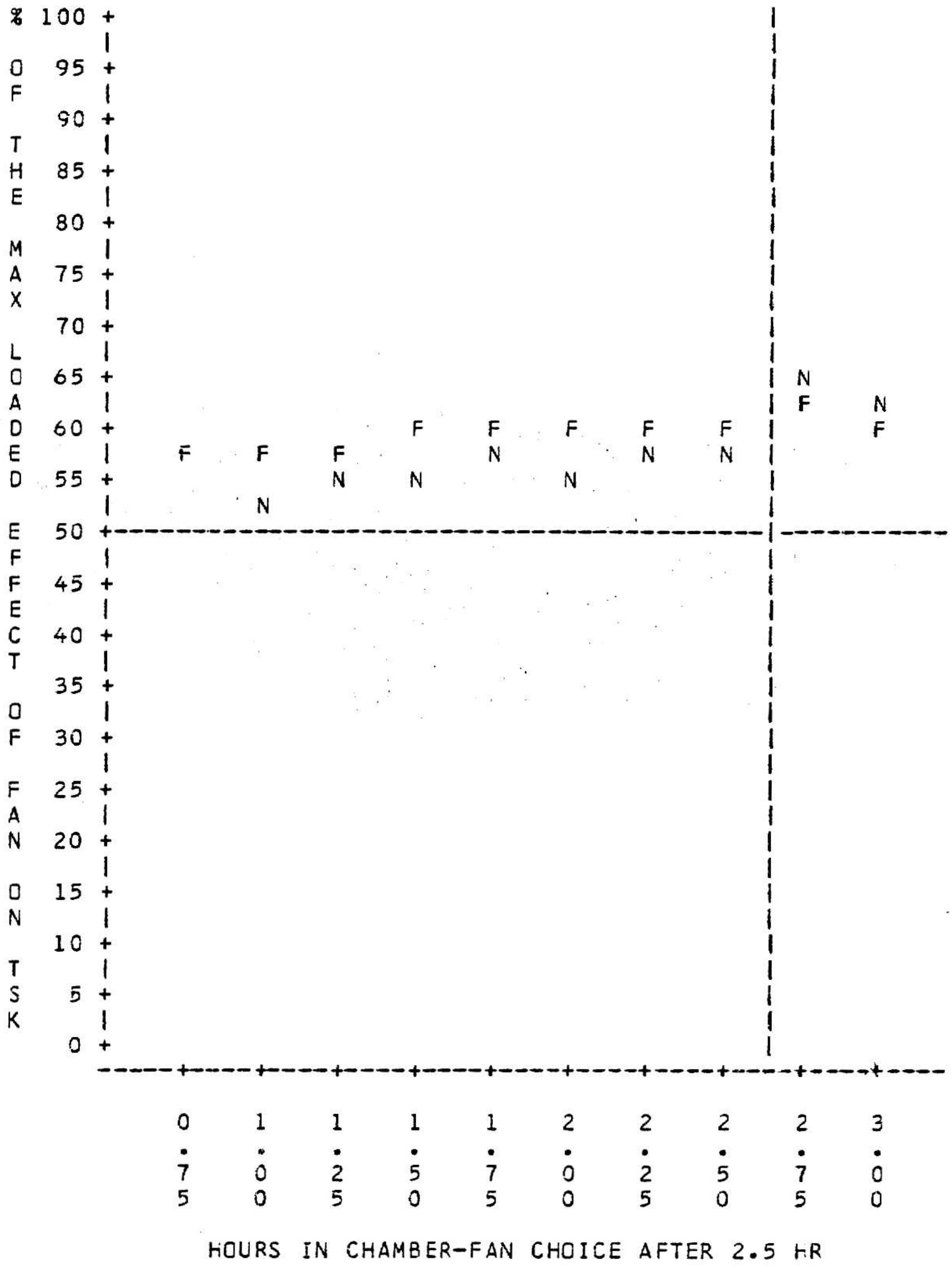
HOURS IN CHAMBER-FAN CHOICE AFTER 2.5 HR

7 OBS HIDDEN

RELATIONSHIP OF DEP VAR SHOWN TO EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=27.8

PLOT OF MLAPIV*EXPINT   SYMBOL IS VALUE OF FANCOND

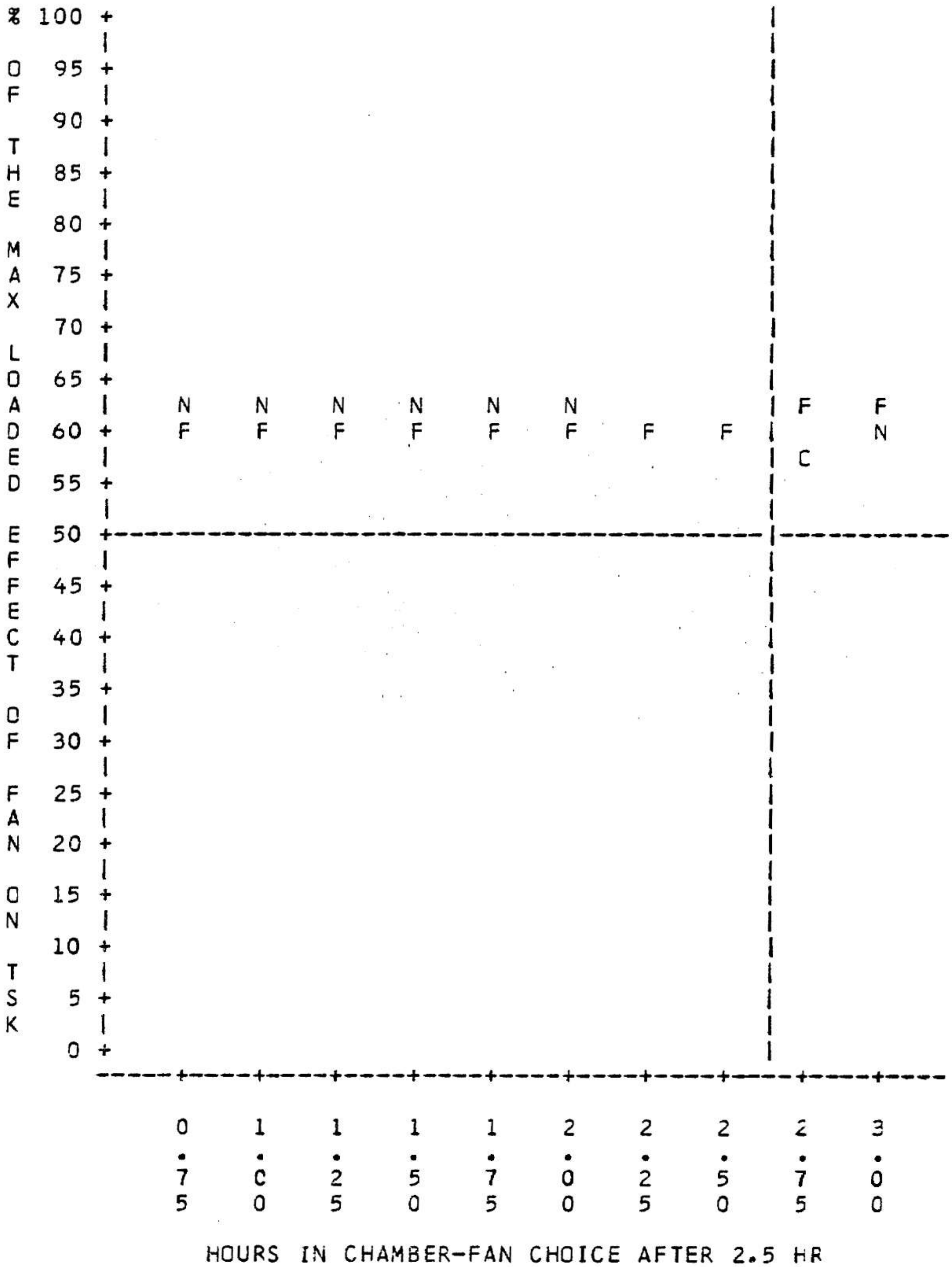


3 OBS HIDDEN

RELATIONSHIP OF DEP VAR SHOWN TO EXPOSURE TIME BY TEMPERATURE
FOR EACH FAN CONDITION: O=OFF--LIKE 6 M (0.35 M/S),
F=FAR=3.0 M (0.85 M/S AVG), N=NEAR=1.5 M (1.3 M/S AVG)

CTEMP=30

PLOT OF MLAPIV*EXPINT   SYMBOL IS VALUE OF FANCOND



4 OBS HIDDEN

APPENDIX S

Supporting Statistics for Balloting Model Equations

Analysis of covariance for balloting model equations shown in Tables 37 and 38 (See Appendix M for label descriptions for outside variables)

Variable, TC Type	GLM: Model Descriptor	Source: Model	Velocity	DBT	MAXCTEMP
Standard Total Comfort Vote	df/total	5/71	2/71	2/71	1/71
	F	16.49	26.64	7.50	8.43
	P>F	0.0001	0.0001	0.002	0.005
	R^2	0.56			
Loaded Average % Comfortable (R Scale)	df/total	5/71	2/71	2/71	1/71
	F	12.80	15.11	6.49	14.43
	P>F	0.0001	0.0001	0.003	0.0003
	R^2	0.49			
Loaded Average % Comfortable (A Scale)	df/total	5/71	2/71	2/71	1/71
	F	16.03	25.06	7.54	9.11
	P>F	0.0001	0.0001	0.002	0.004
	R^2	0.55			
Loaded Average % Comfortable (B Scale)	df/total	5/71	2/71	2/71	1/71
	F	14.96	20.70	8.43	10.57
	P>F	0.0001	0.0001	0.0006	0.002
	R^2	0.53			
Loaded Average Percent Fan Vote	df/total	1/47			1/47
	F	8.40			8.40
	P>F	0.006			0.006
	R^2	0.15			

Variable, TS Type	GLM: Model Descriptor	Source: Model	Velocity	DBT	PRHRRH	PRHRSRAD
Thermal Sensation	df/total	5/71	2/71	2/71	1/71	
	F	18.50	26.47	13.06	6.75	
	P>F	0.0001	0.0001	0.0001	0.02	
	R^2	0.58				
Preference for Temperature change	df/total	5/71	2/71	2/71		1/71
	F	13.99	19.52	12.92		4.41
	P>F	0.0001	0.0001	0.0001		0.04
	R^2	0.51				
Temperature Estimate	df/total	6/71	2/71	2/71	1/71	1/71
	F	8.67	10.87	6.23	7.39	5.34
	P>F	0.0001	0.0001	0.004	0.009	0.03
	R^2	0.44				

APPENDIX T

Subject Statistics

Variable	N	Mean	Std. Error of Mean	Standard Deviation	Minimum Value	Maximum Value
Age	8	22.1	1.0	2.9	20.0	29.0
Height (inches)	8	68.3	0.5	1.3	66.0	70.0
(cm)	8	173.6	1.2	3.4	168.0	178.0
Weight (lbs)	8	146.9	5.4	15.3	125.0	165.0
(kg)	8	66.8	2.5	7.0	56.8	75.0

COMFORT AND COOLING WITH BOX FANS

by

Eric R. Rosen

B. S., Bowling Green University, 1974

An Abstract of a Master's Thesis

submitted in partial fulfillment of the

requirements of the degree

MASTER OF SCIENCE

Department of Industrial Engineering

Kansas State University

Manhattan, Kansas

October, 1981

ABSTRACT

An average fan velocity of 1.3 m/s was preferred over 0.8 m/s as well as over the "still air" control condition on the basis of Thermal Comfort, PPD, and Thermal Sensation at 30.0 C (86 F) DBT, 45% rh. Results with voting over 2.5 hours were comparable to those obtained with a behavioral approach.

The explicitly selected fan velocity has been shown to increase significantly ($p = 0.05$) with temperature within the temperature range studied, 25.6 - 30.0 C (78 - 86 F) DBT. The mean fan velocities explicitly selected after 2.5 hours in the chamber were 1.2 m/s at 30.0 C (86 F), 1.0 m/s at 27.8 C (82 F), and 0.7 m/s at 25.6 C (78 F) DBT, all at 45% rh. Exposure to predetermined fan velocities of ≤0.35 0.85, and 1.3 m/s was not found to affect the explicitly selected fan velocities at the 0.05 level of significance. Thus, the current ceiling of 0.8 m/s (158 ft/min) on air velocity in the workplace is inappropriate and should be abolished.

Scales from the literature reduced to two types; Thermal Sensation and Thermal Comfort Groups. The relationship between these two scales was temperature dependent in the condition range studied. Comfort was associated with coolness and this association changed with temperature. Moreover, a plot of correlation of TS with TC versus temperature should provide a simple way of defining the "ideal temperature" for thermal comfort. This "ideal temperature" will be that temperature at which no relationship between Thermal Comfort and Thermal Sensation can be found.

Although the Thermal Sensation scale appeared to be best suited to formal analysis, a question asking for a Temperature Estimate was most practical. The latter provided a quick, easily quantified, and easily understood measure of the effect of thermally perceived changes in the environment. According to the TE, an average velocity of 0.8 m/s resulted in a perceived temperature which was 2.5 C (4.5 F) lower than in the "still air" ($v \leq 0.35$ m/s) control condition. An average velocity of 1.3 m/s resulted in a perceived temperature 3.5 C (6.3 F) lower than in the control condition. These results were mirrored in the balloting for Thermal Sensation and for the Preference for Temperature change as well. Thus, every 0.1 m/s rise in air velocity offsets a temperature rise of 0.3 C (0.5 F) from 25.6 to 30.0 C (78 to 86 F) DBT at 45% rh.

A pegboard task was found to be sensitive to the variation in environmental conditions. Differences of 4% to 8% of the mean performance level were found between the most extreme exposure conditions at the 0.05 significance level.