THE ASSESSMENT OF THE ABILITY OF VARIOUS HEAT
STRESS INDICES TO PREDICT SAFE WORK BEHAVIOR

by

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CHAPTER I
INTRODUCTION

PURPOSE

The purpose of this research is to describe the influence which the environmental temperature (hot and cold) exerts upon the safety behavior of workers, and to determine the efficiencies of the major thermal indices in predicting workers' safety behavior.

BACKGROUND

HEAT STRESS INDICES

Although many heat stress indices have been developed, there are six which are most commonly used and which have been selected for this study: (1) Natural Wet Bulb temperature (NWB), (2) Corrected Effective Temperature (CET), (3) Heat Stress Index (HSI), (4) Wet Bulb Globe Temperature (WBGT) (5) Wet Globe Temperature (WGT), and (6) New Effective Temperature (NET). In addition, since air temperature or Dry Bulb Temperature (DB) is the most commonly used and understood temperature measure, and is a common component of all other heat stress indices, it is evaluated along with the six indices mentioned above.

Natural Wet Bulb Temperature

Haldane (1905) determined a psychrometric wet bulb thermometer (WB) by using a wet cloth to cover a traditional thermometer under the condition of maximum evaporation. In this thermometer system, the evaporating water removes heat from the thermometer at an evaporation rate which is inversely proportional to the relative humidity. Therefore, the higher the Relative Humidity (RH), the smaller the difference between Dry Bulb temperature (DB) and WB (AIHA, 1975). WB can be measured using a sling or a motorized psychrometer, and NWB is obtained by simply exposing a wet sensor to natural air movement. The effect of air velocity on NWB has been described by numerous investigators. Wind speed has also been reported to cause significant differences between WB and NWB. According to Gagge and Nishi (1975), experiments in their laboratory indicated that the depression of NWB from DB is the least for still air (6 - 9 m/min), and it is about 90% of the WB depression. When air velocity (V) is above 150 m/min, $NWB = WB$.

Ramsey and Wan (1979) assumed the following relationship between NWB and WB as a function of V:

$$V = 210 \text{ m/min} \quad NWB = WB$$

$V = 150 \text{ m/min}$ $NWB = WB + 1 \text{ degC}$ (degC = degree C)

$V = 30 \text{ m/min}$ $NWB = WB + 2 \text{ degC}$

Johnson and Kirk (1980) developed a graph, shown in Figure 1, of the relationship between air velocity and the difference between NWB and WB, by using a heated radiation plane opposite the air source. They assumed effective radiation temperatures of 28 degC, 39 degC, and 47 degC. The three lines represent the difference between NWB and WB for various air velocities. Two conclusions were drawn from their data: first, WB depression from NWB could be predicted as a function of V; second, because DB changes would at least affect radiant conditions over part of the exposed surface of the thermometer, and different effective radiation temperatures for different conditions are certainly possible. But it should be noted that in their study, the V only ranged up to one m/sec (60 m/min) and the difference between WB and NWB was consistently less than two degrees across the whole range.

Figure 1 - Comparison of calculated wet bulb error with data by Dukes-dobos, et al. (1977). Curve parameters are DB/WB/GT. Symbols correspond to those presented by Dukes-Dobos with dark circles and squares belonging to the top curve, triangle to the middle curve, and open circles to the bottom curve. (adapted from Johnson & Kirk, 1980)

Figure 2 and Table 1 have been used to estimate (NWB - WB) which includes the difference between temperature of Vernon globe (GT) and DB temperatures by several investigators (Dukes-Dobos, 1976 and Brief and Confer, 1976). Figure 2 and Table 1 are based on results of a systematic study by Romero-Blanco (1971) which suggests:

- 1) $(NWB - WB)$ has basically a linear relationship with $(GT - DB)$ at any V .
- 2) $(NWB - WB)$ is not affected by V when V is greater than 35 m/min. (Except when $GT - DB \leq 5.6 \text{ degC}$)
- 3) $NWB - WB = 1.18 \text{ degC}$ when $V = 7 \text{ m/min}$ and $GT - DB = 0 \text{ degC}$.

Figure 2 - $(NWB - WB)$ vs $(GT - DB)$ chart from essay by Romero-Blanco, 1971. (Dukes-Dobos, 1976)

Table 1 - Relationship between psychrometric and natural wet bulb readings. (Brief and Confer, 1976)
(degF = degree F)

(GT - DB)	< 10	120-250	300-410	380-520	540-700
UNIT OF V : fpm					

degF	(NWB - WB) degF				

0	2.0	1.5	1.0	0.5	0.1
5	4.0	1.7	1.3	1.0	0.9
10	5.2	2.1	2.0	2.0	2.0
15	6.7	3.2	3.2	3.2	3.2
20	8.1	4.5	4.5	4.5	4.5
25	9.6	5.8	5.8	5.8	5.8
30	11.1	7.0	7.0	7.0	7.0
35	12.6	8.2	8.2	8.2	8.2
40	14.0	9.5	9.5	9.5	9.5
45	15.5	10.8	10.8	10.8	10.8

Botsford (1980) reports that the effect of an air velocity of 228 m/min was to increase man's heat loss by about 275 Kcal/hr within the temperature range of 16.7 degC to 34.4 degC. This increase in heat loss is equivalent to lowering the BOTSBALL temperature (WGT) by about 7 degC.

Kamon (1979) on the other hand reports that "Despite the increase in the ambient evaporative capacity due to higher V, the limit lines describing the exposure limits were not significantly different either at DB ≤ 44 degC for V of 120 and 240 m/min or at DB > 44 degC for V of 60, 120, and 240 m/min." Kamon's opinion is that air velocity does not influence human thermal tolerance under the range of conditions which he

studied.

The dominant opinion represented in these six studies supports two statements concerning the effect of the air velocity on the NWB; 1) a nominal difference between NWB and WB appears in high air velocity, and the difference between NWB and WB is increased as the air velocity is decreased.

Corrected Effective Temperature

Yaglou and Houghton (1923) developed a heat stress index called "Effective Temperature" (ET), an index of the effects on the human body, resulting from exposure to different combinations of air temperature, velocity and humidity. ET has two scales. One scale is for individuals stripped to the waist, while the other, Figure 3, is for fully clothed individuals. An individual's perception of the thermal level under 100% RH defines a value of ET. A different level of temperature and humidity with the same level of thermal perception, is defined as the same ET. For example, as the definition indicates, in an $ET = 25 \text{ degC}$ a person perceives the thermal environment in a 25 degC , saturated (100% RH) environment. If the person has the same thermal perception in a hotter and dryer environment, the ET at that situation is also 25 degC .

Figure 3 - Chart showing normal scale (fully clothed) of corrected effective temperature. (Ellis, et al. 1972)

The lack of simple radiation heat measuring devices was a major factor which made it difficult to include a radiation heat parameter in the ET index. The introduction of the globe thermometer led to the elaboration by Bedford (1946) which includes allowances for radiation. This index is now called Corrected Effective Temperature (CET) and uses a GT instead of a DB temperature.

Later Yaglou (1950) considered that the simple employment of GT instead of DB would not accurately reflect the radiant effects. He used a pseudo wet bulb temperature in place of psychrometric wet bulb, and called it Equivalent Effective Temperature Corrected for Radiation (ETCR). The procedure for determining the pseudo wet bulb temperature is as follows:

- 1) A psychrometric chart, Figure 4, is used to determine the absolute humidity for a given DB and WB. (i.e. dew point temperature)

- 2) The WB value from the intersection of the above absolute humidity level and the DB value equal to the GT are obtained. This wet bulb temperature is called pseudo wet bulb temperature.

Figure 4 - Psychrometric chart. (Ellis, et al. 1972)

An example illustrates this method. Assume the following: DB = 30 degC, WB = 20 degC, GT = 38 degC. From the intersection of 30 degC DB and 20 degC WB in Figure 4, the dew point is found to be 15 degC. With 15 degC dew point and the globe reading of 38 degC (used as an adjusted dry bulb) a pseudo wet bulb temperature of 22.5 degC is found.

In 1957, Yaglou and Minard modified GT into Corrected Globe Temperature by the following formula:

$$\text{Corrected Globe Temperature} = .74(-.95(\text{GT} - \text{DB}) + \text{DB})$$

They called this modification Effective Temperature including Radiation.

New Effective Temperature

ET, CET, ETCR and ETR can be derived from the chart shown in Figure 3 (page 11). These indices describe the thermal sensation of the human body in reference to an ambient environment of RH = 100%. The research group at the Yale University John B. Pierce Foundation Laboratory, (Gagge et al. 1971) used a different approach and called their index New Effective Temperature (NET). They introduced skin wettedness as an important factor of their simulated human thermal system. They defined a standard environment as

follows:

1) Metabolic energy = 58.2 W/m^2 ($\text{W/m}^2 = \text{Watt/meter-square}$)

2) Clo value = 0.6 clo

clo : clothing insulation unit. One clo maintain a thermal gradient of .18 degC over an area of one square meter when the thermal flux is one Kcal/hr.

3) Air Movement = .10 - .15 m/sec.

NET was defined as the temperature of an isothermal environment at 50% Relative Humidity (RH). The above standard environment would exchange the same amount of heat at the same Tsk (Mean Skin Temperature) and skin wettedness as observed in the actual environment and the clothing under consideration. A computer program was used to derive the ASHRAE psychrometric chart showing the relationship between NET and human feeling. (Gagge et al., 1971)

Subsequently a formula to find the NET was derived by iteration as shown below (Gagge and Gonzalez, 1973):

$$T_O = NET + W(2.2hc / h)(0.5NP_{net} - NP_{dp}) \quad (1)$$

Where

TO : Operative Temperature

W : skin wettedness (%)

NPnet : vapor pressure under NET (Torr)

NPdp : vapor pressure under DB (Torr) (=Pa)

hc : convection coefficient ($w \cdot m^{-2} \cdot C^{-1}$)

hr : radiation coefficient ($w \cdot m^{-2} \cdot C^{-1}$)

$h = hc + hr$

$$TO = (hr / h) Tw + (hc / h) DB \quad (2)$$

Where

Tw : mean radiant temperature

Nishi (1977) derived a program for direct calculation of NET using the HP-65 calculator and Equation 3 below.

$$NET = (((Y/w) - 0.032) ** 2 + 0.0614 (Pa + (Y/w) STO - 3.25)) \\ ** (1/2) - (Y/w) - 0.032 / 0.037 \quad (3)$$

Where

Pa : ambient vapor pressure (Torr)

$$STO = Tsk - DRY / 4.36 \quad (4)$$

$$DRY = (h / (1 + 0.155hI_{clo})) (Tsk - TO) \quad (5)$$

$$TO = (hrTw + hcTa) / (hr + hc)$$

$$hr = 4 (Ar / Ad) (((T_{cl} + TO) / 2) + 273) ** 3 \\ = 5.67 (10 ** (-8)) (w \cdot m^{-2} \cdot K^{-4}) \quad (6)$$

Ar/Ad : the effective radiation area and is 0.7 to 0.8

(hr is rather constant at normal temperature)
range and is approximately equal to

$$4.7 (w \cdot m^{**2} \cdot c^{**1})$$

$$hc = 8.6V^{**0.53}$$

$$= 5.66 ((M-0.85) **0.39) (w \cdot m^{**2} \cdot c^{**1}) \quad (7)$$

V : air velocity (m/s)

M : metabolic energy ($w \cdot m^{**2}$)

$$Tw = GT + (2.27(V^{**0.5})) (GT-DB) \quad (8)$$

$$Icloe = (1/0.155h) (Tsk-Tcl) / (Tcl-T0) \quad (9)$$

$$Y = (hc+hr) / 2.2hc * (1+0.143hcIcloe) / (1+0.155 (hc+hr)Icloe) \quad (10)$$

$$Tcl = T0 + Fcl (Tsk-T0) \quad (\text{Gagge, et al, 1972}) \quad (11)$$

$$Fcl = 1 / (1+0.155(hIclo)) \quad (12)$$

Tsk : mean skin temperature

$$= 0.07 T_{head} + 0.175 (T_{chest} + T_{back}) + 0.07 (T_{upperarm} + T_{forearm}) + 0.05 T_{hand} + 0.19 T_{thigh} + 0.2 T_{calf} \quad (13)$$

{could be approached from ET}

$$= 17.02 + 0.6 ET \text{ where } ET \geq 25 \text{ degC} \quad (\text{NIOSH, 1973}) \quad (14)$$

$$= 32.5 \quad \text{where } ET < 25 \text{ degC (NIOSH, 1973)}$$

w : skin wettedness was derived by Gagge (1975) with a normal cloth value (see Table 2)

Iclo = 0.6 in normal summer {short} clothing

Table 2 - Relationship between skin wettedness and mean skin temperature when $clo > 0.6$ (Gagge, et al. 1975).

w (skin wettedness)	Tsk (skin temperature) unit: degC
-----	-----
0.0	Tsk $\leq$ 32.5
0.1	32.5 < Tsk $\leq$ 33.0
0.2	33.0 < Tsk $\leq$ 35.1
0.3	35.1 < Tsk $\leq$ 35.5
0.4	35.5 < Tsk $\leq$ 36.1
0.5	36.1 < Tsk $\leq$ 36.3
0.7	36.3 < Tsk $\leq$ 36.6
0.8	36.6 < Tsk $\leq$ 36.8
1.0	36.8 < Tsk

Heat Stress Index - Belding and Hatch

The Heat Stress Index introduced by Belding and Hatch (1955) is based on the physical analysis of heat exchange. The index number describing the heat stress is determined by dividing the evaporative heat loss required for heat balance (E_{req}) by the maximum evaporative heat possible for the same situation (E_{max}) and expressing the value obtained as a percentage. For practicality the index assumes that human skin temperature is 35 degC and that sweat uniformly wets the body surface. It further assumes that there is no storage of heat in the human body, and that thermal exchanges by conduction and respiration can be ignored. The basic heat balance equation then becomes:

Evaporation Required (Ereq) = Metabolic Heat (M) +
Convective Heat Exchange (C) + Radiation Heat
Exchange (R)

The Maximum Evaporative Capacity (Emax) of the environment is calculated as a function of V and Vapor Pressure (Pa), and the Heat Stress Index (HSI) = (Ereq/Emax)*100. HSI equations and coefficients representing different levels of clothing are summarized by Ramsey and Wan (1979) in Table 3.

Wet Bulb Globe Temperature

The Wet Bulb Globe Temperature index was derived by Yaglou and Minard (1957) for use in U.S. military field operations. The index number is determined by a simple weighting of GT, DB, and NWB according to the following equation:

$$WBGT = .7NWB + .3((GT - DB)K + DB) \quad (15)$$

For indoor, night, or sunless day situations, K is equal to 1 and the equation can be simplified to:

$$WBGT_{indoor} = .7NWB + .3GT \quad (16)$$

Table 3 - HSI equations and coefficients. (Ramsey and Wan, 1979)

R: Radiant Heat (Kcal) M: Metabolic Work Load (Kcal)
 V: Air Velocity (m/min) GT: Globe Temperature (degC)
 Emax: Max Evaporation Capacity (Kcal)
 Kr: Radiant Coefficient
 Ke: Evaporation Coefficient
 Tw: Mean Radiant Temperature (degC)
 Pa: Ambient Vapor Pressure (Torr)
 C: Convection Heat (Kcal)
 Kc: Convection Coefficient
 Ereq: Required Evaporation Capacity (Kcal)
 DB: Dry Bulb Temperature (degC)

EQUATION	COEFFICIENTS (K)		

	SHORTS	STANDARD CLOTHES	STANDARD PLUS COAT

$R = K_r (T_w - 35)$	11.0	6.6	5.28
$C = K_c (V^{**0.6}) (DB - 35)$	1.0	0.6	0.48
$E_{max} = K_e (V^{**0.6}) (42 - Pa)$	2.0	1.2	0.96
$T_w = GT + 0.24 \{ V^{**0.5} \} (GT - DB)$			
$E_{req} = M + R + degC$			
$HSI = (E_{req} / E_{max}) * 100$			(17)

For outdoor exposures with a solar load, the value of K is related to the clothing or the type of skin. In order to simplify the formula, K is assumed to be 0.67 and the equation becomes:

$$\text{WBGT}_{\text{outdoor}} = .7\text{NWB} + .2\text{GT} + .1\text{DB} \quad (18)$$

Wet Globe Temperature

The Wet Globe Temperature (WGT) index is obtained from a single reading of the Wet Globe Thermometer developed by Botsford (1971). The Wet Globe Thermometer exchanges heat with the surroundings by convection, evaporation, and radiation in a manner similar to that of a sweating person. The instrument, a Botsball, consists of an ordinary thermometer with its sensing bulb enclosed by a wet black globe 2.375 inches in diameter (6 cm). The instrument needs a period of at least 5 minutes for thermal stabilization.

SAFETY BEHAVIOR AND HEAT

Safety behavior is the other major variable of interest in this study. There are many factors which influence human safety behavior. Margolis (1975) classified them into two major groups: psychological factors and environmental factors. A worker's level of arousal or activation resulting from job-related

characteristics and demands (e.g. heat, noise, information overload and isolation) should be limited to an intermediate tolerance zone for near-optimum, error-free or accident-free performance. A higher or lower level of activation over a period of time would be likely to create stress as reflected by some form of neurological, physiological or behavioral disruption or disorganization.

The influences of hot environments on human physiological response and fatigue have been demonstrated by numerous research efforts. Considerable attention has also been given to the relationship between the working environment and the performance of sedentary tasks (Ramsey and Morrissey, 1978). The National Institute for Occupational Safety and Health (NIOSH, 1972) suggested the upper limit of exposure for unimpaired mental performance, and said : "For sedentary jobs where continuous unimpaired mental performance is required, no employee shall be exposed to conditions which exceed the limits set forth ...".

But there remains a relevant question as to how and if environmental heat directly affects human safety behavior? One useful approach for evaluating this problem is under way as a research project funded by NIOSH concerning the effect of heat on safe work

behavior (Ramsey and Burford, 1980). This project uses a safety sampling procedure including identification of behavioral categories, development of a statistically valid sampling procedure, taking brief observations of the environment, and development of statistical inference about total activities based on these statistical samplings.

Figure 5 illustrates the concepts of statistical safety sampling (Ramsey and Burford, 1980). Safety sampling is an efficient mechanism for evaluating the behaviors that lead to accidents. It is efficient because as Heinrich (1959) demonstrates in Figure 6, there are so many more opportunities for unsafe practices to be observed than there are actual accidents with minor or major injuries. Ramsey and Burford (1980) developed an unsafe behavior taxonomy based on existing categorization schemes. The unsafe practices of ANSI (1962), and Human Errors of Pope (1972) were modified to reflect the metal machining and hot metal working industries used in their study. Table 4 summarizes this taxonomy.

Two types of data were collected for analysis in this study, and the procedure is described in Chapter II.

Figure 5 - Random event sampling as a representation of continuous activity. (Ramsey & Burford, 1980)

00.3 PERCENT OF ALL ACCIDENTS PRODUCE MAJOR INJURIES

08.8 PERCENT OF ALL ACCIDENTS PRODUCE MINOR INJURIES

90.9 PERCENT OF ALL ACCIDENTS PRODUCE NO INJURIES

Figure 6 - The foundation of major injury.
(Heinrich, 1959)

Table 4 - Taxonomy of unsafe worker behavior.
(Ramsey & Burford, 1980)

1 - CENTRAL TO WORKER

11. IMPROPER USE OF BODY

1. Used hands, not tools (to feed, clean, adjust, grip, hammer).
2. Insecure grip (oily, pinch grasp, too many objects. If one man is carrying a load end must change his grasp.
3. Inappropriate lifting (with back, not legs, extended, torsional). Load is extended or away from body.
4. Should use mech. lift or get help (crane, hoist, two man load).
9. NEC.

12. UNSAFE POSITION OR POSTURE

1. Cramped, awkward, or unsafe position (bend, stoop, work in small quarters). If discretionary.
2. Working too close together (gang too close to each other, tripods in assy, matl. handling). More than one person.
3. Exposed under suspended load (under hoist or fork). Any part of the body exposed to possible hazard from above.
4. Unnecessary exposure (to heat, cold, fumes, paint, electricity, sand, dust). Also failing to remove oneself from exposure.
5. Riding in unsafe position (on forks of lift, on hook of crane). More than one person is on the equipment.
6. Unneces. exposure to moving mat or equip. (Work in aisle or travelway). Too close to moving machinery of equipment.
9. NEC.

13. UNSAFE BODY MOVEMENTS

1. Operating too fast (movement of body, matl. handling). Will be called if loss of control is reasonably possible.
2. Moving body too fast (walking, running). Loss of control is reasonably possible due to undue haste.
3. Feeding too fast (supplying, pushing, drilling, sawing, grinding too fast, motor bogs down). Blade breaks or flexes.
4. Throwing not handling (warehouse, handling parts/pumps). Imparting of uncontrolled kinetic energy.
5. Descending, ascending unsafely (jumping off, down, 2 steps at a time, truck/storage platforms).
6. Inattention to footing, seat, or surround (tripping over curb, platform edges). In

attention occurs around fixed objects.

7. Distracted by outside source (woman walking, watching horseplay, radio too loud). Undue emotional reaction.
8. Failure to follow reg./policy (horseplay, smoking in non-smoking area). Potential for creating a hazard.
9. NEC.
14. FAILED TO USE PROTECTIVE CLOTHING
 1. Goggles, glasses. Substances in the air or the probability thereof. Problem of sand and grinding or blowdown.
 2. Foot/toe protection (shoe and toe devices). No laceup shoes should be worn near molten metal.
 3. Gloves (special to fit job done). Handling of sharp materials, wood splinters, or hot objects.
 4. Face/respiratory protection (dust mask, shield, ear plugs, welding masks, respiratory protection). Visible air quality. Calls on respiratory.
 5. Truck/leg protection (chain saw, firefighting, foundry).
 6. Hard hat/bump cap. During a shakeout or while shoveling under the conveyor.
 9. NEC.
15. FAILED TO DRESS PROPERLY
 1. Loose or inappropriate clothing (sleeves improper length, long trousers, belts). In molten or welding operations. A pocket, or cuffs on pants.
 2. Unrestrained long hair (should use band, net, hat). Hair is not restrained around rotary movement of equipment.
 3. Adornments (rings, watches, necklace, neckties, pocket chains). If something calls our attention to the situation.
 9. NEC.
- 2 - CENTRAL TO TOOLS, EQUIPMENT, MATERIALS
21. TOOL, MATERIAL, EQUIPMENT ERRORS
 1. Wrong tool, equipment, material for job done (wrench as hammer, cheater, hammer or screw driver, clean use screwdriver).
 2. Unsafe use of tool, equip., material (correct equip. used unsafely, spray paint outside booth, welding outside area or in aisle). Blowdown.
 3. Cleaning, oiling, adjusting, moving equip. (changing bits while drill is moving, under power - not coasting to a stop, clean lathe).
 9. NEC.
22. UNSAFE PLACING OF TOOLS, EQUIPMENT, MATERIALS
 1. Unsafe placing of matl. moving/handling equip. (parking, stopping, or leaving carts, elevators, conveying apparatus).
 2. Unsafe placement of matl., tools, scrap

- (tripping, bumping, slipping hazards, poor housekeeping). Transient matter.
- 3. Inattention to tool, material placement (placement on table, unstable, precarious). Only on the bench table.
- 9. NEC.
- 23. FAILURE TO SHUT DOWN POTENTIAL ENERGY
 - 1. Power circuit or flame not secured (maintenance on electric motors, high voltage lines, the unguarded open flame). If the area is unattended.
 - 2. Machine device not shut off, untended (motors and engines, auto feed, welding gases, saws). Large or asymmetrical.
 - 3. Fail to lock, block, or secure against unexpected motion (gas, bottles, shafts, unblocked, tubing on end). Longer than 3'.
 - 9. NEC.
- 24. MAKING SAFETY DEVICE OR EQUIPMENT INOPERATIVE
 - 1. Making device inoperative or failure to use (welding shields, barriers, rails, switches, guards, remove, disconnect, or misadjust safety devices). Decision on the operator's part not to use safety device.
 - 9. NEC.
- 3 - CENTRAL TO MATERIALS HANDLING EQUIPMENT
- 31. COMMON TO CRANE, HOIST, AND FORK
 - 1. Failure to warn (starting, stooping, backing, turning, signals, releasing loads, move load over people). Shakeout.
 - 2. Driving or moving too fast. Lack of control. Erratic movements of forks and shovel.
 - 3. Misjudged clearance, land, or position (cross over line, between boxes, aisles, pass on wrong side).
 - 4. Overloaded, load insecure (beyond capacity, load too high). Not called if greater care taken.
 - 5. Dropping, not placing carefully. High impact noise or movement after placement.
 - 6. Suspended load unattended. (An unattended raised fork with or without additional load).
 - 9. NEC.
- 32. COMMON TO CRANE AND HOIST
 - 1. Hook in passageway or in motion. Hoist chain is swinging on purpose during a shakeout.
 - 9. NEC.
- 33. COMMON TO FORK TRUCK
 - 1. Improperly parked or positioned (no parking zone including aisle, unauthorized parking space). A position not demanded by the work.
 - 2. Passengers without seats (operator allows standing or sitting on vehicle).
 - 3. Fork truck unattended, engine running.
 - 9. NEC.

CHAPTER II

DATA COLLECTION PROCEDURE

Two types of data were collected in this study. First, behavioral data was obtained by making daily observations at two local plants and utilizing the taxonomy and data sheet developed by Ramsey and Burford (1980). Second, thermal components were measured, including NWB, DB, GT, WGT, and WBGT. These data also provided the information necessary for the evaluation of CET, NET, and HSI.

A Rueter - Stokes Heat Stress Monitor, Model RSS-211A was mounted upon a tripod and carried by the observers to several measurement locations in the plant. This instrument, shown in Figure 7, provides direct meter reading output of air velocity, WBGT indoor, WBGT outdoor, dry bulb, wet bulb and globe temperature. In addition to the heat of the environment, the metabolic heat generated from the task was also be evaluated. It is difficult to directly measure the metabolic rate of a worker accurately in a non-laboratory situation, and in fact, the measuring process itself in the real working situation often influences the response of a subject. So the metabolic rate in this study was estimated according to Table 5 (Ramsey 1978).

Figure 7 - Heat stress monitor (Ramsey & Burford, 1980)

Table 5 - Metabolic workload classifications
(Ramsey, 1978)

Work Level	Energy Expenditure Range
Level 1 - Resting	100 Kcal/hr or less
Level 2 - Light	101 to 200 Kcal/hr
Sitting at ease, light hand work (writing, typing, drafting, sewing, bookkeeping), hand and arm work (small bench tools inspecting, assembly, or sorting of light materials), arm and leg work (driving car under average conditions, operating boat switch or pedal). Standing drill press (small parts), milling machine (small parts), coil taping, small armature winding, machining with light power tools, casual walking (up to two mph).	
Level 3 - Moderate	210 to 300 Kcal/hr
Hand and arm work (nailing, filing), arm and leg work (off-road operation of trucks, tractors, or construction equipment), arm and truck work (air hammer operations, tractor assembly, plastering, intermittent handling of moderately heavy materials, weeding, heaving, picking fruits or vegetables), pushing or pulling lightweight carts or wheel barrows, walking two to three mph.	
Level 4 - Heavy	Above 301 Kcal/hr
Heavy arm and truck work, transferring heavy materials shoveling; sledge hammer work; sawing, planing, or chiseling hardwood, hand mowing, digging, ax work, climbing stairs or ramps, jogging, running, walking faster than four mph, pushing or pulling heavily loaded hand carts or wheel barrows, chipping castings, concrete block laying.	

The use of Table 5 provided a general estimate of the metabolic workload, and avoided many of the disadvantages involved in measuring metabolic heat generation more precisely.

Layouts of the two local plants selected for this study are shown in Figure 8 and Figure 9. Data was collected over a five month period (July to November), so that both the hot and cold seasons were included. Data concerning safety behavior and environmental conditions were collected on a schedule of two trips per work day by three observers during normal shift work periods. Approximately 30 work stations (11 tasks) in each plant were observed for safety behavior during each plant visit. A sample data collection sheet is shown in Figure 10. When unsafe behavior was noted, an unsafe behavior code was selected from the Taxonomy (Table 4, page 27) and listed in the "Observation" column of the data sheet.

The next chapter will discuss the methodology applied to quantify and develop the indices which were used in this study.

PLANT A LAYOUT

Figure 8 - Plant A layout (Ramsey & Burford, 1980)

PLANT B LAYOUT

Figure 9 - Plant B layout (Ramsey & Burford, 1980)

HEAT STRESS DATA - PLANT A

COMMENTS

OBSERVER C

DAY WED	DATE 0210	TIME 1130	19.5	26.7	25.5	31.5	21.2	39.3	250		
MACHINE	ID	OBSERVATION	WL	WGT	WBGT IN	WBGT OUT	DB	WB	GT	WIND	NOTE
DRILL	1	141	2	16.6	22.1	22.2	26.3	20.8	27.4	3	
	2	001	2								
GRIND	3	001	1	17.6	22.0	21.8	26.5	20.7	27.2	10	
	4	121 241	1								
	6	001	2								
	7	001	3								
FORKL	37	001	1								
LATHE	11	001	1	17.6	22.3	22.1	26.1	20.7	27.0	2	
	13										

Figure 10 - Data collection sheet (Ramsey & Burford, 1980)

CHAPTER III

INDICES QUANTIFICATION AND PROGRAMMING

Safety behavior of the workers as influenced by environmental temperature was evaluated in terms of the following thermal indices : NWB, CET, HSI, WBGT, WGT, and NET. Additionally WB was calculated as an intermediate point of several these indices (CET, HSI, and NET). Described below are the computational methods which were developed and used to calculate these thermal indices and components.

Psychrometric Wet Bulb Temperature

The difference between GT and DB ($dltD = GT - DB$) varied widely from plant to plant and work station to work station. For example, due to the fact that plant B is a foundry and plant A is a machine shop, the $dltD$ in plant B was higher than in plant A. Additionally, $dltD$ for the work stations near an open door tended to be higher in the summer and lower in the winter than $dltD$ in other locations within the plant.

The difference between WB and NWB has been labeled $dltW$ for this study , where $dltW = NWB - WB$. Johnson and Kirk (1980) indicated that $dltW$ was influenced by different GT and DB but they did not clearly explain

the differences over a wide range of conditions. The systematic study done by Romero-Blanco (1971) developed the data shown in Table 1 and Figure 2 (page 5). Figure 11 incorporates on a simple chart not only the relationships described by Ramsey and Wan (1979), Johnson and Kirk (1980), and Gagge et al. (1975), but also the $dltD$ and $dltW$ described by Romero-Blanco (1971). Since Gagge's paper (1975) was an estimation, the upper "--*--" line in Figure 12 represents an assumed $NWB = 50 \text{ degC}$, and the lower '-*--' line in the same figure represents $NWB = 10 \text{ degC}$. These values were the possible temperature extremes for this study; thus the area between these two "--*--" lines is the $dltW$ range using Gagge estimates.

Since Romero-Blanco (1971) supplied the most systematic and complete study and the other studies present numbers compatible with it, this study used Romero-Blanco's results (Table 1 on page 6) to derive the following equations.

Figure 11 - $dltW$ vs Velocity Diagram. A Combination diagram of the studies by Ramsey and Wan (1979), Romero-Blanco (1971), Johnson and Kirk (1980), and Gagge (1975).

condition	equation
$dltD = 0, V \leq 200$	$dltW1 = (1.1 / 200) (200 - V) \quad (19)$
$dltD = 0, V > 200$	$dltW2 = 0 \quad (20)$
$0 < dltD < 5.6, V \leq 36$	$dltW3 = ((36 - V) (0.0055 + (dltD / 5.6) (0.0055)) + 0.83 + (dltD / 5.6) (0.33) \quad (21)$
$0 < dltD < 5.6, V > 36$	$dltW4 = 0.83 + (dltD / 5.6) (0.33) - (V - 36) ((5.6 - dltD) / 5.6) (0.0055) \quad (22)$
$dltD \geq 5.6, V \leq 36$	$dltW5 = 0.25(dltD) - 0.28 + ((36 - V) / 36) (1.72 + (0.13(dltD - 5.6) / 2.78)) \quad (23)$
$dltD \geq 5.6, V > 36$	$dltW6 = 0.25(dltD) - 0.28 \quad (24)$

The above equations were developed by using the following steps:

- 1) Convert Table 1 to SI system to obtain Table 6.

Table 6 - Relationship between dltW, Velocity, and dltD in SI system.

dltD degC	dltW in degC (unit of V: m/min)				
	V<3.05	36.6-76.2	91.4-125	116-159	165-213
0.0	1.11	0.83	0.56	0.28	0.06
2.8	2.22	0.94	0.72	0.56	0.50
5.6	2.89	1.17	1.11	1.11	1.11
8.3	3.72	1.78	1.78	1.78	1.78
11.1	4.50	2.50	2.50	2.50	2.50
13.9	5.33	3.22	3.22	3.22	3.22
16.7	6.17	3.89	3.89	3.89	3.89
19.4	7.00	4.56	4.56	4.56	4.56
22.2	7.78	5.28	5.28	5.28	5.28
25.0	8.61	6.00	6.00	6.00	6.00

2) Determine the equation for $dltD = 0$. From Figure 12, the line for $dltD=0$ approaches linear. (The slope is equal to $-1.1/200$). The intersection of this line with the vertical ($dltW$) axis is 1.1. So:

When $dltD=0$ and $V \leq 200$,

$$dltW1 = 1.1 - ((1.1/200) V) \quad (19)$$

when $dltD=0$ and $V > 200$,

$$dltW1 = 0 \quad (20)$$

3) Determine the formula for $dltD \geq 5.6$ and $V > 36$, the change in $dltW$ is systematic as shown in Table 7.

Table 7 - Relationship of $dltW$ and $dltD$ when $dltD \geq 5.6$ and $V > 36$.

$dltDi$	$dltWi$	$dltWi - dltWi-1$	a
5.6	1.11	----	-0.290
8.3	1.78	0.67	-0.295
11.1	2.50	0.72	-0.275
13.9	3.22	0.72	-0.255
16.7	3.89	0.67	-0.285
19.4	4.56	0.68	-0.290
22.2	5.28	0.72	-0.270
25.0	6.00	0.72	-0.250
		-----	-----
		AVE 0.70	AVE -0.280

$$dltWi - dltWi-1 = 0.7$$

$$S = dltW/dltD = (dltWi - dltWi-1)/(dltDi - dltDi-1)$$

$$= 0.7/2.8 = 0.25$$

$$dltW = S(dltD) + a$$

$$a = dltW - S(dltD)$$

$$E(a) = 0.28$$

Using the previous description, write equation 24:

$$dltW6 = 0.25(dltD) - 0.28, \text{ where } dltD \geq 5.6, V > 36 \quad (24)$$

4) Develop the formula for $dltD \geq 5.6$ and $V \leq 36$.

The change in $dltW$ will be based on $dltD \geq 5.6$ and $V > 36$ and is shown in Table 8.

Table 8 - Relationship of $dltW$ and $dltD$ when $dltD \geq 5.6$ and $V \leq 36$.

$dltD$	Q_i ($dltD_i -$ $dltD_{i-1}$)	W_a ($V <$ 3.05)	W_b ($36.6 -$ 76.2)	P_i ($dltW_a -$ $dltW_b$)	$degC$ ($P_i -$ P_{i-1})	$degF$ ($P_i -$ P_{i-1})
5.6	---	2.87	1.17	1.72	----	---
8.3	2.7	3.72	1.78	1.94	0.22	0.4
11.1	2.8	4.50	2.50	2.00	0.06	0.1
13.9	2.8	5.33	3.22	2.11	0.11	0.2
16.7	2.8	6.17	3.89	2.28	0.17	0.3
19.4	2.7	7.00	4.56	2.44	0.16	0.3
22.2	2.8	7.78	5.28	2.50	0.06	0.1
25.0	2.8	8.61	6.00	2.61	0.11	0.2

Part of Figure 11 is described in the following diagram:

Figure 12 - Diagram of the relationship between dltW and dltD when $D \geq 5.6$ and $V \leq 36$.

$A = P_i$ from Table 8, P_i can be assumed to increase at a constant rate :

$$P_i - P_{i-1} = 0.13$$

$$D/C = A/B, \quad dltD = C(A/B), \quad degC = \{((36-V)/36)B\},$$

$$dltD = \{((36-V)/36)A\}$$

From Table 8:

$$P_1 = 1.72 + 0.13(0)$$

$$P_2 = 1.72 + 0.13(8.3 - 5.6)/Q_i \quad (\text{set } Q_i = 2.78)$$

$$P_3 = 1.72 + 0.13(11.1 - 5.6)/Q_i$$

.

.

.

So for an arbitrary point P_x ,

$$P_x = 1.72 + 0.13(dltD - 5.6) / 2.78 = A$$

$$D = ((36 - V) / 36) A$$

$$= ((36 - V) / 36) (1.72 + 0.13(dltD - 5.6) / 2.78)$$

And for an arbitrary point x ,

$$dltW_x = 0.25 (dltD_x) - 0.28 + ((36 - V_x) / 36) (1.72 + 0.13 (dltD_x - 5.6) / 2.78) \quad (23)$$

5) Determine the formula for $0 < dltD \leq 5.6$ and $V > 36$. The following assumption is made:

Figure 13 - Diagram of the relationship between $dltW$ and $dltD$ when $0 < dltD \leq 5.6$ and $V > 36$.

$$dltW_x = 0.83 + A - \deg C$$

$$\text{Since } dltW = 1.1666 : (36.6 < V \leq 76.2, dltD = 5.6)$$

$$dltW = 0.8333 : (36.6 < V \leq 76.2, dltD = 0.0)$$

$$0.33 = W1 - W2$$

$C = D(C/D)$: set the slope of $PX = S = -C/B$

$$C = B(S), \quad B = Vx - 36, \text{ so } \deg C = (V - 36)S$$

The slope of W2Q2 is $-1.1/200$, and for W1Q1 is 0.

So when the line moves from W1Q1 to W2Q2 , the slope changes from 0 to $-1.1/200$. For an arbitrary line

PX, the slope of PX is: $S = ((5.6 - d1tD) / 5.6) (1.1 / 200)$

So $C = ((5.6 - d \ln D) / 5.6) (V - 36)$, and

$$\begin{aligned} dltW4 = & 0.83 + (dltD/5.6) 0.33 - (V-36) ((5.6-dltD) \\ & /5.6) 0.0055 \end{aligned} \quad (22)$$

$$dltWx = B + (dltD/5.6) 0.33 + 0.83$$

$$B = A(S), \text{ Set } S = B/A \text{ slope of } PX$$

$$\text{The slope of } N1W1 = (2.89 - 1.17) / 36 = 0.0478$$

$$\text{The slope of } N2W2 = 1.1 / 200 = 0.0055$$

$$\text{So, } S = 0.0055 + (dltD/5.6) (0.0478 - 0.0055)$$

$$A = 36 - Vx$$

$$\begin{aligned} \text{So } dltW3 = & (36 - Vx) (0.0055 + (dltD/5.6) (0.0478 - 0.0055) + \\ & 0.83 + (dltD/5.6) (0.33)) \end{aligned} \quad (21)$$

Corrected Effective Temperature

CET is used rather than ET in this study, since this index has a broader basis of application. Radiant heat is a commonly encountered environmental situation, and one which was present in the plants in which data was taken for this study. Differences in radiant heat sources, the use of fans or coolers, and whether the windows or doors were open produced differences between DB and GT.

The differences among CET, ETCR, and ETR are small and of marginal significance under most conditions. Additionally, CET is the most widely accepted measure and is easy to use. Therefore CET was selected for use in this study.

The following is an example of how close the indices

of ET, CET, ETCR, and ETR, and how air velocity affects them:

Set DB = 32.2 degC, WB = 21.1 degC, GT = 34.4 degC

	low air (V = 0)	high air V (unit of V:m/min) (V = 210)	
ET	25.3 degC	21.4 degC	
CET	26.1 degC	23.1 degC	
ETCR	26.3 degC	23.2 degC	Pseudo WB=21.8 degC
ETR	26.1 degC	22.8 degC	Corrected GT=33.8 degC

To determine the CET, value for WB was determined from NWB, GT, DB and V by using the appropriate equation (No. 19, 20, 21, 22, 23, or 24), NWB, DB, GT and V were read directly from the Rueter-Stokes Heat Stress Monitor. CET was determined from the following equations:

$$\text{If } 0 \leq V \leq 10, \text{ then } CET = WB + (GT - WB) * ((-0.1975) * WB + 8.275) / (((-0.1975) * WB + 8.275) + (6.85 - (-0.1975) * GT + 8.275)) \quad (25)$$

$$\text{If } 10 < V \leq 30, \text{ then } CET = WB + (GT - WB) * ((-0.1975) * WB + 8.275) / (((-0.1975) * WB + 8.275) + (6.85 - (-0.1975) * GT + 8.275)) - (2.55 - 0.1 * (GT - WB) - 0.07 * (WB - 5) * 5 / (GT - WB)) \quad (26)$$

$$\text{If } 30 < V, \text{ then } CET = WB + (GT - WB) * ((-0.1975) * WB + 8.275) / (((-0.1975) * WB + 8.275) + (6.85 - (-0.1975) * GT + 8.275)) - (2.55 - 0.1 * (GT - WB) - (0.07 * (WB - 5)) * 5 / (GT - WB)) * (0.0071 * V + 0.787)$$

$$* \text{LOG10} (2.5 * V - V ** 2 / 120 - 57.5)$$

(27)

The above equations were developed by using the following steps:

1) Select the possible range for WB, and GT, i.e. WB = (5,30), and GT = (10,60). Figure 15, which is a subpart of Figure 3 (page 8), expresses the range which was used to determine the CET.

Figure 15 - Partial of the CET chart used in this study.

following Figure 16.

Figure 16 - The relationship among GT, WB, and CET when $V = 0$.

Since $AB = EF$, then $DE / AB = DE / FE$.

Since triangle PHI is similar to triangle GDC,

then $DE / FE = GC / HI$

HG + CI = FJ + AF

$$HI = GC + AJ$$

$$DE = FE * GC / HI$$

$$= AB * GC / (GC + AJ)$$

$$GC = 8.275 - .1975 * WB$$

$$AB = GT - WB$$

$$AJ = 6.85 + 8.275 - (-.1975) * GT$$

So CET = WB (at point "C") + DE

$$= WB + (GT - WB) * ((-.1975) * WB + 8.275) / ((-.1975) * WB + 8.275) + (6.85 - (-.1975) * GT + 8.275)) \quad (25)$$

3) Determine the formula for the cases when $10 < V \leq 30$. Figure 17 illustrates the idea of the methodology:

Figure 17 - Diagram of CET when $V > 0$. Line DAC represents the same degree CET. Line EBC represents the observation.

$$\text{CET at B} = \text{CET at C} - AB$$

AB can be determined from heuristic interpolation method as described below:

Get the correspondent AB length (unit in degC) for several possible conditions. Data sets DIFF5, DIFF10, DIFF15, and DIFF20 have the following definition:

$$\text{DIFF}(X) = \{ \text{SET} \mid \text{CONDITION} \}$$

$$\text{DIFF5} = \{ AB(i) \mid GT-WB=5, WB=5, 10, 15, \dots, 30, V=30 \}$$

$$\text{DIFF10} = \{ AB(i) \mid GT-WB=10, WB=5, 10, 15, \dots, 30, V=30 \}$$

$$\text{DIFF15} = \{ AB(i) \mid GT-WB=15, WB=5, 10, 15, \dots, 30, V=30 \}$$

$$\text{DIFF20} = \{ AB(i) \mid GT-WB=20, WB=5, 10, 15, \dots, 30, V=30 \}$$

Using the above data with the interpolation method used to develop Equations 21, 22, 23, and 24, the following formula can be used to estimate the length of AB:

$$AB = 2.55 - .1 * (GT - WB) - .07 * (WB - 5) * 5 / (GT - WB)$$

So, when $10 < V \leq 30$, the CET can be estimated by the following formula:

$$\text{If } 10 < V \leq 30, \text{ then CET} = WB + (GT - WB) *$$

$$\begin{aligned}
 & ((-.1975) * WB + 8.275) / (((-.1975) * WB + 8.275) + \\
 & (6.85 - (-.1975) * GT + 8.275)) - (2.55 - .1 * (GT \\
 & - WB) - .07 * (WB - 5) * 5 / (GT - WB)) \quad (26)
 \end{aligned}$$

4) Determine the formula for the cases when $V > 30$. The CET scale in this V range is a logarithm of increasing V . Following the same analysis procedure used in developing Equation 26, the length of ED was determined from the following formula:

$$\begin{aligned}
 ED &= AB * (.0071 * V + .787) * \text{LOG10} (2.5 * V - \\
 & V ** 2 / 120 - 57.5) \\
 &= (2.55 - .1 * (GT - WB) - .07 * (WB - 5) * 5 \\
 & / (GT - WB)) * (.0071 * V + .787) * \text{LOG10} \\
 & (2.5 * V - V ** 2 / 120 - 57.5)
 \end{aligned}$$

So the CET at point E is:

$$\begin{aligned}
 \text{If } 30 < V, \text{ then CET} &= WB + (GT - WB) * (((-.1975) \\
 & * WB + 8.275) / (((-.1975) * WB + 8.275) + (6.85 - \\
 & (-.1975) * GT + 8.275)) - (2.55 - .1 * (GT - WB) - \\
 & (.07 * (WB - 5)) * 5 / (GT - WB)) * (.0071 * V + .787) \\
 & * \text{LOG10} (2.5 * V - V ** 2 / 120 - 57.5) \quad (27)
 \end{aligned}$$

These Equations 25, 26, and 27 were determined using the above four steps. The accuracy of these three equations was verified by selecting a set of widely

spread data points. The variation of the values was less than 0.3 degC, which is within the accuracy range of the graph.

Heat Stress Index

HSI is the only index which includes the effect of metabolic work load. Using the equations and coefficients shown in Table 3 (page 17), the equation is as follows:

$$\text{HSI} = \frac{\{K_r (GT + 0.24 (V^{**0.5})) (GT - DB) - T_{sk}\} + (V^{**0.6}) K_c \{DB - T_{sk}\} + M}{\{K_e (V^{**0.6}) (P_{sk} - P_a)\}} \quad (28)$$

In the above equation $P_{sk} = 42$, $T_{sk} = 35$, and other coefficients appropriate for standard clothes (i.e. $K_r = 6.6$, $K_c = 0.6$, $K_e = 1.2$) were selected for equation (25). P_a can be found as a function of DB and WB according to the following formula derived by Nishi (1977):

$$P_a = e^{**} (18.669 - 4030.18 / (WB + 235)) - 0.5 * (DB - WB) \quad (29)$$

Where, $e = 2.71828$, root of natural log.

New Effective Temperature

Three methods are available to obtain the NET. The first one is to program an ASHRAE psychrometric Chart (Gagge et al. 1971), and then use the same general technique described for obtaining CET. The second method is to use equation 1 (page 12), but this method utilizes an extremely inefficient iterative solution. Using SAS programming and assuming NET by iteration, would necessitate an ASHRAE Psychrometric Chart be stored in memory to determine the saturated vapor pressure of NET, and then, the vapor pressure would have to be checked in equation 1 to see if it was balanced. If equation 1 did not balance, the program would return to another assumption concerning the value of NET, and make an iteration of the same test. Since there are two unknown variables in equation 1, an iterative method of trial and error would be the only solution method available.

The best approach is to use equation 3, but this requires that four variables be known or found; P_a , W , Y and STO . P_a can be found from equation 29 with known values of DB and WB . W can be found from Table 1. Y can be derived from equation 10 and STO can be derived from equation 4.

In equation 10, h_c can be derived from equation 7, and h_r can be assumed to be equal to 4.7 as interpolated from the following set of conditions:

1) $T_0 = 20, T_{sk} = 35, h_r = 4.62$

2) $T_0 = 30, T_{sk} = 35, h_r = 4.85$

It is apparent that h_r is a factor that is not sensitive to T_0 .

I_{clo} can be derived from equation 9 and T_{cl} can be derived from equation 11. F_{cl} can be found from equation 12. I_{clo} was assumed to be 0.6 in a normal clothing situation. When one operates with some protective clothing I_{clo} is equal to 1; and this will cause only 1.8 degC of difference in T_{cl} . In order to get ST_0 , T_{sk} can be derived from equation 13 and DRY can be derived from equation 5. This procedure provided all the elements necessary to calculate the NET.

The next chapter will describe how to analyze data to understand the relationship between thermal indices and human unsafe behavior.

CHAPTER IV

STATISTICAL ANALYSIS

Data obtained during the observations was extracted as shown in Table 10 from the previously described data sheets, Figure 10. This permitted the use of the Statistical Analysis System (SAS, 1979) for data reduction and standard statistical analysis. Data collected in this study consists of 7017 observations. For a temperature range of approximately 30 degrees, this number of observation represents an average of 234 observations for each one degree data cell. The analysis procedure used is discussed below:

VARIABLES

The possible factors or independent variables and their levels which potentially influence the models are:

Thermal indices (T):

NWB (8 to 30 degC),

CET (8 TO 29 degC),

BB (= WGT) (6 to 35 degC),

WBGT (10 to 39 degC),

NET (14 to 50 degC),

RHSI (4 to 40, the range of HSI is from -100

to 900 and the formula, $RHSI = (HSI + 100) / 20$, was applied to rescale the HSI index to a smaller range 0 to 50 to enhance computer generated summary tables),
DB (12 to 50 degC).

Metabolic Work Load (WL) : 150 Kcal, 250 Kcal, 350 Kcal.

Period (P) : early a.m., late a.m., early p.m., late p.m.

Day (D) : Monday, Tuesday, Wednesday, Thursday, Friday

Machine (M): Lathe, Grinding, Welding, shipping & receiving, floor grinding, shake process, pouring, pattern making, drilling, bore miling, Numerical Control tapping, assembling, painting, fork lifting, thermal core making, chemical core making, ISO core making, mold shaking, core making, mulling, pin machining, crating, shot tumbling, and bench grinding.

Table 9 - Sample data for analysis using SAS (SAS, 1979)

DOSE	DATE	DAY	PLANT	RESERV	TIME	MACHINE	DO	HL	BR	SECTION	HEIGHT	CB	KB	GT	RIND	OSM	OSN	OSU
50	11217	MON	B	A	1005	SHAKE	2	2	7.6	5.0	5.0	3	3	3	8			
51	11217	THU	B	B	1040	SHUT	1	3	7.5	4.9	4.5	7	4	9	5			
52	11217	MON	B	A	1100	BENCH	2	3	7.5	7.0	7.0	4	5	2	100			
53	11217	THU	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
54	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
55	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
56	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
57	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
58	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
59	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
60	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
61	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
62	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
63	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
64	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
65	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
66	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
67	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
68	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
69	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
70	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
71	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
72	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
73	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
74	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
75	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
76	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
77	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
78	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
79	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
80	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
81	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
82	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
83	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
84	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
85	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
86	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
87	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
88	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
89	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
90	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
91	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
92	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
93	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
94	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
95	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
96	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
97	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			
98	11217	MON	B	A	1005	CHEMS	2	2	7.7	7.0	7.0	4	5	2	100			

Taxonomy (TA) : 1 (unsafe behavior related with body movement), 2 (unsafe behavior related with material handling), 3 (unsafe behavior related with transportation)

Observer (O) : C, R, and S, which represents the three data collectors utilized in this study.

For proper statistical analysis a decision concerning random and fixed factors must be made. Theoretically speaking, temperature is a random factor, but careful analysis shows that it is questionable to assume that temperature operates as a pure random variable, since a set of continuous temperatures exist for each index. For example, with CET, the temperature may take any value from 8 degC to 29 degC, with NET, the temperature range is from 14 degC to 50 degC with no blank cell, and with each of the other indices, a similar pattern is found. So the following description is more accurate: Temperature is originally a random factor, but the number of data points is so large that temperature covers a continuous range and behaves as if it is a fixed factor. Additionally, the difference between the results obtained from two models, one being a fixed model and the other a mixed model with temperature as a random factor, was too small to be identified. The analysis of the fixed factorial model

was selected for use in this study.

The dependent variable in this study is human unsafe work behavior.

MODELS

A significant statistical analysis is based on a well designed model. ANOVA (Analysis of Variance) and GLM (General Linear Model) are two methods used here to evaluate the research data. In using either of these two methods, the large variance of Unsafe Behavior Rate (UBR) becomes the first problem to be solved.

$$UBR = \text{Unsafe Observations} / \text{Total Observation} \quad (30)$$

As noted by Ramsey and Burford (1980), it is well known that the number of occurrences per unit, (e.g. UBR) often follows a Poisson distribution, where such response variables are not only non-normal but variances and means that are equal. When proportions or percentages are used as the response variable, the data are binomial and again variances are related to means and basic assumptions of ANOVA and GLM do not hold. Some studies have shown that lack of normality is not too serious in applying the ANOVA or GLM technique, but most statisticians recommend that a

transformation be made on the original data if it is known to be non-normal. Recommendations for proper transformations given in Davies, 1954, indicate that for proportional data (P) which follows a binomial distribution, an $\arcsin(P^{1/2})$ transformation is appropriate as in Equation 31:

$$USBR = \text{ARCSIN} (UBR^{1/2}) \quad (31)$$

This transformation may be derived as follows. If the probability of occurrence of a certain event, such as the unsafe behavior of total behavior, is p , the expected proportion of such events in n trials will be p and the variance of the proportion found will be given by:

$$\text{Var} (x) = (p * (1 - p)) / n, \quad E(x) = p$$

In order to find a function f , such that $\text{Var} (f(x)) = \text{constant}$, for a certain value x , the first order Taylor's expansion is:

$$f(x) = f(a) + (x-a) f'(a), \text{ where } a \text{ is a given point}$$

$$\text{Set } a = E(x) = p$$

$$f(x) = f(p) + (x-p)f'(p)$$

$$E(f(x)) = E(f(p)) + E((x-p)f'(p))$$

$$= f(p) + E(x-p)E(f'(p)), \text{ since } E(x-p)=0$$

$$= f(p)$$

$$\text{Var}\{f(x)\} = E\{f(x)^2\} - (E\{f(x)\})^2$$

$$\text{since } (E\{f(x)\})^2 = (f(p))^2$$

$$\begin{aligned} f(x)^2 &= (f(p) + (x-p)f'(p))^2 \\ &= (f(p))^2 + 2(x-p)f'(p)f(p) \\ &\quad + ((x-p)f'(p))^2 \end{aligned}$$

$$\begin{aligned} E\{f(x)^2\} &= f(p)^2 + E\{x-p\}E\{2f'(p)f(p)\} \\ &\quad + E\{((x-p)f'(p))^2\} \\ &= (f(p))^2 + (E\{(x-p)^2\}) \\ &\quad (E\{(f'(p))^2\}) \end{aligned}$$

$$\begin{aligned} \text{Then, } \text{Var}\{f(x)\} &= (f(p))^2 + (E\{(x-p)^2\})(E\{(f'(p))^2\}) \\ &\quad - (f(p))^2 \\ &= E\{(x-p)^2\} E\{(f'(p))^2\} \\ &= \text{Var}(x) * (f'(p))^2 \\ &= (p(1-p)/n) * (f'(p))^2 \\ &= \text{constant } (k) \end{aligned}$$

$$(f'(p))^2 = nk/(p(1-p))$$

$$f'(p) = (nk/(p(1-p)))^{1/2}$$

$$\begin{aligned} f(p) &= \text{Integration of } (nk/(p(1-p)))^{1/2} \\ &= \text{Arcsin}(p^{1/2}) \end{aligned}$$

So an $\text{Arcsin}(p^{1/2})$ is a good transformation of the raw data.

The second problem encountered is that of sample size. In either ANOVA or GLM model, the number of replications in each cell needs to be greater than 1.

This study uses each different degC as a cell, and each cell contains 3 measures of observed unsafe behavior. (i.e. calculate the USBR for each 1/3 degC, then 3 USBRs can be obtained for each degC). In order to meet the confidence level and the accuracy requirement that establish as a reasonable criteria for this study, equation 32 (Miller & Freund, 1977) is used to determine what sample size should be:

$$n = P(1 - P) ((Z / E) ** 2) \quad (32)$$

n : sample size

Z : the coefficient of a 95% confidence interval
(= 1.96)

E : the desired accuracy (+0.1 to -0.1)

P : the mean of USBR (= 0.1)

So, $n = 0.1 * 0.9 * ((1.96/0.1) ** 2) = 35$. This means that for 25 degree C for a particular heat stress index, that 2625 (= 3 * 25 * 35) observations are sufficient for a USBR = 0.1 with 0.1 level of accuracy and 95% degree of confidence. On the average, 35 observations were made in each replication with the number of observation ranging from 20 to 50.

Several models were tried to determine the major factors influencing USBR, and also the best method for grouping data to obtain an adequate sample size. The dependent variables are labeled USBR1, USBR2, USBR3,

USBR11, USBR15, and USBR18 and the methods for grouping the data are described in the following Table 10 and Figures 18, 19, 20, 21, 22, and 23. The methods used for each of these models are described in Table 10. The methods listed in Table 10 specify the specific grouping approaches which were utilized. For example, model A used an ANOVA which included the factors of thermal indices (T), Work Load (WL), Period (P), and Day (D) in the format displayed in Figure 18. This is defined as Model USBR1, where $USBR1 = T + WL + P + D$. This grouping of data allowed the calculation of percent of behaviors observed which were related as unsafe within each combination cell of (T, WL, P, D). This grouping is identified as the formula $USBR1 = 1 / (T, WL, P, D)$.

Table 10 - Brief table showing the analysis in models A through F.

MODEL I.D.	MODEL	FORMULA	FIG. NO.
A	$USBR1 = T + WL + P + D$	$USBR1 = 1 / (T, WL, P, D)$	18
B	$USBR2 = T + M + T * M$	$USBR2 = 1 / (T, M)$	19
C	$USBR3 = T + TA + WL$	$USBR3 = 1 / (T, TA, WL)$	20
D	$USBR11 = T, T^{**2} + T$	$USBR11 = 1 / (T, P, WL)$	21
E	$USBR15 = T, T^{**2} + T$	$USBR15 = 1 / (T, WL)$	22
F	$USBR18 = T, T^{**2} + T$	$USBR18 = 1 / (T, TA)$	23

Model B: ANOVA with thermal indices (T) and machine (M) factors.

Model USBR2 = T + M + T*M

Formula USBR2 = 1 / (T, M)

Figure 19 describes this model in table format.

MACHINE USBR2	ANOVA with T, M in USBR2				
	GRIND	DRILL	LATHE	NCTAP	BQ
15	.01 .12 .31	.22 .11 .32	.17 .15 .04	.21 - - - - - -	- - -
16	.32 .51 .11	.01 .21 1			
17	.31 1				

Figure 19 - ANOVA table for model B.

Model C: ANOVA with thermal indices (T), taxonomy (TA), and work load (WL) factors.

Model USBR3 = T + TA + WL

Formula USBR3 = 1 / (T, TA, WL)

Figure 20 describes this model in table format.

TAXONOMY USBR3	ANOVA with T,WL,TA in USBR3								
	BODY MOV.(1)			MTL' HDLG (2)			TRANS (3)		
	1	2	3	1	2	3	1	2	3
15	.12	.31	.21	.32	.35	---	---	---	
	.31	.28	.13	.42	.41	---	---	---	
	.37	.29	.36	.40	--	--	--	--	
16	.35	.31	.27	.48	--	--	--		
	.13	.01	.13						
	.24	.70							
17	.10								

Figure 20 - ANOVA table for model C.

Model D: Regression according to the 4 time periods. (i.e. divide the whole data set into 4 subdata sets according to the periods and do the GLM analysis in each subdata set.)

Model USBR11 = T, T**2 + T

Formula USBR11 = 1 / (T, P, WL)

Figure 21 describes this model in table and diagram.

Figure 21 - GLM table and diagram for model D.

Model E: Regression according to the 3 work loads.
 Model $USBRI5 = T, T^2 + T$
 Formula $USBRI5 = 1 / (T, WL)$
 Figure 22 describes this model in table and diagram.

Figure 22 - GLM table and diagram for model E.

Model F: Regression according to the 3 taxonomies.
 Model $USB18 = T, T^2 + T$
 Formula $USB18 = 1 / (T, TA)$
 Figure 23 describes this model in table and diagram.

Figure 23 - GLM table and diagram for model F.

Using the array of models described in this chapter, the results and evaluation of each model will be discussed in the following chapter.

CHAPTER V

RESULTS AND DISCUSSION

To evaluate the effectiveness of each model, the following methods were used: First, the significance level of each R-square value (square of correlation coefficient) was used to judge the associated model. This is directly available from the SAS programming output (i.e. "PR > F" in the GLM or ANOVA result table). Second, the R-square values were also used. A model with the larger sample size and the smaller R-square could be in the same significance level with the other model with the smaller sample size and the larger R-square. The summary of R-square, sample size, and PR > F of each index are shown in Table 11. The R-square value of each model is shown in the first row of each box. The sample size is in the second row, and the PR>F is in the third row. Each column in Table 11 shows statistical results for one of the thermal indices. A brief description of each model is provided in the left most column. For example, data bounded in row and column by "*", can be interpreted as follows: Model A, with dependent variable USBR1, thermal index DB, ANOVA for T (i.e. DB), WL, P, and D. The R-square of this model is .0338, the sample size is 1197, and the PR>F is .0001.

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		1.0950	1.0433	1.0724	1.0414	1.0913	1.1621	1.0676	
2nd		67	45	49	49	55	72	68	
		1.0390	1.3862	1.1711	1.3698	1.0790	1.0021	1.0994	

(E)		1.0348	1.1218	1.0095	1.1035	1.0023	1.0274	1.0920	
1st		82	55	57	57	64	82	57	
U		1.0913	1.0084	1.4659	1.0138	1.7066	1.1347	1.0206	
S	WL=1	-----							
B		1.1489	1.1330	1.2281	1.1531	1.2419	1.0647	1.2085	
R	2nd	82	55	57	57	64	82	57	
15		1.0016	1.0228	1.0008	1.0104	1.0002	1.0689	1.0016	

		1.00001	1.0710	1.0511	1.0383	1.0054	1.0025	1.0699	
1st		86	54	55	61	66	91	79	
		1.9831	1.0492	1.0940	1.1272	1.5548	1.6338	1.0178	
WL=2		-----							
		1.0933	1.1208	1.0516	1.1538	1.0448	1.0252	1.0773	
2nd		86	54	55	61	66	91	79	
		1.0164	1.0352	1.2458	1.0072	1.2313	1.3216	1.0451	

		1.00098	1.0991	1.0175	1.0056	1.0051	1.0117	1.0265	
1st		64	44	49	50	55	77	66	
		1.8045	1.0352	1.3593	1.6024	1.6004	1.3467	1.1883	
WL=3		-----							
		1.0177	1.1163	1.0187	1.0951	1.0065	1.0137	1.0265	
2nd		64	44	49	50	55	77	66	
		1.5740	1.0745	1.6416	1.0910	1.8410	1.5958	1.4234	

(F)		1.1620	1.1318	1.0669	1.0432	1.0359	1.3638	1.3861	
1st		67	46	45	45	53	78	63	
U		1.0007	1.0121	1.0827	1.1656	1.1702	1.0001	1.0001	
S	TA=1	-----							
B		1.5325	1.3084	1.5067	1.5002	1.5769	1.4781	1.4081	
R	2nd	67	46	45	45	53	78	63	
18		1.0001	1.0003	1.0001	1.0001	1.0001	1.0001	1.0001	

		1.0990	1.0329	1.0063	1.0169	1.0000	1.0716	1.2294	
1st		47	35	33	34	37	49	40	
		1.0294	1.2899	1.6542	1.4568	1.9967	1.0603	1.0015	
TA=2		-----							
		1.5142	1.1549	1.6275	1.4110	1.5096	1.6538	1.4144	
2nd		47	35	33	34	37	49	40	
		1.0001	1.0622	1.0001	1.0002	1.0001	1.0001	1.0001	

		1.1739	1.3510	1.0288	1.1042	1.0106	1.2914	1.7794	
1st		30	19	20	23	26	31	26	
		1.0196	1.0059	1.4624	1.1240	1.6101	1.0014	1.0001	

		1.5344	1.6973	1.5230	1.4161	1.6835	1.8716	1.7837	
2nd		30	19	20	23	26	31	26	
		1.0001	1.0001	1.0013	1.0035	1.0001	1.0001	1.0001	

Analysis of Table 11 results in the following description. The values of $PR>F$ are consistently larger in model D and E than in the other models, thus indicating their poor suitability for predicting USBR. The comparison of the R-squares for model A, B, C, and F, indicates that models C and F seem to be the best two models in the prediction for the USBR because the R-squares in model A and B are comparatively smaller. For models D, E, and F, changing the T factor from first order regression to second order regression, results in significant improvements to all thermal indices.

In the SAS outputs (which are not shown here because such a Table would be extremely large), the most significant factors for the Unsafe Behavior Rate are thermal indices (T) and Work Load (WL). Performing a stepwise regression analysis with all factors in WBGT index, the first factor entering the model is WL with R-square equal to 0.3385. The second factor is T with its R-square equal to 0.3508. Other factors have only a very small R-square value that does not exceed 5% significance level.

Since WL appears to play a major role in predicting USBR, another set of models (G through M), shown in Table 12, were selected to incorporate their

influences. These models evaluate how much improvement is obtained from the first and second order calculations of T when work load is included. That will also help to select the USBR formula appropriate for each model.

Table 12 - Brief formula showing the analysis in model G through M. USBR1 = T , $T+T^{**2}$, $T+WL$, $T+T^{**2}+WL$, are four different analysis as: USBR1 = T , USBR1 = $T+T^{**2}$, USBR1 = $T+WL$, and USBR1 = $T+T^{**2}+WL$.

MODEL I.D.	MODEL

G	USBR1 = T , $T+T^{**2}$, $T+WL$, $T+T^{**2}+WL$
H	USBR2 = T , $T+T^{**2}$, $T+WL$, $T+T^{**2}+WL$
I	USBR3 = T , $T+T^{**2}$, $T+WL$, $T+T^{**2}+WL$
J	USBR11 = T , $T+T^{**2}$, $T+WL$, $T+T^{**2}+WL$
K	USBR15 = T , $T+T^{**2}$, $T+WL$, $T+T^{**2}+WL$
L	USBR18 = T , $T+T^{**2}$, $T+WL$, $T+T^{**2}+WL$
M	USBR3 = T , $T+T^{**2}$, $T+T^{**2}+T^{**3}$

The R-squares, sample sizes, and "PR > F" in model G through M are shown in Table 13.

Table 13 - Result of models G through M. The method of reading this Table is the same as Table 11.

```

-----
| R - SQUARE |
| SAMPLE SIZE |
| PR > F      |
-----

```

MODEL	DB	NWB	CET	BB	WBGT	NET	RHSI
(G)	.0043	.0057	.0050	.0076	.0028	.0070	.0016
T	1197	944	1041	932	1010	1279	1132
U	.0234	.0205	.0225	.0077	.0938	.0027	.1847
S							
B	.0058	.0135	.0156	.0076	.0131	.0089	.0024
R T**2	1197	944	1041	32	1010	1279	1132
1 +T	.0316	.0016	.0003	.0282	.0013	.0034	.2516
	.0293	.0283	.0204	.0328	.0227	.0253	.0150
T+WL	1197	944	1037	928	1006	1275	1129
	.0001	.0001	.0001	.0001	.0001	.0001	.0002
	.0301	.0347	.0288	.0329	.0301	.0268	.0152
T**2	1197	944	1037	928	1006	1275	1129
+T+WL	.0001	.0001	.0001	.0001	.0001	.0001	.0007
(H)	.0009	.0090	.0060	.0065	.0029	.0040	.0014
T	1757	1350	1408	1386	1425	1764	1488
U	.2107	.0005	.0036	.0027	.0417	.0081	.1480
S							
B	.0014	.0108	.0068	.0069	.0066	.0047	.0021
R T**2	1757	1350	1408	1386	1425	1764	1488
2 +T	.3043	.0007	.0082	.0083	.0092	.0151	.2031
	.0207	.0263	.0214	.0291	.0291	.0231	.0215
T+W	1757	1350	1402	1380	1419	1758	1482
	.0001	.0001	.0001	.0001	.0001	.0001	.0001
	.0208	.0275	.0218	.0302	.0308	.0235	.0217
T**2	1757	1350	1404	1380	1419	1758	1482
+T+WL	.0001	.0001	.0001	.0001	.0001	.0001	.0001
(I)	.0058	.0125	.0016	.0040	.0013	.0830	.2698
T	239	181	180	190	211	268	216
U	.2389	.1329	.5947	.3862	.6016	.0001	.0001
S							
B	.2209	.1219	.1708	.1225	.1905	.2296	.2892
R T**2	239	181	180	190	211	268	216
3 +T	.0001	.0001	.0001	.0001	.0001	.0001	.0001
	.4012	.1740	.3789	.3606	.3508	.3627	.4633

Table 13 - continued

T+WL	239	181	180	190	211	268	216
	.0001	.0001	.0001	.0001	.0001	.0001	.0001
	.5079	.2662	.4711	.4544	.4271	.4596	.4900
T**2	239	181	180	190	211	268	216
+T+WL	.0001	.0001	.0001	.0001	.0001	.0001	.0001
(J)	.0026	.0200	.0089	.0161	.0012	.0052	.0002
T	562	409	434	426	471	592	496
U	.2258	.0041	.0497	.0087	.4495	.0798	.7318
S							
B	.0031	.0415	.0119	.0191	.0079	.0053	.0018
R T**2	562	409	434	426	471	592	496
11 +T	.4332	.0002	.0760	.0169	.1564	.2109	.6395
	.0215	.0490	.0263	.0452	.0369	.0272	.0193
T+WL	558	405	430	422	467	588	494
	.0024	.0001	.0033	.0001	.0002	.0003	.0082
	.0218	.0697	.0290	.0491	.0418	.0273	.0198
T**2	558	405	430	422	467	588	494
+T+WL	.0068	.0001	.0059	.0001	.0002	.0012	.0200
(K)	.0001	.0856	.0227	.0316	.0004	.0014	.0184
T	238	159	167	174	191	256	205
U	.8652	.0002	.0511	.0187	.7834	.5468	.0518
S							
B	.0186	.0941	.0302	.0922	.0045	.0087	.0226
R T**2	238	159	167	174	191	256	205
15 +T	.1085	.0002	.0798	.0002	.6523	.3301	.0984
	.0530	.1022	.0573	.0734	.0735	.0579	.0776
T+WL	238	155	163	170	187	252	204
	.0018	.0003	.0086	.0016	.0009	.0006	.0003
	.0705	.1094	.1659	.1412	.0751	.0645	.0795
T**2	238	155	163	170	187	252	204
+T+WL	.0008	.0009	.0121	.0001	.0026	.0010	.0009
(L)	.0888	.0355	.0078	.0047	.0132	.2715	.4072
T	145	102	100	104	118	160	131
U	.0003	.0565	.3792	.4894	.2127	.0001	.0001
S							
B	.4547	.1737	.2858	.2918	.3963	.5149	.4615
R T**2	145	102	100	104	118	160	131
18 +T	.0001	.0001	.0001	.0001	.0001	.0001	.0001
	.1090	.1359	.0451	.0318	.0407	.2717	.4075
T+WL	145	102	100	104	118	160	131
	.0003	.1605	.1045	.1925	.0896	.0001	.0001
	.4558	.1743	.3018	.2966	.4021	.5152	.4650
T**2	145	102	100	104	118	160	131
+T+WL	.0001	.0003	.0001	.0001	.0001	.0001	.0001

(M)	.0058	.0125	.0016	.0041	.0013	.0830	.2698	
T	239	181	180	190	210	268	216	
U	.2389	.1329	.5947	.3862	.6016	.0001	.0001	
S								
B	.2209	.1219	.1708	.1225	.1905	.2296	.2892	
R T**2	239	181	180	190	211	268	216	
3 +T	.0001	.0001	.0001	.0001	.0001	.0001	.0001	
T**3	.2217	.2069	.1914	.1597	.2343	.2849	.2922	
+T**2+	239	181	180	190	211	268	216	
T	.0001	.0001	.0001	.0001	.0001	.0001	.0001	

From Table 13, the sample sizes of USBR1 (i.e. model G) and USBR2 (i.e. model H) are comparatively very large (i.e. > 1000). In those two models (model G and H), there are only 7 observations in each replication on the average. (i.e. Total observations/sample size = $7000/1000 = 7$). Using 7 observations to determine an USBR results in a very low level of confidence. Applying equation 32 (page 59) with $n=7$, $P=0.1$, and $E=0.1$, the Z becomes only 0.88, which from the Normal Distribution Table yields a confidence interval of 62%. Therefore USBR1 and USBR2 will not be used in this study. The same situation occurs for USBR11, i.e. model J in Table 13, which shows an average sample size of 500. Using the same assumption (i.e. $n=7000/500=14$, $P=0.1$, and $E=0.1$), the Z equals to 1.25 and the confidence interval is 79%. Therefore, USBR11 was also not used for this study.

From Table 13, Models I and L show a higher R-square

in comparison with other models; on the average R-squares in model I and L are 0.4 greater than that in another models. Therefore USBR3 (i.e. model I) and USBR18 (i.e. model L) represent the best two figures for predicting USBR.

USBR18 yields 120 replications on the average and about 60 observations within each replication (7000/120). This sample size is considerably larger than is necessary for data following a normal distribution. The statistical principle is that with an acceptable number of observations within each replication, the larger the number of replications the higher will be the accuracy of the model. In USBR3 (i.e. model I), the average number of replications is 210 and this gives about 30 observations for each replication. Applying the same assumption to equation 32, the Z will be equal to 1.88 and this results in a confidence level of 94%. This analysis suggests the selection of USBR3 as the best model for the final evaluation of the experimental variables.

Examination of model M in Table 13, indicates the following important characteristics. As T was changed from the first order to the second order, every index reached the 0.0001 significance level. As T was increased from the second order to the third order, the

R-square values increased very little (i.e. 0.035 on the average). Therefore a third order model offers very little improvement for use as a predictor of unsafe behavior for all indices.

Although USBR3 appears to be the best model for analyzing the data. All the indices in USBR3 exhibit high correlation coefficients and F-values which are statistically significant with the "PR > F" equal 0.0001. In order to identify the better indices, one acceptable approach is to add a disturbing factor to the model. For example, if in the ANOVA of USBR3 to T, the R-square = 0.100 and the PR>F = 0.01, then adding a disturbing factor, say period, to this model, results in R-square = 0.121 and the PR>F = 0.03. That is because period is a poor response factor to unsafe behavior rate. When factors such as period get into the model, the confidence level of the whole model will be reduced. The disturbing factor will have much less effect on confidence level for the well related indices (e.g. HSI) than for the poorly related indices (e.g. BB). The following are the descriptions of models N through P which utilize period as a disturbing factor, and the result is shown in Table 14. The SAS computer program of this analysis is shown in the appendix.

Model N. ANOVA of thermal indices, work load,

observer, taxonomy, day, period, and machine. i.e. treat each different degree of thermal index (T) as a different level. Starting with the thermal indices (T), an ANOVA of USBR3 vs T can be conducted. Subsequently the ANOVA of USBR3 vs T and WL, ... Add those factors one by one into the ANOVA analysis to evaluate the correlation coefficients of each index. The brief formulas of each test are as follows: USBR3 = T, T+WL, T+WL+O, T+WL+O+TA, T+WL+O+TA+D, T+WL+O+TA+D+P, T+WL+O+TA+D+P+M.

Model O. The same analysis as in model N, but treat factor thermal index (T) as an unique level factor.

Model P. The same process as used in Model O but with the second order of thermal index (T^2). The brief formulas of each test are as follows: USBR3 = $T+T^2$, $T+T^2+WL$, $T+T^2+WL+O$, $T+T^2+WL+O+TA$, $T+T^2+WL+O+TA+D$, $T+T^2+WL+O+TA+D+P$, $T+T^2+WL+O+TA+D+P+M$.

Table 14 - Result of test for N, O, and P. The method of reading this Table is the same as Table 11.

DEPENDENT VARIABLE : URBR3

R - SQUARE								
SAMPLE SIZE								
PR > F								

MODEL	DB	NWB	CET	BB	WBG	NET	RHSI	

(N)	.2868	.3790	.2532	.2396	.3145	.3772	.5100	
T	239	181	180	190	211	268	216	
	.0001	.0001	.0001	.0001	.0001	.0001	.0001	

T+WL	.2926	.3879	.2769	.2585	.3386	.3962	.5023	
	239	181	180	190	211	268	216	
	.0001	.0001	.0001	.0001	.0001	.0001	.0001	

T+WL+O	.2990	.4008	.2791	.2588	.3515	.4040	.5077	
	239	181	180	190	211	268	216	
	.0001	.0001	.0001	.0002	.0001	.0001	.0001	

T+WL+O	.3104	.4027	.2901	.2599	.3501	.4108	.5090	
+TA	239	181	180	190	211	268	216	
	.0001	.0001	.0002	.0009	.0001	.0001	.0001	

T+WL+O	.3197	.4284	.2981	.2742	.3597	.4142	.5131	
+TA+D	239	181	180	190	211	268	216	
	.0001	.0001	.0004	.0013	.0001	.0001	.0001	

T+WL+O	.3205	.4917	.3025	.2882	.3605	.4233	.5178	
+TA+D+P	239	181	180	190	211	268	216	
	.0002	.0008	.0001	.0019	.0001	.0001	.0001	

T+WL+O	.3724	.5501	.4154	.4016	.4201	.5007	.6057	
+TA+D+P	239	181	180	190	211	268	216	
+M	.0030	.0001	.0022	.0021	.0001	.0001	.0001	

(O)	.0058	.0125	.0016	.0040	.0013	.0830	.2698	
T	239	181	180	190	211	268	216	
	.2389	.1329	.5947	.3862	.6016	.0001	.0001	

T+WL	.0362	.0469	.0031	.0099	.0219	.0863	.2656	
	239	181	180	190	211	268	216	

Table 14 - continued

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	.0328	.0351	.9056	.6046	.2010	.0001	.0001	
T+WL+O	.0726	.0478	.0130	.0191	.0924	.1007	.2788	
	239	181	180	190	211	268	216	
	.0034	.1211	.8072	.6100	.0013	.0001	.0001	
T+WL+O	.0857	.0540	.0240	.0385	.1094	.1232	.2820	
+TA	239	181	180	190	211	268	216	
	.0072	.2818	.8341	.5095	.0024	.0001	.0001	
T+WL+O	.0990	.0794	.0343	.0547	.1250	.1995	.2860	
+TA+D	239	181	180	190	211	268	216	
	.0192	.2096	.8699	.5018	.0042	.0001	.0001	
T+WL+O	.1079	.2802	.0504	.1453	.1404	.2097	.3507	
+TA+D+P	239	181	180	190	211	268	216	
	.0233	.0001	.7797	.0120	.0037	.0001	.0001	
T+WL+O	.1851	.3720	.2311	.2583	.2588	.3149	.4014	
+TA+D+P	239	181	180	190	211	268	216	
+M	.0593	.0001	.1236	.0218	.0033	.0001	.0001	
(P)	.2209	.1219	.1708	.1225	.1905	.2296	.2892	
T**2+T	239	181	180	190	211	268	216	
	.0001	.0001	.0001	.0001	.0001	.0001	.0001	
T**2+T+	.2261	.1399	.1786	.1345	.2179	.2384	.2826	
WL	239	181	180	190	211	268	216	
	.0001	.0001	.0001	.0001	.0001	.0001	.0001	
T**2+T+	.2324	.1405	.1817	.1361	.2347	.2399	.2894	
WL+O	239	181	180	190	211	268	216	
	.0001	.0002	.0001	.0001	.0001	.0001	.0001	
T**2+T+	.2472	.1476	.1932	.1416	.2554	.2494	.2909	
WL+O+TA	239	181	180	190	211	268	216	
	.0001	.0010	.0001	.0010	.0001	.0001	.0001	
T**2+T+	.2542	.1693	.2004	.1538	.2627	.2790	.2954	
WL+O+TA	239	181	180	190	211	268	216	
+D	.0001	.0013	.0001	.0023	.0001	.0001	.0001	
T**2+T+	.2583	.3152	.2046	.1741	.2628	.2846	.3062	
WL+O+TA	239	181	180	190	211	268	216	
+D+P	.0001	.0001	.0003	.0028	.0001	.0001	.0001	
T**2+T+	.3188	.4081	.3164	.2527	.3523	.3943	.4026	
WL+O+TA	239	181	180	190	211	268	216	
+D+P+M	.0001	.0001	.0028	.0289	.0001	.0001	.0001	

Models N and P of Table 14, show that each index produces a low "PR > F" (all of them are lower than 0.01). This indicates that all the indices have a very good predictive relationship with human safety behavior. The indices which exhibit the highest of predictability, however, are HSI, NET, WBGT and DB in Model O of Table 14.

Generally speaking, the best predictor is HSI. HSI is well related to Unsafe Behavior Rate in both the linear and the second order models. It is related to USBR3 with not only a very low "PR > F" but also with the highest R-square. HSI is the only index which includes the factor of metabolic work load, and this no doubt contributes to its ability to predict human safety behavior. Both Table 13 on page 72 and the stepwise regression described on page 70 support the positive relationship between WL and Unsafe Behavior Rate. When work load is increased, USBR increased and based upon its equations (eq. 28), HSI is also increased. So the strong linear relationship indicated between HSI and USBR is one that is expected. The second order relationship is a better predictor than the linear. These regressions between HSI and USBR3 are shown in Figures 24 and 25.

Figure 24 - Linear Regression of USBR vs. HSI.

USBR3

1.6 —

1.5 —

1.4 —

1.3 —

1.2 —

1.1 —

1.0 —

0.9 —

0.8 —

0.7 —

0.6 —

0.5 —

0.4 —

0.3 —

0.2 —

0.1 —

0.0 —

5

10

15

20

25

30

$$\text{USBR3} = 0.207 - 0.002\text{RHSI} + 0.001\text{UHSI}^{**2}$$

$$R = 0.538$$

$$N = 216$$

$$\text{PR} > \text{F} : 0.0001$$

$$\text{RHSI} = \frac{\text{HSI} + 100}{20}$$

TEMPERATURE IN REVISE HSI SCALE

Figure 25 - Second Order Regression of USBR vs. HSI.

Among the pure thermal indices, NET appears to be the best predictor. It demonstrates high significance level with USBR3 on both linear and second order regression models. From Table 14, it may be observed that in the linear regression of T and USBR3, NET is the only index which is significant at 1% " $PR > F$ " (See Figure 26). The second order regression of NET to USBR3 however, significantly improves the R-square (0.288 vs 0.479). So the second order model for NET show in Figure 27 is the better model to predict the human unsafe behavior. Another strong evidence of NET being a good predictor is that NET has not only the highest sample size among all the indices, but also the highest R-square.

Although the analysis identifies HSI or NET as the best predictors of human unsafe behavior, the use of these indices is considerably more complicated than the use of WBGT or DB, which can be obtained relatively easily and which provide a comparable method for estimating unsafe behavior. To calculate HSI the metabolic work load must be measured or estimated. To calculate NET the sweat rate or skin wettedness must be estimated or measured, clothing values must be measured, the mean radiant temperature must be measured, etc. The necessity of obtaining this extra information affects the convenience and practical usage

of both HSI and NET.

The WBGT can be obtained from direct reading instruments (eg, the Rueter-Stokes Heat Stress monitor used in this study) or with simple instruments to measure DB, GT, and NWB. DB can be obtained with a shielded thermal sensor in the air. These practical reasons support DB and WBGT as predictors for the human safety behavior. Although the linear regressions for DB and WBGT are marginally meaningful, the second order regression provides a predictor for unsafe behavior which is as good for practical purposes as either NET or HSI. The regression diagrams of USBR3 vs. DB and USBR3 vs. WBGT are shown in Figure 28, 29, 30, and Figure 31.

Figure 26 - Linear Regression of USBR vs. NET.

Figure 27 - Second Order Regression of USBR vs. NET.

USBR3
1.6

87

Figure 28 - Linear Regression of USBR vs. DB.

Figure 29 - Second Order Regression of USBR vs. DB.

USBR3
1.5

Figure 30 - Linear Regression of USBR vs. WBGT.

Figure 31 - Second Order Regression of USBR vs. WBGT.

CHAPTER VI

SUMMARY, CONCLUSIONS AND RECOMMENDATION

SUMMARY

The purpose of this research was to describe the influence which the environmental temperature (heat or cold) exerts upon the safety behavior of workers, and to determine the efficiencies of the major thermal indices at predicting workers' safety behavior.

Actual temperature and safety sampling data were taken in two local plants for a five month period (July through November) in conjunction with the NIOSH project, Effects of Heat on Safe Work Behavior (Ramsey and Burford, 1980). The data was converted to the following thermal indices: Dry Bulb Temperature (DB), Natural Wet Bulb Temperature (NWB), Corrected Effective Temperature (CET), Heat Stress Index (HSI - B & H), Wet Bulb Globe Temperature (WBGT), Wet Globe Temperature (WGT), and New Effective Temperature (NET). In the above process equations were developed to estimate WB as a function of NWB and CET as a function of GT, WB, and V.

A comprehensive statistical analysis of these thermal indices with the associated safety behavior

data was then conducted. The dependent variable was unsafe behavior rate. The independent variables were temperature, metabolic work load, day of week, period of day, machine, observer, and unsafe behavior taxonomy. ANOVA and General Linear Model analyses were utilized to determine the relationships between heat stress and human safe behavior, and to evaluate which thermal indices were the better predictors of human safe behavior.

CONCLUSIONS

The same general pattern was observed for each of the thermal indices. The second order regression of each thermal index shows the Unsafe Behavior Rate to be lowest in the middle range of each index. (i.e. 0 to 70 HSI, 25 to 33 degC of NET, 27 to 33 degC of DB, 19 to 26 degC of WBGT, 17 to 23 degC of CET, 16 to 22 degC of WGT, and 15 to 21 degC of NWB.) Increasing levels of unsafe behavior were noted both above and below these midrange values. The pattern is summarized as a composite typical curve in Figure 32. The pattern of safe behavior is consistent with the commonly accepted arousal theory which has been used to help explain many human performance activities as a function of physical environments. Safety behavior which is the inverse of the unsafe behavior data collected in this study follows the arousal curve relationship with safe

behavior being at maximum levels at midrange conditions, but becoming less safe at thermal conditions either above or below this midrange.

The potential accident rate (Unsafe Behavior Rate) is directly related to the number of accident. Since the unsafe behavior rate represents behavior which leads to accidents, Figure 32 typifies not only unsafe behavior but also accident occurrence. In applying this result to a work place, it would first be necessary a firm to establish a dollar cost per accident. Whenever the thermal index gets below A or above B in Figure 32, not only is the unsafe behavior increased, but the rate of increase is amplified. This means that there will be an increasing cost of accidents beyond these points A and B. It would also be necessary for the firm to establish the costs associated with counter-measures to reduce either the heat stress or the cold stress (e.g. buying a new air condition system, changing the work/rest schedule, changing the work hours, protective clothing, or sheltered rest areas). Comparing the counter-measure costs to the accident costs will provide a cost-benefit tradeoff as a decision rule.

It should be noted that since each of the indices evaluated in this study showed the same general

relationship, any of them could be used as reasonably accurate predictors of human safe work behavior. It was necessary to add a disturbing factor to the models before different levels of precision were identifiable. Generally speaking, when comparing indices, HSI appears to be slightly better than the other indices at predicting human unsafe work behavior. But HSI is the only index which includes the human metabolic work load as a variable and can be found only after a series of calculations. NET appears to be the next best among the pure thermal indices, but its determination also requires considerable extra measurement and calculation. WBGT and DB on the other hand are in practical terms equivalently accurate predictors of human unsafe work behavior, and are indices which can be obtained and evaluated much more easily than either the HSI or NET.

RECOMMENDATION FOR FURTHER RESEARCH

This study emphasizes on the relationship between indoor heat environment and human safe behavior. Further studies of the relationship between human safe behavior and indoor cold environment such as found in frozen food packing plants, outdoor heat environments such as found in underground or surface mining, and outdoor cold environments such as at construction during the winter will also be valuable. This study

includes only the summer and autumn time periods. However, in order to determine the relationship between unsafe behavior and the four seasons, similar studies should be done for a full year. Studies of the physiological response to the heat in the work place can also be done and, then, that result compared with the results of this study. Also, a complete system may be built up to realize how heat influences human physiological conditions as well as how physiological conditions influence the safety behavior.

Figure 32 - The relationship of Unsafe behavior vs Thermal Indices.

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APPENDIX

THIS IS THE SAS PROGRAM TO BUILD UP TABLE 14.
THE OTHER TABLES ARE ALMOST THE SAME LIKE THIS ONE.
ALL COMMAND WILL BE FOLLOWED BY A 'TITLE' WORD.

TITLE JOB CONTROL CARDS.

```
// JOB (RJD$JJ,456479535,3,,6),'701T01130 RHSI'  
/*JOBPARM BANNER  
// EXEC SAS  
//IN1 DD DSN=WYL.JJ.RJD.D8191130,DISP=SHR  
//IN2 DD DSN=WYL.JJ.RJD.D701818,DISP=SHR  
//SYSOUT DD SYSOUT=A  
//SYSIN DD *
```

TITLE DATA SET FROM 8/19 TO 11/30.

```
DATA D8191130;  
INFILE IN1;  
  INPUT (DATE SET DAY PLANT OBSERV TIME MACHIN ID WL BB  
  WBG TIN WBG TOT DB NWB GT  
  WIND DM WM OBS1 OBS2 OBS3) (@1 5. @6 1. $3. $1. $1.  
  @12 4. $5.  
  @21 3. @24 1.  
  @25 3.1 @28 3.1 @31 3.1 @34 3.1 @37 3.1 @40 3.1 @43  
  3. @46 3.  
  @49 3. @52 3.  
  @55 3. @58 3.);
```

TITLE DATA SET FROM 7/01 TO 8/18.

```
DATA D701818;  
INFILE IN2;  
  INPUT (DATE SET DAY PLANT OBSERV TIME MACHIN ID WL BB  
  WBG TIN WBG TOT DB NWB GT  
  WIND DM WM OBS1 OBS2 OBS3) (@1 5. @6 1. $3. $1. $1.  
  @12 4. $5.  
  @21 3. @24 1.  
  @25 3.1 @28 3.1 @31 3.1 @34 3.1 @37 3.1 @40 3.1 @43  
  3. @46 3.  
  @49 3. @52 3.  
  @55 3. @58 3.);
```

TITLE COMBINE THE ABOVE DATA SETS TO ONE DATA SET.

```
DATA DV;SET D8191130 D701818;  
  IF WIND>=2 THEN V=WIND;  
  IF WIND<2 THEN V=1;  
DATA DWB; SET DV;
```

TITLE GET TW---MEAN RADIANT TEMPERATURE.

$TW = GT + (2.27 * (V/60) ** 0.5) * (GT - DB) ;$

TITLE GET HC---CONDUCTIVE COEFFICIENT.

$HC = 8.6 * (V/60) ** 0.53 ;$

TITLE CONVERT NATURE WET BULB TO PSYCHROMETRIC WET BULB.

IF (GT-DB) <= 0 & V <= 200 THEN WB = NWB - (200 - V) * 1.1 / 200 ;

IF (GT-DB) <= 0 & V > 200 THEN WB = NWB ;

IF 0 < (GT-DB) < 5.6 & V <= 36 THEN WB = NWB - (36 - V) * (.0055 + (GT-DB) * .0076)

- .83 - (GT-DB) *

0.0059 ;

IF 0 < (GT-DB) < 5.6 & V > 36 THEN WB = NWB - .83 - (GT-DB) * .0059 + (V - 36) * (5.6

- (GT-DB) * .0055

/ 5.6 ;

IF (GT-DB) >= 5.6 & V <= 36 THEN WB = NWB - .25 * (GT-DB) + .28 - (36 - V) * (1.72

+ .13 * (GT-DB - 5.6)

/ 2.78) / 36 ;

IF (GT-DB) >= 5.6 & V > 36 THEN WB = NWB - .25 * (GT-DB) + .28 ;

TITLE ADJUST SOME ERROR DATA.

IF TIMI < 730 THEN TIME = TIMI + 1200 ;

IF TIMI >= 730 & TIMI <= 1730 THEN TIME = TIMI ;

IF MACHIN = 'OUTDR' THEN DELETE ;

IF GT < 13 OR NWB < 3 OR NWB > 50 OR V > 300 THEN DELETE ;
DATA DETPA ; SET DWB ;

TITLE GET OPERATIVE TEMPERATURE & THE SUM OF CON.
& RAD. COEFFICIENT..

$TO = (4.7 * TW + HC * DB) / (4.7 + HC) ;$

$H = 4.7 + HC ;$

TITLE GET CORRECTED EFFECTIVE TEMPERATURE.

IF 0 <= V <= 10 THEN CET = WB + (GT - WB) * ((- .1975) * WB + 8.275) / ((- .1975) * WB + 8.275) +

(6.85 - (- .1975) * GT + 8.275) ;

IF 10 < V <= 30 THEN CET = WB + (GT - WB) * ((- .1975) * WB + 8.275) / ((- .1975) * WB + 8.275) +

(6.85 - (- .1975) * GT + 8.275) - (2.55 - .1 * (GT - WB) - .07 * (WB - 5) * 5 / (GT - WB)) ;

IF 30 < V THEN CET = WB + (GT - WB) * ((- .1975) * WB + 8.275) / ((- .1975) * WB + 8.275) +

(6.85 - (- .1975) * GT + 8.275) - (2.55 - .1 * (GT - WB) - .07 * (WB - 5) * 5 / (GT - WB))

```
* (.0071*V+.787)
*LOG10(2.5*V-V**2/120-57.5) ;
```

TITLE GET EFFECTIVE TEMPERTURE.

```
IF 0<=V<=10 THEN ET=WB+(DB-WB)*((-0.1975)*WB+8.275)
/((-0.1975)
*WB+8.275) +
```

```
(6.85-(-0.1975)*DB+8.275) );
IF 10<V<=30 THEN ET=WB+(DB-WB)*((-0.1975)*WB+8.275)
/((-0.1975)
*WB+8.275) +
```

```
(6.85-(-0.1975)*DB+8.275) ) - (2.55-.1*(DB-WB) -.07*
(WB-5)*5/(DB-WB) ) ;
```

```
IF 30<V THEN ET=WB+(DB-WB)*((-0.1975)*WB+8.275) /
((-0.1975)*WB+8.275) +
```

```
(6.85-(-0.1975)*DB+8.275) ) - (2.55-.1*(DB-WB) -.07*
(WB-5)*5/(DB-WB) )
```

```
* (.0071*V+.787)
```

```
*LOG10(2.5*V-V**2/120-57.5) ;
```

TITLE GET PA---AIR VAPOR PRESSURE.

```
PA=EXP(18.669-4030.18/(WB+235))-.5*(DB-WB);
DATA DHSITSK; SET DETPA;
```

TITLE GET HSI.

```
HSI=(6.6*(GT+.2*V**.5*(GT-DB)-35)+V**.6*.6*(DB-35)
+WL*100+50)
```

```
*100/(1.2*V**.6*
(42-PA)) ;
```

TITLE GET SKIN TEMPERATURE.

```
IF ET>=25 THEN TSK=17.02+.6*ET;
```

```
ELSE TSK=32.5;
```

```
IF CET<0 THEN DELETE;
```

```
DATA DTCL; SET DHSITSK;
```

TITLE GET CLOTH TEMPERATURE.

```
TCL=TO+1/(1+.155*H*.6)*(TSK-TO);
```

```
DATA DW; SET DTCL ;
```

TITLE GET ICLOE---FOR CALCULATING NET.

```
ICLOE=(1/.155/H)*(TSK-TCL)/(TCL-TO);
```

TITLE GET SKIN WETTEDNESS.

```
IF TSK<=32.5 THEN W=0.06;
```

```
IF 32.5<TSK<=33.0 THEN W=0.1;
```

```
IF 33.0<TSK<=35.1 THEN W=0.2;
```

1/15/6
1/15/6

```

IF 35.1<TSK<=35.5 THEN W=0.3;
IF 35.5<TSK<=36.1 THEN W=0.4;
IF 36.1<TSK<=36.3 THEN W=0.5;
IF 36.3<TSK<=36.6 THEN W=0.7;
IF 36.6<TSK<=36.8 THEN W=0.8;
IF TSK>36.8 THEN W=1.0;
DATA DYSTO; SET DW;

```

TITLE GET Y & STO---FOR CALCULATING NET.

wrong

```

Y=H/2.2/HC*(1+.143*HC*ICLOE)/(1+.155*H*ICLOE);
STO=TSK-(H/(1+.155*H*ICLOE))*(TSK-TO)/4.86;
DATA DNET; SET DYSTO;

```

TITLE GET NET---NEW EFFECTIVE TEMPERATURE.

```

NET=(((Y/W)-.032)**2+.0614*(PA+Y/W*STO-3.25))
** .5-Y/W-.032)/.0307;
DATA TEMPR; SET DNET;

```

TITLE CONVERT HSI TO RHSI & NOW T IS RHSI.
(IF GOING TO ANA.THE OTHER
INDICES, JUST PUT THAT INDEX ON T.

```

T=(HSI+100)/20;
DATA INDOR; SET TEMPR;

```

TITLE GROUP DATA TO DEGREE/3 SCALE TO GET 3
REP IN EACH DEG.

```

IF T<.4 THEN TP=.2;
IF T<.7 & T>=.4 THEN TP=.5;
IF T<1 & T>=.7 THEN TP=.8;
IF T<1.4 & T>=1 THEN TP=1.2;
IF T<1.7 & T>=1.4 THEN TP=1.5;
IF T<2 & T>=1.7 THEN TP=1.8;
IF T<2.4 & T>=2 THEN TP=2.2;
IF T<2.7 & T>=2.4 THEN TP=2.5;
IF T<3 & T>=2.7 THEN TP=2.8;
IF T<3.4 & T>=3 THEN TP=3.2;
IF T<3.7 & T>=3.4 THEN TP=3.5;
IF T<4 & T>=3.7 THEN TP=3.8;
IF T<4.4 & T>=4 THEN TP=4.2;
IF T<4.7 & T>=4.4 THEN TP=4.5;
IF T<5 & T>=4.7 THEN TP=4.8;
IF T<5.4 & T>=5 THEN TP=5.2;
IF T<5.7 & T>=5.4 THEN TP=5.5;
IF T<6 & T>=5.7 THEN TP=5.8;
IF T<6.4 & T>=6 THEN TP=6.2;
IF T<6.7 & T>=6.4 THEN TP=6.5;
IF T<7 & T>=6.7 THEN TP=6.8;
IF T<7.4 & T>=7 THEN TP=7.2;
IF T<7.7 & T>=7.4 THEN TP=7.5;
IF T<8 & T>=7.7 THEN TP=7.8;

```

```
IF T<8.4 & T>=8 THEN TP=8.2;
IF T<8.7 & T>=8.4 THEN TP=8.5;
IF T<9 & T>=8.7 THEN TP=8.8;
IF T<9.4 & T>=9 THEN TP=9.2;
IF T<9.7 & T>=9.4 THEN TP=9.5;
IF T<10 & T>=9.7 THEN TP=9.8;
IF T<10.4 & T>=10 THEN TP=10.2;
IF T<10.7 & T>=10.4 THEN TP=10.5;
IF T<11 & T>=10.7 THEN TP=10.8;
IF T<11.4 & T>=11 THEN TP=11.2;
IF T<11.7 & T>=11.4 THEN TP=11.5;
IF T<12 & T>=11.7 THEN TP=11.8;
IF T<12.4 & T>=12 THEN TP=12.2;
IF T<12.7 & T>=12.4 THEN TP=12.5;
IF T<13 & T>=12.7 THEN TP=12.8;
IF T<13.4 & T>=13 THEN TP=13.2;
IF T<13.7 & T>=13.4 THEN TP=13.5;
IF T<14 & T>=13.7 THEN TP=13.8;
IF T<14.4 & T>=14 THEN TP=14.2;
IF T<14.7 & T>=14.4 THEN TP=14.5;
IF T<15 & T>=14.7 THEN TP=14.8;
IF T<15.4 & T>=15 THEN TP=15.2;
IF T<15.7 & T>=15.4 THEN TP=15.5;
IF T<16 & T>=15.7 THEN TP=15.8;
IF T<16.4 & T>=16 THEN TP=16.2;
IF T<16.7 & T>=16.4 THEN TP=16.5;
IF T<17 & T>=16.7 THEN TP=16.8;
IF T<17.4 & T>=17 THEN TP=17.2;
IF T<17.7 & T>=17.4 THEN TP=17.5;
IF T<18 & T>=17.7 THEN TP=17.8;
IF T<18.4 & T>=18 THEN TP=18.2;
IF T<18.7 & T>=18.4 THEN TP=18.5;
IF T<19 & T>=18.7 THEN TP=18.8;
IF T<19.4 & T>=19 THEN TP=19.2;
IF T<19.7 & T>=19.4 THEN TP=19.5;
IF T<20 & T>=19.7 THEN TP=19.8;
IF T<20.4 & T>=20 THEN TP=20.2;
IF T<20.7 & T>=20.4 THEN TP=20.5;
IF T<21 & T>=20.7 THEN TP=20.8;
IF T<21.4 & T>=21 THEN TP=21.2;
IF T<21.7 & T>=21.4 THEN TP=21.5;
IF T<22 & T>=21.7 THEN TP=21.8;
IF T<22.4 & T>=22 THEN TP=22.2;
IF T<22.7 & T>=22.4 THEN TP=22.5;
IF T<23 & T>=22.7 THEN TP=22.8;
IF T<23.4 & T>=23 THEN TP=23.2;
IF T<23.7 & T>=23.4 THEN TP=23.5;
IF T<24 & T>=23.7 THEN TP=23.8;
IF T<24.4 & T>=24 THEN TP=24.2;
IF T<24.7 & T>=24.4 THEN TP=24.5;
IF T<25 & T>=24.7 THEN TP=24.8;
IF T<25.4 & T>=25 THEN TP=25.2;
IF T<25.7 & T>=25.4 THEN TP=25.5;
IF T<26 & T>=25.7 THEN TP=25.8;
```

```
IF T<26.4 & T>=26 THEN TP=26.2;
IF T<26.7 & T>=26.4 THEN TP=26.5;
IF T<27 & T>=26.7 THEN TP=26.8;
IF T<27.4 & T>=27 THEN TP=27.2;
IF T<27.7 & T>=27.4 THEN TP=27.5;
IF T<28 & T>=27.7 THEN TP=27.8;
IF T<28.4 & T>=28 THEN TP=28.2;
IF T<28.7 & T>=28.4 THEN TP=28.5;
IF T<29 & T>=28.7 THEN TP=28.8;
IF T<29.4 & T>=29 THEN TP=29.2;
IF T<29.7 & T>=29.4 THEN TP=29.5;
IF T<30 & T>=29.7 THEN TP=29.8;
IF T<30.4 & T>=30 THEN TP=30.2;
IF T<30.7 & T>=30.4 THEN TP=30.5;
IF T<31 & T>=30.7 THEN TP=30.8;
IF T<31.4 & T>=31 THEN TP=31.2;
IF T<31.7 & T>=31.4 THEN TP=31.5;
IF T<32 & T>=31.7 THEN TP=31.8;
IF T<32.4 & T>=32 THEN TP=32.2;
IF T<32.7 & T>=32.4 THEN TP=32.5;
IF T<33 & T>=32.7 THEN TP=32.8;
IF T<33.4 & T>=33 THEN TP=33.2;
IF T<33.7 & T>=33.4 THEN TP=33.5;
IF T<34 & T>=33.7 THEN TP=33.8;
IF T<34.4 & T>=34 THEN TP=34.2;
IF T<34.7 & T>=34.4 THEN TP=34.5;
IF T<35 & T>=34.7 THEN TP=34.8;
IF T<35.4 & T>=35 THEN TP=35.2;
IF T<35.7 & T>=35.4 THEN TP=35.5;
IF T<36 & T>=35.7 THEN TP=35.8;
IF T<36.4 & T>=36 THEN TP=36.2;
IF T<36.7 & T>=36.4 THEN TP=36.5;
IF T<37 & T>=36.7 THEN TP=36.8;
IF T<37.4 & T>=37 THEN TP=37.2;
IF T<37.7 & T>=37.4 THEN TP=37.5;
IF T<38 & T>=37.7 THEN TP=37.8;
IF T<38.4 & T>=38 THEN TP=38.2;
IF T<38.7 & T>=38.4 THEN TP=38.5;
IF T<39 & T>=38.7 THEN TP=38.8;
IF T<39.4 & T>=39 THEN TP=39.2;
IF T<39.7 & T>=39.4 THEN TP=39.5;
IF T<40 & T>=39.7 THEN TP=39.8;
IF T<40.4 & T>=40 THEN TP=40.2;
IF T<40.7 & T>=40.4 THEN TP=40.5;
IF T<41 & T>=40.7 THEN TP=40.8;
IF T<41.4 & T>=41 THEN TP=41.2;
IF T<41.7 & T>=41.4 THEN TP=41.5;
IF T<42 & T>=41.7 THEN TP=41.8;
IF T<42.4 & T>=42 THEN TP=42.2;
IF T<42.7 & T>=42.4 THEN TP=42.5;
IF T<43 & T>=42.7 THEN TP=42.8;
IF T<43.4 & T>=43 THEN TP=43.2;
IF T<43.7 & T>=43.4 THEN TP=43.5;
IF T<44 & T>=43.7 THEN TP=43.8;
```

```

IF T<44.4 & T>=44 THEN TP=44.2;
IF T<44.7 & T>=44.4 THEN TP=44.5;
IF T<45 & T>=44.7 THEN TP=44.8;
IF T<45.4 & T>=45 THEN TP=45.2;
IF T<45.7 & T>=45.4 THEN TP=45.5;
IF T<46 & T>=45.7 THEN TP=45.8;
IF T<46.4 & T>=46 THEN TP=46.2;
IF T<46.7 & T>=46.4 THEN TP=46.5;
IF T<47 & T>=46.7 THEN TP=46.8;
IF T<47.4 & T>=47 THEN TP=47.2;
IF T<47.7 & T>=47.4 THEN TP=47.5;
IF T<48 & T>=47.7 THEN TP=47.8;
IF T<48.4 & T>=48 THEN TP=48.2;
IF T<48.7 & T>=48.4 THEN TP=48.5;
IF T<49 & T>=48.7 THEN TP=48.8;
IF T<49.4 & T>=49 THEN TP=49.2;
IF T<49.7 & T>=49.4 THEN TP=49.5;
IF T<50 & T>=49.7 THEN TP=49.8;
IF T<50.4 & T>=50 THEN TP=50.2;
IF T<50.7 & T>=50.4 THEN TP=50.5;
IF T<51 & T>=50.7 THEN TP=50.8;
IF T<51.4 & T>=51 THEN TP=51.2;
IF T<51.7 & T>=51.4 THEN TP=51.5;
IF T<52 & T>=51.7 THEN TP=51.8;
IF T<52.4 & T>=52 THEN TP=52.2;
IF T<52.7 & T>=52.4 THEN TP=52.5;
IF T<53 & T>=52.7 THEN TP=52.8;
IF T<53.4 & T>=53 THEN TP=53.2;
IF T<53.7 & T>=53.4 THEN TP=53.5;
IF T<54 & T>=53.7 THEN TP=53.8;
IF T<54.4 & T>=54 THEN TP=54.2;
IF T<54.7 & T>=54.4 THEN TP=54.5;
IF T<55 & T>=54.7 THEN TP=54.8;
IF T<55.4 & T>=55 THEN TP=55.2;
IF T<55.7 & T>=55.4 THEN TP=55.5;
IF T<56 & T>=55.7 THEN TP=55.8;
IF T<56.4 & T>=56 THEN TP=56.2;
IF T<56.7 & T>=56.4 THEN TP=56.5;
IF T<57 & T>=56.7 THEN TP=56.8;
IF T<57.4 & T>=57 THEN TP=57.2;
IF T<57.7 & T>=57.4 THEN TP=57.5;
IF T<58 & T>=57.7 THEN TP=57.8;
IF T<58.4 & T>=58 THEN TP=58.2;
IF T<58.7 & T>=58.4 THEN TP=58.5;
IF T<59 & T>=58.7 THEN TP=58.8;
IF T<59.4 & T>=59 THEN TP=59.2;
IF T<59.7 & T>=59.4 THEN TP=59.5;
IF T<60 & T>=59.7 THEN TP=59.8;

```

TITLE GET THE SAFE & UNSAFE DATA FROM EACH OBSERVATION.

```

N1=0; N2=0; N3=0; N4=0;
  IF OBS1=0 THEN N1=N1+1;
  IF OBS2=0 THEN N2=N2+1;

```



```

      IF OBS3=0 THEN N3=N3+1;
      IF OBS1=0 & OBS1=1 THEN N4=N4+1;
      NUM=N1+N2+N3; US=N2+N3+N4;

```

TITLE GROUP TIME TO HOURLY DATA.

```

      IF TIME<830 THEN TME=8;
      IF TIME<930 & TIME>=830 THEN TME=9;
      IF TIME<1030 & TIME>=930 THEN TME=10;
      IF TIME<1130 & TIME>=1030 THEN TME=11;
      IF TIME<1230 & TIME>=1130 THEN TME=12;
      IF TIME<1330 & TIME>=1230 THEN TME=13;
      IF TIME<1430 & TIME>=1330 THEN TME=14;
      IF TIME<1530 & TIME>=1430 THEN TME=15;
      IF TIME<1630 & TIME>=1530 THEN TME=16;
      IF TIME>=1630 THEN TME=17;

```

TITLE DIVIDE DATA TO 4 PERIOD.

```

      IF TIME<930 THEN PERIOD=1;
      IF TIME<1230 & TIME>=930 THEN PERIOD=2;
      IF PLANT='A' & TIME<1400 & TIME>=1230 THEN PERIOD=3;
      IF PLANT='B' & TIME<1500 & TIME>=1230 THEN PERIOD=3;
      IF PLANT='A' & TIME>=1400 THEN PERIOD=4;
      IF PLANT='B' & TIME>=1500 THEN PERIOD=4;
      DATA TXNY; SET INDOR;

```

TITLE WORKING ON THE DATA SET TO GET THE RIGHT GROUP
ACCORDING TO TAXONOMY.

```

      DROP OBS1-OBS3;
      OBS=OBS1; OUTPUT;
      OBS=OBS2; OUTPUT;
      OBS=OBS3; OUTPUT;
      DATA TXMY; SET TXNY;
      IF OBS=0 THEN DELETE;
      IF OBS=0 THEN K=1;
      IF OBS<110 & OBS=0 THEN TAXY=1;
      IF OBS<210 & OBS>110 THEN TAXY=11;
      IF OBS<310 & OBS>210 THEN TAXY=12;
      IF OBS>310 THEN TAXY=13;
      PROC SORT DATA=TXMY; BY TP WL ;
      PROC MEANS N NOPRINT;
      VAR K ; BY TP WL ;
      OUTPUT OUT=DVD N=NDVD;
      PROC SORT DATA=TXMY ; BY TP WL TAXY;
      PROC MEANS N NOPRINT;
      VAR K; BY TP WL TAXY;
      OUTPUT OUT=DEF N=NDEF;
      DATA AN6; MERGE DEF DVD; BY TP WL ;
      DATA RAN7; SET AN6 ;
      IF TAXY=1 THEN DELETE;

```

TITLE CALCULATE USRR3.

USBR3=ARSIN(SQRT(NDEF/NDVD));

TITLE GROUP DATA IN EACH DEGREE BASE.

```

IF TP>=0 & TP<1 THEN TEMP=1;
IF TP>=1 & TP<2 THEN TEMP=2;
IF TP>=2 & TP<3 THEN TEMP=3;
IF TP>=3 & TP<4 THEN TEMP=4;
IF TP>=4 & TP<5 THEN TEMP=5;
IF TP>=5 & TP<6 THEN TEMP=6;
IF TP>=6 & TP<7 THEN TEMP=7;
IF TP>=7 & TP<8 THEN TEMP=8;
IF TP>=8 & TP<9 THEN TEMP=9;
IF TP>=9 & TP<10 THEN TEMP=10;
IF TP>=10 & TP<11 THEN TEMP=11;
IF TP>=11 & TP<12 THEN TEMP=12;
IF TP>=12 & TP<13 THEN TEMP=13;
IF TP>=13 & TP<14 THEN TEMP=14;
IF TP>=14 & TP<15 THEN TEMP=15;
IF TP>=15 & TP<16 THEN TEMP=16;
IF TP>=16 & TP<17 THEN TEMP=17;
IF TP>=17 & TP<18 THEN TEMP=18;
IF TP>=18 & TP<19 THEN TEMP=19;
IF TP>=19 & TP<20 THEN TEMP=20;
IF TP>=20 & TP<21 THEN TEMP=21;
IF TP>=21 & TP<22 THEN TEMP=22;
IF TP>=22 & TP<23 THEN TEMP=23;
IF TP>=23 & TP<24 THEN TEMP=24;
IF TP>=24 & TP<25 THEN TEMP=25;
IF TP>=25 & TP<26 THEN TEMP=26;
IF TP>=26 & TP<27 THEN TEMP=27;
IF TP>=27 & TP<28 THEN TEMP=28;
IF TP>=28 & TP<29 THEN TEMP=29;
IF TP>=29 & TP<30 THEN TEMP=30;
IF TP>=30 & TP<31 THEN TEMP=31;
IF TP>=31 & TP<32 THEN TEMP=32;
IF TP>=32 & TP<33 THEN TEMP=33;
IF TP>=33 & TP<34 THEN TEMP=34;
IF TP>=34 & TP<35 THEN TEMP=35;
IF TP>=35 & TP<36 THEN TEMP=36;
IF TP>=36 & TP<37 THEN TEMP=37;
IF TP>=37 & TP<38 THEN TEMP=38;
IF TP>=38 & TP<39 THEN TEMP=39;
IF TP>=39 & TP<40 THEN TEMP=40;
IF TP>=40 & TP<41 THEN TEMP=41;
IF TP>=41 & TP<42 THEN TEMP=42;
IF TP>=42 & TP<43 THEN TEMP=43;
IF TP>=43 & TP<44 THEN TEMP=44;
IF TP>=44 & TP<45 THEN TEMP=45;
IF TP>=45 & TP<46 THEN TEMP=46;
IF TP>=46 & TP<47 THEN TEMP=47;
IF TP>=47 & TP<48 THEN TEMP=48;
IF TP>=48 & TP<49 THEN TEMP=49;
IF TP>=49 & TP<50 THEN TEMP=50;

```

```

IF TP>=50 & TP<51 THEN TEMP=51;
IF TP>=51 & TP<52 THEN TEMP=52;
IF TP>=52 & TP<53 THEN TEMP=53;
IF TP>=53 & TP<54 THEN TEMP=54;
IF TP>=54 & TP<55 THEN TEMP=55;
IF TP>=55 & TP<56 THEN TEMP=56;
IF TP>=56 & TP<57 THEN TEMP=57;
IF TP>=57 & TP<58 THEN TEMP=58;
IF TP>=58 & TP<59 THEN TEMP=59;
IF TP>=59 & TP<60 THEN TEMP=60;
DATA RAN6; MERGE RAN7 TXMY;

```

TITLE MODEL (N) ANOVA FOR ALL FACTORS, ONE BY ONE
GET INTO
ANALYSIS.

```

PROC GLM DATA=RAN6;
  CLASS TEMP;
  MODEL USBR3=TEMP;
PROC GLM DATA=RAN6;
  CLASS TEMP WL;
  MODEL USBR3=TEMP WL;
PROC GLM DATA=RAN6;
  CLASS TEMP WL OBSERV;
  MODEL USBR3=TEMP WL OBSERV;
PROC GLM DATA=RAN6;
  CLASS TEMP WL OBSERV TAXY;
  MODEL USBR3=TEMP WL OBSERV TAXY;
PROC GLM DATA=RAN6;
  CLASS TEMP WL OBSERV TAXY DAY;
  MODEL USBR3=TEMP WL OBSERV TAXY DAY;
PROC GLM DATA=RAN6;
  CLASS TEMP WL OBSERV TAXY DAY PERIOD;
  MODEL USBR3=TEMP WL OBSERV TAXY DAY PERIOD;
PROC GLM DATA=RAN6;
  CLASS TEMP WL OBSERV TAXY DAY PERIOD MACHIN;
  MODEL USBR3=TEMP WL OBSERV TAXY DAY PERIOD MACHIN;

```

TITLE MODEL (O) ANOVA FOR ALL FACTORS, ONE BY ONE
GET INTO
ANALYSIS.

```

PROC GLM DATA=RAN6;
  MODEL USBR3=TEMP;
PROC GLM DATA=RAN6;
  CLASS WL;
  MODEL USBR3=TEMP WL;
PROC GLM DATA=RAN6;
  CLASS WL OBSERV;
  MODEL USBR3=TEMP WL OBSERV;
PROC GLM DATA=RAN6;
  CLASS WL OBSERV TAXY;
  MODEL USBR3=TEMP WL OBSERV TAXY;
PROC GLM DATA=RAN6;

```

```

CLASS WL OBSERV TAXY DAY;
MODEL USBR3=TEMP WL OBSERV TAXY DAY;
PROC GLM      DATA=RAN6;
CLASS WL OBSERV TAXY DAY PERIOD;
MODEL USBR3=TEMP WL OBSERV TAXY DAY PERIOD;
PROC GLM      DATA=RAN6;
CLASS WL OBSERV TAXY DAY PERIOD MACHIN;
MODEL USBR3=TEMP WL OBSERV TAXY DAY PERIOD MACHIN;

```

```

TITLE MODEL (P) ANOVA FOR ALL FACTORS, ONE BY ONE
GET INTO
      ANALYSIS.

```

```

PROC GLM      DATA=RAN6;
MODEL USBR3=TEMP TEMP*TEMP;
PROC GLM      DATA=RAN6;
CLASS WL;
MODEL USBR3=TEMP TEMP*TEMP WL;
PROC GLM      DATA=RAN6;
CLASS WL OBSERV;
MODEL USBR3=TEMP TEMP*TEMP WL OBSERV;
PROC GLM      DATA=RAN6;
CLASS WL OBSERV TAXY;
MODEL USBR3=TEMP TEMP*TEMP WL OBSERV TAXY;
PROC GLM      DATA=RAN6;
CLASS WL OBSERV TAXY DAY;
MODEL USBR3=TEMP TEMP*TEMP WL OBSERV TAXY DAY;
PROC GLM      DATA=RAN6;
CLASS WL OBSERV TAXY DAY PERIOD;
MODEL USBR3=TEMP TEMP*TEMP WL OBSERV TAXY DAY PERIOD;
PROC GLM      DATA=RAN6;
CLASS WL OBSERV TAXY DAY PERIOD MACHIN;
MODEL USBR3=TEMP TEMP*TEMP WL OBSERV TAXY DAY PERIOD
MACHIN;

```