STUDY OF HEAT EXPOSURE IN THE WORK ENVIRONMENT IN JEDDAH

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Abstract. The present work was conducted to define the magnitude of the problem of heat exposure in Jeddah and the role of both the climatic and the industrial factors on the total heat load. Indoor heat exposure was studied in an industrial complex of 5 plants for cables' manufacturing. Outdoor heat exposure was studied in shaded and unshaded operations in Jeddah Islamic Port (JIP). The heat exposure parameters, including air temperature (Ta), wet bulb temperature (Tw), and globe temperature (Tg), as well as the wet bulb globe temperature (WBGT) heat stress index, the relative humidity and the air velocity, were assessed at representative locations. Results of the study indicated that:

(a) the levels of heat exposure exceeded the TLV in mostly all the work areas where no air-conditioning is provided.
(b) the ambient heat is the factor contributing most to the heat load both in summer and in winter.
(c) the radiant heat from furnaces and hot metal rolling and milling adds more heat load to the work environment in specific operations.

An outline of a control strategy has been suggested, emphasizing evaporative engineering heat control, work and hygienic practices and auxiliary cooling clothing.

1. Introduction

Heat stress presents a main problem to people living in the tropical and subtropical zones, similar to many areas in the Kingdom of Saudi Arabia (KSA). In addition to naturally occurring hot climates, there are many situations in industry and other trades where 'artificial' hot climates may be created by industrial operations. Such climatic and artificial factors may lead to convective or radiant heat gains by the human body and may limit or prevent the heat dissipation from the body leading to the occurrence of heat disorders. Mild and severe casualties have been reported from both naturally occurring and artificial climates. For example, deaths were reported in natural and artificial climates where the heat stress was very high. However, the incidence of less heat disorders occurs with much greater frequency (Leithead and Lind, 1964; Minard, 1966; NIOSH, 1986; Mutchler, 1991).

In Jeddah, the climatic heat exposure, as well as the industrial heat exposure, has been knowm to produce physiological and psychological strain among men exposed to such conditions in industry, trade and some types of business, and principally affects their physical performance and productivity and leads to heat disorders among them. Such effects might vary in extent according to different

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climatic seasons (i.e. summer v. winter). Meanwhile, a careful appraisal of all factors in the environment that go to make up the total heat stress, and a knowledge of how men may be expected to respond to different combinations of work and climate, ought to help greatly in the evaluation and the prevention of heat problems. Therefore, the present study was conducted in order to define:

(a) the magnitude of the problem of heat exposure in Jeddah, which represents an important area in KSA, housing 40% of the Saudi industries, and where exposure to heat varies from 'normal' to 'hot';
(b) the role of both the climatic and industrial factors in the total load of heat exposure; and
(c) the impact of the seasonal variation (summer v. winter) on the role of the climatic factors contributing to the heat exposure.

These data are needed by the health, labour and industrial authorities to propose a 'hot-weather hygiene' strategy in KSA.

The study included two major enterprises:

1. an industrial complex of five plants for cables' manufacturing, where indoor heat exposure might be studied, and
2. Jeddah Islamic Port (JIP), where many industrial and trading operations are performed outdoors and, therefore, presenting a unique chance for the systematic study of outdoor heat exposure.

2. Description of Enterprises and Industrial Operations

2.1. Cables' Industries

The selected cables' industries enteprise include different plants and operations which are summarized below.

2.1.1. *Power cables plant*

These include the following operations.

(a) Drawing: to elongate copper or aluminum rods and draw them into wires using three sets of drawing machines; heat is produced and the dies and wires are cooled by lubricant liquids.
(b) Stranding: as required by the cables' specifications, using special stranding machines.
(c) Insulation: by the first extruded layer over the conductor (i.e. wire) using PVC or cross linked polyethylene, applied by lines of machinery where the plastic(s) used for insulation is (are) heated and extruded.
(d) Assembling: where two, three, four (multi-core) insulated conductors are assembled using a switching machine.
(e) Inner covering: where a non-hygroscopic filling compound is used to fill the interstices of the assembled cores to give the cable a circular shape.

(f) Armouring: by tape, round wire or flat wire (steel or aluminum) for the mechanical protection of the wire against damage, specially in the case of direct burial laying.
(g) Sheathing, where the armoured cable is covered by an extruded layer of PVC.

2.1.2. *Telecommunications cables plant*
These include the following operations:
(a) Drawing (tandem line): where copper wire (maximum diameter 2.5 mm) is further drawn, annealed, pressure centered, covered with extruded PVC, cooled, subjected to electric capacitance measurement, and wound on reels and stored by a robot handling system for further processing.
(b) Group twinning: where two individual wires are twisted together, then further assembled with other pairs, according to colour coding, forming subunits.
(c) Drum twisting: where the subunits are grouped and stranded to form the main unit.
(d) Jacketing: where jelly filling is applied to wires of some specific cables which will be subjected in their use to high temperature or presssure (standing up to 100–130 °C with a pressure range of 1–20 psi); it is then covered by mylar tape and outer jelly binder, followed by aluminum plastic applications and plastic coating, then cooled, checked by a laser beam for thickness, and reeled; the product is then ready for shipping or armouring.
(e) Armouring: where the cable is sheathed with jelly and steel tape.

2.1.3. *Copper rod mill plant*
These include the following operations:
(a) Smelting: electrolytic copper is charged into a shaft furnace where it is smelted (1100 °C), the molten copper then flows into a holding furnace (1150 °C).
(b) Casting: where the molten copper flows to the lauching holding furnace and then to the continuous casting machine forming a copper bar that is water cooled at different stages.
(c) Rolling, milling and coiling: where the rod is fed into a rolling mill to be rolled to 8 mm diameter, then cleaned in the milling machine, wax coated and coiled while cooling.

2.1.4. *Polyvinyl chloride (PVC) compounding plant*
This is where all the compounding and materials handling operations are mostly automated. In the plasticizing operation, all the ingredients (resin, fillers, lubricants, etc) are drawn automatically from the bulk storage of raw materials through belts or pumps and added in certain proportions and in specific sequence, and kept in a high intensity mixing system with programmed temperature set(s) prior to being discharged as a dry blend or pellets of PVC.

2.1.5. *Reels plant*

This is a supporting factory producing wooden cable reels of different sizes, and includes the following operations:

(a) Level planing and cutting, where wooden boards are fed into an automated planer then into a circular cutter to be cut into required shapes and sizes.
(b) Nailing: performed automatically in a machine controlled by a laser beam to produce flanged reels.

2.2. Jeddah Islamic Port (JIP)

JIP is considered one of the earliest established ports in the world, as for more than one thousand years it has been receiving ships from various parts of the world (SPAP, 1989). Today, it is one of the prominent ports in KSA, as well as one of the most important ports worldwide, due to its strategic location on the Red Sea and because of the excellent developments that have been achieved there. For example the port is, at present, capable of receiving tremendous numbers and sizes of ships, delivering nearly 55% of the Kingdom's imports and foods, since it contains huge shipping and storage facilities. The following lists the main facilities there with a brief reference to the main design features as related to heat exposure.

1. Fifty-three docks (11.2 km in length) where goods are unloaded and handled mechanically in open unshaded areas.
2. Docks for containers (container field) where unloading and handling operations take place either in open unshaded areas or under sheds of corrugated steel or asbestos-cement sheets (shaded areas), while the offices there are air-conditioned.
3. Docks for rolling conventional goods (Ro–Ro Stations) in both shaded and unshaded areas.
4. Several specialized stations for delivery of loose grains (Al-Haboob Station) and loose cement; both are unshaded operations except for the affiliated offices which are air-conditioned.
5. The largest live-stock station in the world (live stock terminal, shaded).
6. Ship-repair complex (Haudh Al-Malik: including two floating blocks 10 000 and 22 000 tons, and a dock for marine boats), where operations are conducted in both shaded and unshaded areas.
7. Several sheded workshops (central, containers, etc.), where a few air-conditioned operations are also performed.
8. Several specialized storage facilities including: cooling and freezing storages (freezing goods: 6300 m^2), storage for lubricating oils and grease (oil station), warehouses for hazardous materials, a tremendous number of warehouses for conventional goods, covered storage areas (4000 m^2) and several unshaded storages for general loadings and utilities; most of the unloading and material handling operations related to these storages take place in open unshaded areas, while a few affiliated facilities and offices are air-conditioned.

Also the port includes several advanced services, in particular a large water desalination plant (one million gallons/day), electric power stations, telecommunication centres, fire fighting stations, marine pollution control facilities, safety centres, marine and training centres, a large administrative building, where the work environments of most of these services are air-conditioned.

Most important, JIP is the conventional port for the transport of pilgrims of Makkah where the 'Passenger Station' (including two docks and a marine rolling dock) accommodates 75% of the pilgrims. Most of the unloading and material handling operations take place in unshaded spaces, while most of the passenger-related activities (e.g. passengers field, passport building, etc) take place in air-conditioned areas.

3. Methodology

The two enterprises studied were first visually surveyed through a walk-through survey in order to be familiar with operations, to pinpoint the operations and locations where heat exposure might present a problem to workers, to determine factors that might contribute to heat stress, and, most important, to select representative measurement stations of heat exposure.

The measurements were made during the summer (July–September, 1990G) in the cables' manufacturing industrial complex. In JIP the measurements were conducted during August, 1991G, and during March, 1992G (a cooler season).

The locations of the measurements were carefully selected so that the data acquired would be meaningful in terms of the heat exchange between man and the environment. The modes of heat exchange between man and the environment include convection, radiation and evaporation. Convection is a function of the temperature gradient between the skin (Ts) and ambient air (Ta), and the movement (velocity) of air past the surface (V). Radiation is a function, primarily, of the gradient between the mean radiant temperature of the solid surroundings (Tr) and skin temperature (Ts). Evaporation is a function of the air movement (V) and the difference in vapor pressure between the perspiration on the skin (PWs) and the air (PWa). Consequently, the four environmental factors, Ta, Tr, PWa and V, define the thermal exchanges, and several instruments are used for their assessment. The common glass thermometers, thermocouples and thermistors are used for determining air temperature (Ta). The anemometers which depend upon the rate of cooling of the heated element by moving air are the instruments of choice for measuring air velocity (V) in the work environment. The psychrometers measure the amount of water vapor in the air (humidity); dry bulb temperature (Ta) and wet bulb temperature (Tw) are determined and the air vapor pressure (Pwa) is read directly from a psychrometric chart or table, where the relative humidity (RH) can also be read. The measurement of the mean radiant temperature of the solid surroundings (Tr) is most often effected by means of a blackened sphere, or Vernon globe. It consists of a copper sphere about 15 cm in diameter, the exterior of which is painted flat black, with a thermometer bulb or termocouple sensitive element placed in its centre. The temperature of the globe (Tg) is measured after the thermal equilibrium is established (usually after about 15 to 20 min) when the heat loss (or gain) of the globe by convection is balanced by the heat gain (or loss) by radiation. The mean radiant temperature (Tr) at the globe location may be calculated from the globe temperature (Tg), air temperature (Ta) and air velocity (V) readings (NIOSH, 1973, 1986; Mitchler, 1991).

The heat stress refers to the aggregate of environmental and physical factors that constitute the total heat load on the body. Several indexes for assessing it have been devised and survived. The Wet Bulb Globe Temperature (WBGT) index, intended originally as a simple expression of the heat stress, proved to be very successful in its monitoring and in minimizing heat casualties. Consequently, it has been adopted as the most acceptable index for heat stress (AIHA, 1973; NIOSH, 1973; ASHRAE, 1977; NIOSH, 1986; Olesen and Madsen, 1988; Peters, 1988; Mutchler, 1991, ACGIH, 1994).

Therefore, the four parameters (viz: Ta, Tw, Tg, and WBGT) were measured in all the selected locations in the enterprises studied, and the relative humidity was computed, as well. The air velocity was also measured at each of the locations studied in JIP. The Bruel and Kajer (B&K) WBGT heat stress monitor type 1219 was used for the measurement of the above stated temperature parameters (B&K, 1985), and the air velocity was measured using the thermal anemometer Model-31440 (Hisamatu, 1985).

The data were collected in a pretested form and statistically analysed.

4. Results and Discussion

4.1. Heat Exposure in the Cables' Manufacturing Industrial Complex

The results of the thermal environmental assessments are presented in Table I. Since the heat produced by the body and the environmental heat, together, determine the total heat load, the work load of the different workers' groups has been established by ranking their jobs using the metabolic rate tables available in the literature (Minard, 1966; Fanger, 1972; AIHA, 1973; NIOSH, 1986; Mutchler, 1991).

The application of this method led to the conclusion that mostly all the tasks in the plants studied may be considered 'moderate work' (M) with an average metabolic heat production of 5–6 K cal/min. Therefore, a WBGT Threshold Limit Value (TLV) of 26.7 °C is required for continuous work during an 8-h shift (ACGIH, 1994).

The data presented in the table indicate that the levels of WBGT at the different operations exceed the TLV; the mean levels ranged from 28.0 °C to 37.6 °C. This calls for a rapid action to control the problem of heat stress in the plants studied.

TABLE I

Results of thermal environmental assessments in studied cables' plants. Mean (S.D.)

Plant and department	No. of measurement sets	Heat stress parameters (°C)				Relative humidity (%)	Predominant work type
		Ta	Tw	Tg	WBGT		
Power cable plant							
Drawing	5	36.7 (0.59)	27.2 (0.63)	37.4 (0.66)	29.7 (1.32)	48.4 (2.51)	M
Stranding	5	36.9 (1.05)	27.7 (1.45)	37.4 (0.68)	30.5 (0.84)	50.0 (6.29)	M
Insulation	3	35.5 (0.49)	25.7 (0.32)	35.8 (0.61)	28.9 (0.38)	47.0 (1.73)	M
Armouring	4	34.3 (0.30)	25.0 (0.30)	34.7 (0.15)	28.0 (0.19)	54.3 (7.23)	M
Grand mean	17	36.0 (1.26)	26.6 (1.39)	36.5 (1.30)	29.4 (1.27)	50.0 (5.35)	
Telecommunication cable plant							
Drawing	4	34.6 (1.04)	25.8 (0.41)	35.5 (1.03)	28.7 (0.50)	50.0 (4.97)	M
Bobbin storage	3	34.3 (0.41)	25.7 (0.35)	35.7 (0.35)	28.7 (0.35)	49.3 (1.16)	M
Group twining	4	33.4 (1.02)	25.2 (0.29)	34.9 (0)	28.1 (0.28)	50.8 (2.50)	M
Jacketing	2	33.5 (0.14)	25.6 (0.35)	34.0 (0.28)	28.1 (0.28)	51.5 (4.95)	M
Armouring	5	33.5 (0.91)	25.4 (0.38)	34.3 (0.33)	28.1 (0.33)	50.8 (3.83)	M
Grand mean	18	33.9 (0.91)	25.2 (0.39)	34.9 (0.80)	28.3 (0.43)	50.4 (3.31)	
Copper rod milling plant							
Charging station	3	33.5 (0.72)	26.8 (0.44)	34.3 (0.42)	29.0 (0.41)	57.0 (4.00)	M
Shaft furnace	3	35.8 (0.27)	29.0 (0.15)	47.5 (076)	34.6 (0.35)	61.7 (2.89)	M
Holding furnace	3	39.4 (0.55)	31.7 (0.31)	51.2 (5.09)	37.6 (1.71)	58.3 (3.79)	M
Launching holding furnace	3	34.7 (0.47)	28.3 (0.71)	36.2 (0.51)	30.7 (0.66)	61.0 (1.73)	M
Casting machine	3	35.6 (1.20)	28.4 (0.50)	37.6 (0.32)	31.2 (0.36)	58.7 (1.16)	M

TABLE I

Continued.

Plant and department	No. of measurement sets	Heat stress parameters (°C)				Relative humidity (%)	Predominant work type
		Ta	Tw	Tg	WBGT		
Curve roller	3	34.2 (0.56)	27.8 (0.12)	38.5 (0.95)	30.5 (0.69)	62.3 (4.62)	M
Rolling Mill	3	33.3 (0.27)	27.0 (0.06)	37.2 (0.56)	30.3 (0.46)	59.3 (2.89)	M
Milling	3	33.5 (0.15)	26.9 (0.12)	39.3 (0.36)	30.4 (0.29)	59.3 (1.16)	M
Coiling system	3	33.0 (0.25)	27.1 (0.12)	33.5 (0.25)	29.1 (0.06)	65.0 (0)	M
Grand mean	27	35.8 (2.04)	28.1 (1.57)	39.5 (6.06)	31.5 (2.83)	60.3 (3.44)	
PVC Compounding plant	8	33.5 (0.61)	26.1 (0.51)	33.7 (0.74)	28.4 (0.50)	55.3 (3.50)	M
Reels plant	8	36.0 (0.33)	27.3 (0.61)	36.4 (0.26)	30.1 (0.38)	52.3 (2.60)	M
Control rooms[a] (n=5)	15	24.8 (1.31)	19.5 (1.26)	27.8 (1.90)	22.0 (1.30)	58.8 (6.82)	L

[a] Air-conditioned.

However, it has been indicated by the ACGIH as a note to the TLV for heat stress that 'higher heat exposures than those stated in the TLV are permissible if the workers have been undergoing medical surveillance and it has been established that they are more tolerant to work in heat than the average worker; but workers should not under any circumstances, be permitted to continue their work when their deep body temperature exceeds 38 °C'.

The data presented also show that the Tg readings were close to the Ta readings in all the locations studied except around the furnaces and the rolling and milling operations in the copper rod mill. This might have indicated that the industrial operations did not contribute much to the heat load there, the main contributing factor being the ambient climatic conditions. This is further supported by the fact that the few outdoor measurements of Ta, Tw and Tg in shadow during the period of the study averaged Ta = 35.5 °C, Tw = 27.0 °C, and Tg = 38.8 °C, yielding WBGT of 30.7 °C. On the other hand, in the copper rod plant it has been demonstrated that the radiant heat from the furnaces and the rolling and milling operations of the red

TABLE IIA

Results of thermal environmental assessments in JIP shaded outdoor operations. Mean (S.D.)

Department and/or location	No. of measurement sets	Month	Heat stress parameters (°C)				Relative humidity (%)	Air velocity (m/min)	Predominant work type
			Ta	Tw	Tg	WBGT			
Container workshop	7	March	29.1 (0.56)	23.9 (0.17)	30.9 (0.56)	26.0 (0.20)	63.6 (2.72)	8.9 (2.04)	H
	7	August	30.4 (0.35)	26.0 (0.27)	32.8 (0.79)	28.1 (0.39)	71.0 (1.30)	25.1 (5.90)	H
Livestock terminal	9	March	30.1 (0.12)	25.6 (0.12)	33.3 (0.21)	27.9 (0.21)	70.6 (0.24)	13.7 (2.46)	H
	9	August	31.3 (0.18)	26.7 (0.18)	34.0 (0.09)	28.9 (0.14)	71.2 (1.34)	24.6 (12.54)	H
Central workshop	14	March	30.0 (0.92)	23.0 (0.67)	31.7 (1.13)	25.6 (0.74)	54.8 (3.02)	20.7 (11.22)	M
	14	August	31.6 (0.69)	27.0 (0.47)	33.2 (0.46)	28.9 (0.43)	69.3 (2.87)	20.4 (9.42)	M
Container field	4	March	32.4 (0.41)	25.0 (0)	37.6 (0.65)	28.8 (0.19)	55.8 (2.80)	77.8 (6.70)	H
	4	August	35.4 (0.41)	32.5 (0)	38.6 (0.65)	34.3 (0.19)	80.0 (2.45)	43.1 (2.20)	
Ro–Ro station	1	March	34.0	26.5	39.0	29.8	56.0	168.0	H
	1	August	35.0	28.0	39.0	30.9	58.0	66.0	H
Houdh Al-Malik	23	March	30.6 (0.52)	26.6 (0.34)	31.7 (0.58)	28.1 (0.34)	73.2 (2.14)	15.2 (9.72)	M
	23	August	31.6 (0.38)	27.6 (0.17)	32.6 (0.31)	29.1 (0.21)	73.7 (2.29)	14.7 (9.0)	M

hot copper is the main contributing factor to the heat load there; higher Tg(s) up to 54.3 °C were recorded in some locations and the WBGT peaked up to 37.6 °C there.

4.2. Heat Exposure in the JIP Operations

Table II presents the results of heat assessments in the outdoor operations of JIP. The work-load in the different operations listed in the table has been ranked 'heavy' (H) in 12 operations, 'medium' (M) in 10 operations and 'light' (L) in only 4 operations, requiring WBGT TLV of 25.0 °C, 26.7 °C, and 30.0 °C, respectively, for continuous work during an 8-h shift (ACGIH, 1994).

TABLE IIB

Results of thermal environmental assessments in JIP unshaded outdoor operations. Mean (S.D.)

Department and/or location	No. of measurement sets	Month	heat stress parameters (°C)				Relative humidity (%)	Air velocity (m/min)	Predominant work type
			Ta	Tw	Tg	WBGT			
Passengers station	8	March	27.6 (0.40)	20.0 (0.24)	32.3 (1.16)	23.2 (0.42)	45.1 (1.76)	75.6 (11.16)	L
	8	August	32.8 (0)	27.0 (0)	35.2 (1.14)	29.3 (0.22)	63.3 (0)	60.4 (4.98)	L
Container field	26	March	33.9 (0.32)	21.6 (0.51)	38.1 (0.35)	26.4 (0.33)	31.4 (2.04)	59.8 (9.96)	H
	26	August	35.9 (0.32)	27.4 (0.51)	39.5 (0.35)	30.8 (0.38)	51.4 (2.02)	60.2 (10.38)	H
Oil station	1	March	34.0	20.5	38.0	25.4	28.0	51.0	L
	1	August	35.0	27.5	39.0	30.7	58.0	31.0	L
Ro–Ro station	6	March	32.1 (1.69)	25.3 (0.76)	34.8 (1.86)	28.3 (0.95)	59.8 (4.78)	40.8 (38.4)	H
	6	August	33.7 (1.70)	27.8 (0.80)	38.0 (0.76)	30.7 (0.89)	63.8 (4.81)	40.5 (37.8)	H
Al-Haboob station	15	March	33.2 (0.76)	23.9 (0.31)	36.9 (0.91)	27.5 (0.34)	45.3 (3.60)	96.0 (42.78)	M
	15	August	35.1 (0.56)	27.4 (0.53)	38.1 (0.80)	30.4 (0.59)	56.3 (1.90)	89.2 (42.90)	M
Haudh Al-malik	15	March	30.6 (0.78)	26.8 (0.45)	34.6 (0.97)	28.8 (0.57)	74.6 (2.40)	62.4 (26.46)	M
	15	August	32.6 (0.85)	28.2 (0.47)	35.6 (0.80)	30.3 (0.47)	73.4 (3.36)	76.4 (30.36)	M
Freezing goods	6	March	32.5 (0.28)	24.5 (0)	33.8 (1.87)	27.8 (0.54)	51.2 (0.31)	34.6 (12.12)	M
	6	August	34.3 (0.39)	27.3 (0.62)	39.2 (0.37)	30.8 (0.39)	59.3 (4.07)	37.0 (13.74)	M

The data presented indicate that the levels of WBGT exceed the TLV in mostly all the operations (except for the shedded central Workshop and Oil Station in March and the Passenger Station in March and August). This has called for scheduling the work of the workers to convene with their work-load and the load of heat exposure, as well as establishing air-conditioned rooms for their rest in the different work stations.

In the shaded areas a maximum difference of 3 °C was observed between Tg and Ta, and in the unshaded areas a difference of about 5 °C was observed. These findings support the conclusion stated above that the ambient climatic conditions in Jeddah represent the main contributing factors to heat stress in most of the operations in industry, as well as in other trades, whether indoors or outdoors.

Meanwhile, the mean heat exposure parameters (Ta, Tw, Tg and WBGT) of August significantly exceeded those of March ($p<0.01$) in all the locations (except for the Ta in the Ro-Ro station and the Tg in the shedded Central Workshop and Containers' Field). It may be noted, however, that the summer of 1991 has been known to be milder than previous summers. For example, the mean Ta, Tw and Tg recorded outdoors in the cables' plants in 1990 were higher (to some extent) than the readings of 1991. Also, the mean Ta recorded by the CMEC meteorological station during August, 1990 (32.3±1.34 °C) was higher than the mean of August, 1991 (31.2±2.01 °C) (CMEC, 1991). Furthermore, greater differences between summer and winter readings could have been observed had the measurements been made during December-February, which represent the winter season in Jeddah.

On the other hand, mostly all the operations which were peformed indoors with the provision of air-conditioning, whether by central or window units, complied with the WBGT TLV (Table III). The work load was considered 'light' in most of the departments and locations, and was 'moderate' in only a few of them.

5. Conclusions and Recommendations

It may be concluded that heat exposure presents a human factors problem in the different operations of the enterprises studied, which may have a negative impact on workers' efficiency and, consequently, on the enterprises' production. The ambient heat, relevant to the local climate conditions, represents the main contributing factor to the indoor and outdoor heat exposure. Moreover, the radiant heat from the industrial operations in the copper rod plant of the cables' industry adds more heat load to the environment of this plant.

This situation calls for a rapid action to control the heat exposure in the operations studied. It is recommended that the control strategy (Leithead and Lind, 1964; Fanger 1972; AIHA, 1973; ASHRAE, 1977; NIOSH, 1986; Holmer, 1988; Mutchler, 1991) should emphasize:

1. Evaporative engineering heat control through increased air movement by the use of fans and blowers placed in convenient places to the workers; this represents the simplest and cheapest approach to increasing the rate of evaporative heat loss.
2. Work and hygienic practices and administrative controls, including mainly:
   (a) limiting and modifying the duration of exposure time;
   (b) reducing the metabolic component of the total heat load;
   (c) enhancing the heat tolerance of the workers by heat acclimatization, physical conditioning, etc;
   (d) training the workers in safety and health procedures to work in hot environments; and

TABLE III

Summary of thermal environmental assessments in the air-conditioned buildings, departments or locations of JIP. Grand mean (S.D.)

Department and/or location	Type of air conditioning system	No. of measurement sets[a]	Month	heat stress parameters (°C) Ta	Tw	Tg	WBGT	Relative humidity (%)	Air velocity (m/min)	Predominant work type
Administrative building	Central	43								L
Training centre	Central	8								L
Marine	Central	20								
building			March	25.1	20.2	25.9	21.9	62.9	6.2	L
Container	Central	24		(1.49)	(1.82)	(1.46)	(1.61)	(7.34)	(6.3)	
building										
Safety	Central	9								L
building			August	25.5	21.4	27.8	23.3	68.9	7.1	
Passenger	Central	12		(2.90)	(3.90)	(2.29)	(2.75)	(5.12)	(4.4)	
field										L
										L
Marine control	Window Unit	1								M
Passport	-"-	9								M
building			March	26.2	19.7	26.8	21.8	54.0	12.9	
Container	-"-	1		(1.34)	(1.29)	(0.73)	(0.79)	(8.33)	(14.8)	M
workshop										
			August	27.1	27.1	28.4	23.8	37.2	13.4	
Oil station	-"-	1		(1.27)	(2.18)	(0.86)	(1.57)	(14.8)	(6.15)	L
Grain station	-"-	2								L

[a] The stated numbers represent the measurement sets at each of March and of August.

(e) medical screening of workers to eliminate individuals with low heat tolerance and low physical fitness.

3. Auxiliary body cooling and protective clothing such as air-cooled garments for workers in extreme hot areas, and aluminized air-cooled garments for workers around the furnaces in the copper rod plant. In other operations, loose and light clothing made of cotton are preferable if compatible with the safety requirements.

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