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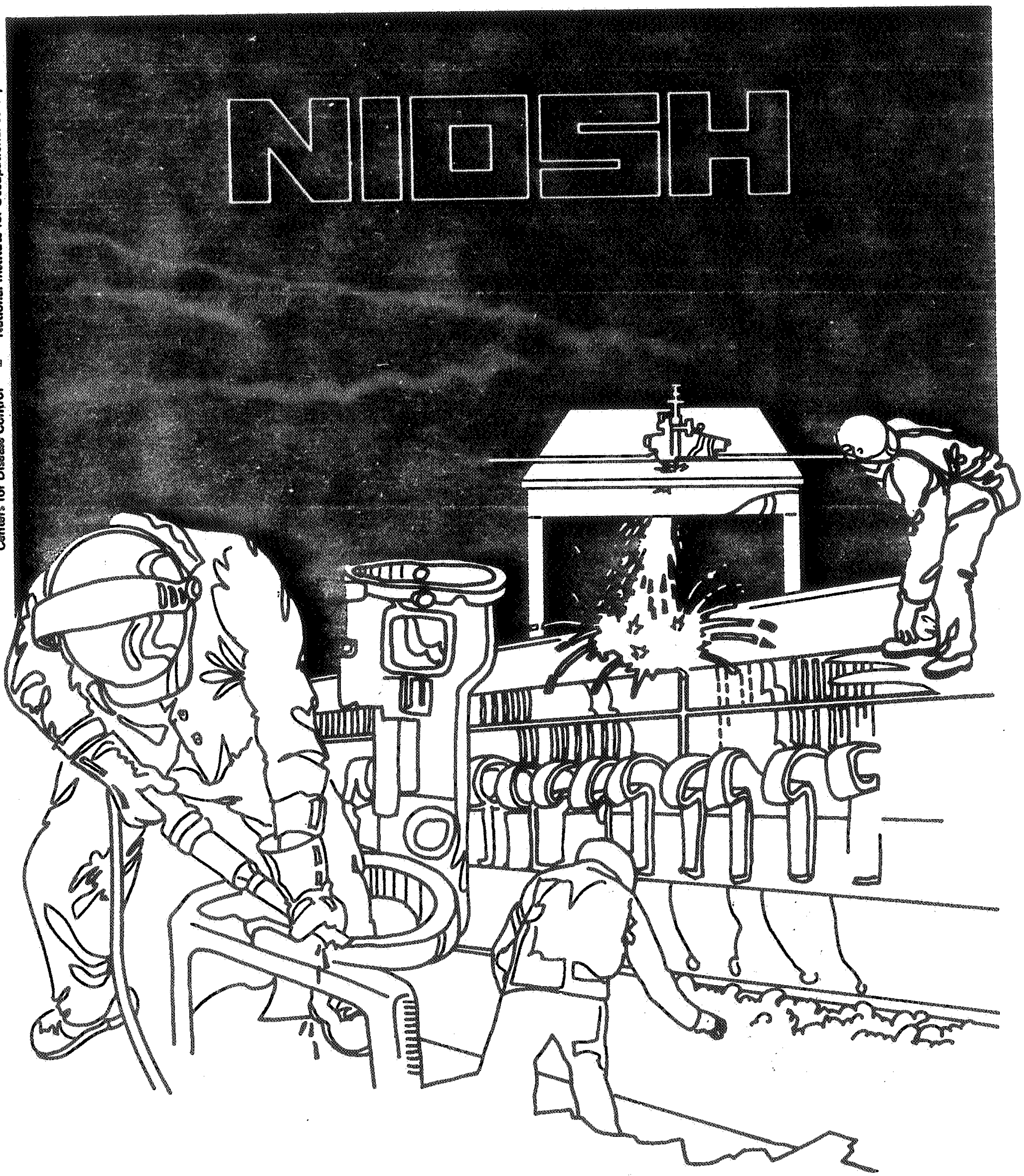

Health Hazard Evaluation Report

HETA 81-257-1115
DAVIS MONTHAN AIR FORCE BASE
TUCSON, ARIZONA

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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DAVIS MONTHAN AIR FORCE BASE
TUCSON, ARIZONA
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I. SUMMARY

On March 30, 1981, the National Institute for Occupational Safety and Health (NIOSH) received a request from the local union to conduct a health hazard evaluation of heat stress and solvent exposures to workers engaged in preservation servicing of mothballed planes at Davis Monthan Air Force Base, Tucson, Arizona.

On August 25-28, 1981, a medical/environmental evaluation was conducted. Five breathing zone air samples for lead were collected and all five were below the detection limit of 0.001 milligrams per sample. Five breathing zone air samples were collected for chromium and these sample concentrations ranged from less than 0.002 milligrams per sample to a high of 0.05 mg/M^3. Nine breathing zone air samples were collected for methyl ethyl ketone (MEK), methylene chloride (MCL), and total hydrocarbons. Only one sample was above detection limits for MCL and MEK, giving levels of 3 and 64 mg/M^3 respectively. Total hydrocarbons sample concentrations ranged from less than 0.1 to 299 mg/M^3. None of these breathing zone air concentrations that were collected exceeded the evaluation criteria established for this evaluation and did not pose a health hazard.

Heat stress was assessed by using environmental measurements of wet bulb, dry bulb, and globe temperatures; by administering questionnaires; by monitoring oral temperatures, pulse and weight; and for workers wearing impervious suits, by monitoring skin temperature on chest and calf. On all three days of the study the wet bulb globe temperature (WBGT) had exceeded 26.7^o Celcius (C) (the upper limit for continuous, moderately strenuous work) by 10:30 a.m. On the third day the WBGT exceeded 31.1^{o}C about 1:00 p.m. (the upper limit for 75% rest, 25% work per hour). Workers reported few symptoms of heat stress, but one worker on diuretics reported leg cramps on an evening during the study. Oral temperatures were not elevated; however, each worker had at least one episode where beginning-of-rest pulse showed an excessive rate. This was most likely when the full impervious suit was worn, less likely when only the pants were worn, and least likely in regular work clothes--although there was only one instance of the last. Skin monitoring was not completely satisfactory, but in five out of six recordings in which it can be determined, skin temperature equaled or exceeded core body temperature at least briefly. Only two workers showed excessive weight losses over shift, indicating inadequate fluid replacement. Both drank beer during the day, an unsuitable replacement fluid because alcohol has a diuretic effect.

On the basis of environmental and medical monitoring and individual questionnaires, NIOSH concluded that workers were subjected to a "hot environment" and showed some mild effects of heat stress. Environmental sampling showed there were no excessive exposures to lead, chrome pigment, MEK, methylene chloride, or total hydrocarbons. Recommendations are included for reducing heat stress and for monitoring for heat stress in Section VIII of this report.

KEYWORDS: SIC 4582 (Aircraft Storage), heat stress, impervious suit, chromium, lead, methyl ethyl ketone, methylene chloride, total hydrocarbons

II. INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) received a request on March 30, 1981, from a representative of the American Federation of Government Employees, Local 2924, to conduct a health hazard evaluation of heat stress and solvent exposures to workers engaged in preservation servicing of mothballed planes at Davis Monthan Air Force Base, Tucson, Arizona. The activity is conducted outdoors in full sun. To gain relief from excessive heat while wearing impervious suits, the workers are inclined to open the suits, thus exposing themselves to the solvents. After awaiting development of skin sensors to help monitor the physicologic response to heat stress, the environmental/medical survey was conducted August 25-28, 1981. Outdoor temperatures on those three days reached 39.4, 42.2, and 43.9 degrees Celsius (C) respectively (103, 108, and 111 degrees Fahrenheit (F). An interim report giving environmental data and recommendations was sent April 15, 1982, so the information would be available at the start of the 1982 hot season.

III. BACKGROUND

Davis Monthan Air Force Base serves as the repository for mothballed planes for all of the Services. Planes are received and carefully inspected for defects and missing parts. They are then mothballed. Mothballed planes are periodically unsealed, serviced, and resealed. They are also cannablized for spare parts or reconditioned and restored to service or sold. The preservation service workers are responsible for stripping and reapplying the seals.

Work is carried out on a large concrete and metal pad in full sun. There is a small air-conditioned building which contains a change room, showers and restrooms, an eating area, and a couple of office desks. Workhours during the summer are 6:30 a.m. to 3:00 p.m. with a thirty minute lunch break and a 15 minute break morning and afternoon. In addition, if necessary, the workers are free to take a brief break for water or to cool off.

When a plane is received for servicing the first procedures remove the old tape and sealants. Chipping and scraping is performed as needed, often sitting on the plane's surface. Following this the plane is sprayed with a solvent mixture containing methyl ethyl ketone (MEK), methylene chloride, and aliphatic hydrocarbons. As necessary hand application is also used. When all desired material has been removed, the plane is washed with water and a detergent and then rinsed with water. Although not being done at the time of this study, the planes are then retaped and resealed if they are to remain mothballed. Some of the washing procedures require a full impervious suit, but the majority of the time the workers either do not have to wear the suits or only wear the pants. Most wear "slicker" type suits which allow some ventilation under the arms and coming up between the pants and the jacket. There also are light-weight plastic suits which fit more tightly at all openings. Respiratory protection in neither provided for nor used by the workers.

IV. DESIGN AND METHODS

A. Environmental

Wet bulb globe temperature (WBGT) measurements were made using a wet bulb, globe, and dry bulb thermometer. A direct reading (Wibget WBGT) monitor was also used. This instrument gives direct readings for wet bulb, dry bulb, and globe temperatures. This instrument will also give the WBGT automatically.

Lead and chrome paint pigments are present on the airplanes and since workers were chipping and rubbing on this paint, breathing zone air samples were collected for lead and chromium. Samples were collected on AA filters using vacuum pumps operated at 1.5 liters per minute. These samples were analyzed by NIOSH P&CAM Method No. 173.

Breathing zone air samples for methyl ethyl ketone (MEK), methylene chloride, and total hydrocarbons were collected on organic vapor charcoal sampling tubes using vacuum pumps operated at 50 cubic centimeters per minute. These samples were analyzed by NIOSH P&CAM Method No. 127.

2. Medical

On each of the three days of the study the workers who were to wear the impervious suits had pre-work weight, oral temperature, and resting pulse measured. They were asked a brief questionnaire for acute irritative, pulmonary, cardiac, neurologic, dermatologic, and other symptoms which might be present when starting the shift. They then had a continuously recording monitor for skin temperature attached with sensors on chest and calf. Oral temperature and resting pulse were then checked at the beginning of each break. When possible a resting pulse was also obtained before return to work. Besides oral temperature and pulse, weight was checked at the end of work (or when shedding the impervious suit), and a brief questionnaire for acute symptoms again administered.

On the second day all men had oral temperature, resting pulse, weight check, and pre- and post-shift questionnaires following the same regimen as those wearing suits. Skin temperatures were not monitored on workers not wearing full suits. A longer medical questionnaire was administered to each man at some point during the three days of the study.

Oral temperatures were taken with an electronic thermometer. Pulse was obtained with an electronic meter in which the sensor clipped on a finger. It updated the determination every ten seconds. The skin temperature monitor was a modified heart monitor. It recorded two channels, one from a sensor held on the chest with a harness made from elastic bandages, and the other from a sensor taped to the calf. Each channel recorded temperatures of 35^{o}C (95^{o}F) and above. In the strip chart readout from the recording the two channels were graphed as well as the integrated skin temperature using the formula $T_{sk} = 0.58 \times T_{chest} + 0.42 \times T_{calf}$. This integration was accurate only when both chest and calf temperatures exceeded 35^{o}C.

The first step in analysis of the data was to graph all temperature and pulse readings to the same time scales and compare curves with known events.

V. EVALUATION CRITERIA

A. Environmental

Three sources of criteria used to assess the workroom concentrations of the chemicals were (1) recommended Threshold Limit Values (TLVs) and their supporting documentation as set forth by the American Conference of Governmental Industrial Hygienists (ACGIH), 1981, (2) the NIOSH criteria for a recommended standards, and (3) the Occupational Safety and Health Administration (OSHA) standards (29 CFR 1910.1000), July 1980.

	Permissible Exposure Limits 8-Hour Time-Weighted Exposure Basis
Chromium VI compounds..................	0.5 mg/M³ (NIOSH, ACGIH)
(measured as chromium)	1.0 mg/M³ (OSHA)
Lead.................................	0.05 mg/M³ (NIOSH, ACGIH, OSHA)
Methyl ethyl ketone (MEK)..............	590 mg/M³ (NIOSH, ACGIH, OSHA)
Methylene chloride.....................	360 mg/M³ (NIOSH, ACGIH, OSHA)
Total hydrocarbons*....................	525 mg/M³ (NIOSH, ACGIH, OSHA)

mg/M³ = milligrams of substance per cubic meter of air.
* = This solvent was very similar to Stoddard and, therefore, the 1981 TLV for Stoddard was chosen for the evaluation criteria.

Occupational health standards are established at levels designed to protect individuals occupationally exposed to toxic substances on an 8-hour per day, 40-hour per week basis over a normal working lifetime.

Both NIOSH[1] and ACGIH[2] recommend the use of the Wet Bulb Globe Temperature (WBGT) in assessing hot environments. Three different temperature measurements are required: 1) Wet Bulb (WB) temperature where the thermometer bulb is kept wet allowing cooling by evaporation. The dryer the air and the greater the breeze, the lower the temperature reading relative to the dry bulb temperature. 2) Dry Bulb (DB) temperature which is simply a temperature reading. This is primarily air temperature, but is slightly affected by radiant heat (sun or surroundings). 3) Globe Temperature (GT) in which the thermometer bulb is inside a hollow black globe. Radiant heat absorbed by the black globe heats the air inside giving a higher reading than the dry bulb temperature.

WBGT is calculated using one of two formulas:

1. Outdoor with solar load

$$WBGT = 0.7 \times WB + 0.2\ GT + 0.1\ DB$$

2. Indoors or Outdoors with no solar load

$$WBGT = 0.7\ WB + 0.3\ GT$$

Recommended Threshold Limit Values (TLVs)[2] assume the worker has had time to acclimate (about one week). Permissible WBGT levels vary with how strenuous the work is and on how much of an hour is spent working and how much is spent resting. Appropriate levels for this particular study are indicated in Figures I, II, and III along with the environmental measurements. These levels assume the worker has an adequate fluid and salt intake and is wearing normal clothing. The TLVs are considered safe for most workers without surveillance. Higher heat exposures are permitted with adequate medical surveillance.

B. Medical

The body's heat load derives from basic metabolic processes, muscular activity, and environmental sources, such as the sun, hot surfaces through contact or by radiation, and the air (if it is above body temperature). The body maintains a fairly uniform internal temperature through a number of adaptive mechanisms either to produce more heat or to get rid of excess heat as the situation demands. The three most important methods involve blood flow to the skin, muscular activity, and sweating. Blood flow to the skin is increased when the body needs to lose heat to the environment and decreased when it needs to conserve heat. Muscular activity is increased when more heat is needed (shivering for example) and decreased (if possible) when less heat is desired. Sweating is the major method of losing heat in a hot environment and depends on the evaporation of the sweat to produce the cooling. When regularly exposed to hot environments the body acclimates over about a week so the individual can better handle the stress caused by the heat.

Increases in blood flow in general are most easily monitored by measuring the heart rate (pulse). This does not distinguish between added blood flow to muscles because of activity and increased flow to the skin because of the need to get rid of excess body heat, but does give a fair measure of the overall strain on the heart. Pulse rates in excess of 110 beats per minute at the start of a rest period are considered excessive.[3]

Although core body temperature is most reliably measured by rectum, oral temperatures are considerably easier to measure and run about one degree lower than rectal temperatures. Their disadvantages are that they take longer (if a glass clinical thermometer is used) and that they are influenced by cold or hot drinks, smoking, etc. Oral temperatures at the beginning of a rest period should not exceed 37.6^{o}C (99.6^{o}F).[3]

Short term swings in body weight are due to gain or loss of water. Thus a loss of body weight over shift can be used to assess how much water has been lost through sweating and not been replaced. A loss of greater than 1.5% of total body weight is excessive and requires greater attention to fluid replacement.[3] The body loses salt along with the water which must also be replaced, preferably in food, although beverages with 0.1% salt can also be used. (One level tablespoon of salt in 15 quarts of water or one level teaspoon of salt in one gallon of water represents 0.1% salt.)

Studies[4] have shown that when the skin temperature approaches the core body temperature heat tolerance is limited. This can be expected to occur when either the environmental load is extremely high or when heat loss through sweating is greatly impaired. The latter might occur when there is high humidity and little air movement--an impervious suit being one way to achieve this. When skin temperature over the majority of the body exceeds core body temperature, the body can be expected to gain heat from the environment. In this study any time the integrated skin temperature exceeded the initial oral temperature by 1°C or more, it was considered that the individual was gaining heat from the environment and was, therefore, at risk of suffering ill effects from heat strees on this basis alone.

C. Heat Stress[1]

Figure IV diagrams various reactions to heat stress. The problems caused by a failure to fully cope with the stress are to the right of the figure.

1. Heat syncope (fainting) and heat edema occur in unacclimated workers standing erect and immobile in the heat. Blood and body fluid tend to accumulate in the feet and legs, reducing the blood returning to the heart and consequently reducing blood flow to the brain. Treatment is to have the person lie down. Prevention is to move around.

2. Heat cramps and water intoxication can occur when the salt lost in sweating is not adequately replaced but the water is. The muscle cramps are most likely to occur in the most used muscles and can occur either during work or after work. Although more likely in unacclimated workers, it can occur in anyone who sweats a lot, drinks lots of salt-free fluids, and fails to increase salt consumption. Persons on diuretics, which interfere with the body's salt regulating mechanisms, should consult with their doctors on how to handle both the medical problem for which they are on the medication and the body's need for extra salt for the sweat. Under more severe conditions the problem can progress to salt depletion heat exhaustion.

3. Heat exhaustion, either due to salt depletion or water depletion, leads to weakness, extreme fatigue, giddiness, nausea, and headache. The skin is clammy and moist indicating that sweating is still active. Complexion may be pale, ruddy, or flushed. Oral temperature may be normal or low, but the rectal temperature is usually elevated (37.5° to 38.3°C, 99.5° to 101°F). The worker may faint on trying to stand, and is shocky (weak, thready pulse, and low blood pressure). The major problem is a loss of circulating body fluid (dehydration). Correction is to replace the fluid with a balance of water and salt. Milder cases can probably be handled with rest and fluids (such as the 0.1% salt solution). More serious cases should receive prompt medical attention. (DO NOT TRY TO FORCE LIQUIDS INTO AN UNCONSCIOUS PERSON.)

4. Heat stroke represents a complete breakdown of the body's heat regulating mechanism. It is a medical emergency which is usually fatal if not treated promptly. Of prime importance in emergency first aid is RAPIDLY COOLING the person by immersion in cold water, wrapping the naked person in wet towels, and fanning to allow

evaporative cooling or some similar method of cooling. The three cardinal signs of heat stroke are:[1] (1) hot, dry skin: red, mottled, or cyanotic; (2) an elevated body temperature usually 41°C (106°F) or higher, and rising; (3) brain disorders: mental confusion, delirium, loss of consciousness, convulsions, and coma.

5. Skin problems associated with heat exposure include heat rash (prickley heat) in which sweat ducts get clogged with a resulting inflammation of the sweat glands. It is characterized by discomfort and tiny red visicles in the affected area. It is caused by the skin remaining constantly wet with unevaporated sweat and can be prevented by allowing the skin to dry between heat exposures. In the dry Southwest this is only likely to be a problem in skin folds, or on prolonged and repeated use of an impervious suit.

   Anhidrotic heat exhaustion is somewhat similar to heat rash and may follow an extensive heat rash. It shows up as a non-sweating area of skin with "gooseflesh" like eruption caused by deep blocking of the sweat ducts. It is unlikely in temperate climates where the hot season is of only limited duration.

D. Toxicological

Insoluble Chromium VI Pigments (Chrome Pigments)[5] -- Chromium is an essential trace element in the body. However, excessive concentrations of soluble chromium salts can cause toxicity, the most notable being skin and nasal ulcers and perforation of the nasal septum. They are irritating to mucous membranes and are capable of sensitizing the individual and causing a dermatitis. The insoluble chrome pigments, under suitable conditions of acidity, might do the same. Allergic sensitization is the most likely ill effect to be seen. The other toxic effects mentioned are unlikely. The most serious long term health effect is an increased risk of respiratory cancer[6], although the procedures utilized in this job are unlikely to produce particles small enough to reach the lung.

Lead[7] -- Inhalation (breathing) of lead dust and fume is the major route of lead exposure in industry. A secondary source of exposure may be from ingestion (swallowing) of lead dust deposited on food, cigarettes, or other objects. Once absorbed, lead is excreted from the body very slowly. Absorbed lead can damage the kidneys, peripheral and central nervous systems, and the blood forming organs (bone marrow). These effects may be felt as weakness, tiredness, irritability, digestive disturbances, high blood pressure, kidney damage, mental deficiency, or slowed reaction times. Chronic lead exposure is associated with infertility and with fetal damage in pregnant women.

Blood lead levels below 40 ug/deciliter* whole blood are considered to be normal levels which may result from daily environmental exposure. However, fetal damage in pregnant women may occur at blood lead levels as low as 30 ug/deciliter. Lead levels between 40-60 ug/deciliter in lead-exposed workers indicate excessive absorption of lead and may result in some adverse health effects. Levels of 60-100 ug/deciliter represent unacceptable elevations which may cause serious adverse health effects. Levels over 100 ug/deciliter are considered dangerous and often require hospitalization and medical treatment.

The Occupational Safety and Health Administration (OSHA) standard for lead in air is 50 ug/M^3 calculated as an 8-hour time-weighted average for daily exposure. The standard also dictates that workers with blood lead levels greater than 60 ug/100 g whole blood* must be immediately removed from further lead exposure if confirmed by a follow-up test and, starting from March 1, 1983, workers with average lead levels of 50 ug/100g or greater must also be removed. Removal is also possible on medical grounds. Removed workers have protection for wage, benefits, and seniority for up to 18 months until they can return to lead exposure areas.

Methyl Ethyl Ketone (MEK) -- MEK is an irritant to the eyes, mucous membranes, and skin. Repeated exposure to high concentrations may cause numbness of the fingers, arms, and legs. MEK may also produce defatting dermatitis. MEK may be recognized at low concentrations by its odor which is similar to acetone but more irritating. Maintaining worker exposures below 590 mg/M^3 for an 8 hour day, 40 hour work week should provide adequate protection.[8]

Methylene Chloride -- Methylene chloride is irritating to the skin on repeated or prolonged contact. Splashing of the liquid into the eye is painfully irritating but is not likely to cause serious injury. Signs and symptoms of toxicity include fatigue, weakness, sleepiness, light-headedness, nausea, and numbness and tingling of the limbs. Exposure to methylene chloride may cause elevated carboxyhemoglobin levels which may be significant in smokers, workers with anemia or heart disease, or those exposed to carbon monoxide.[9]

Total Hydrocarbons (Stoddard Solvent)-- This aliphatic solvent usually does not cause adverse health problems. A bulk sample should be analyzed for aromatic content since they are sometimes contaminated with benzene. From a practical point of view, and in the absence of benzene, the manifestation of exposures to Stoddard solvent include: giddiness, vertigo, nausea, headache, and anesthetic stupor. In cases of acute, high exposure, full recovery without sequelae is the rule. Repeated or prolonged skin exposure can be irritating and can lead to a defatting dermatitis.[10] Maintaining the time-weighted average (TWA) for an 8-hour day, 40-hour week below 525 mg/M^3 should eliminate any health risk.

VI. RESULTS AND DISCUSSION

A. Environmental

On August 27-28, 1981, an environmental evaluation was conducted. Five breathing zone air samples for lead were collected and all five were below the detection limit of 0.001 milligrams per sample (Table 1). Five breathing zone air samples were collected for chrome and these sample concentrations ranged from less than 0.002 milligrams per sample to a high of 0.05 mg/M^3 (Table 1). Nine breathing zone air samples were collected for methyl ethyl ketone (MEK), methylene chloride (MCL), and total hydrocarbons (Table 2). Only one sample was above detection limits for MCL and MEK. These were 3 and 64 mg/M^3 respectively.

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* 1 ug/deciliter whole blood is roughly equivalent to 1 ug/100 g whole blood.

Total hydrocarbons sample concentrations ranged from less than 0.1 to 299 mg/M^3. None of these breathing zone air concentrations exceeded the evaluation criteria established for this evaluation and did not pose a health hazard. Low levels of exposure to all chemicals monitored was due to good work practices and because the work was performed outside with plentiful ventilation.

B. Medical

There were eight workers, all men, in the preservation service area with a median age of 61 (range 25 to 66). Data was obtained on seven of them and covered 14 episodes (one episode per day, one to three days per man). Starting oral temperatures averaged 36.15^{o}C (97.1^{o}F) and ranged from 35.3^o to 36.9^{o}C. There were no significant changes in oral temperature during the study. Starting pulse rate averaged 79.1 beats per minute and ranged from 66 to 104. The worker with the starting pulse of 104 dropped to 74 on the next determination. Figures V through VII graph individual monitoring results for the three days. All seven workers had at least one instance where their pulse at the beginning of a break exceeded 110 beats per minute. In all there were seven such episodes. These will be discussed in greater detail along with the environmental measures of heat stress.

Weight change over shift averaged a 0.73% drop, ranging from a 0.9% gain to a 2.4% drop. There were only three episodes where the drop exceeded 1.5%, two in the same worker. Both of these workers drank beer during the day. None of the others did. Alcohol has a diuretic effect on the kidney by inhibiting the secretion of anti-diuretic hormone.[11] Thus the kidneys are less able to conserve water, making dehydration more likely.

Three of the workers were on diuretics. One complained of leg cramps during one of the nights during the study. He had sustained a 1.2% loss in body weight the previous day. Excessive salt loss is a likely cause for the cramps.

One worker said he nearly passed out the first day back after being East, undoubtedly representing a loss of acclimation.

Three workers exercised regularly. Although this could be expected to increase their ability to withstand heat stress, the study group was too small to demonstrate any difference.

All seven of the workers wore a skin monitor at some time during the study. In all, ten recordings were made. Of these, three recordings failed, three recordings were poor to fair with only limited useful data, and four recordings were good. Of six recordings which were good enough to give at least some integrated skin temperature readings, five showed episodes where the skin temperature equaled or exceeded the core body temperature and one did not. One recording with very poor calf recordings showed a few isolated instances where the integrated skin temperature exceeded the core temperature. These findings will be discussed in greater detail along with the environmental measures of heat stress.

C. Heat Stress Assessment

Figures I, II, and III plot environmental temperatures for the three study days. Four horizontal lines are drawn on the graphs representing wet bulb globe temperatures (WBGTs) at which changes in work practices are needed to make heat stress related problems unlikely.[10] It was assumed that the work fell into the Moderate category. As long as the WBGT is below the lowest line (Line 1), continuous work in regular work clothes should be possible without danger for acclimated workers. (ACGIH defines continuous work as including a 15 minute break morning and afternoon and a half hour for lunch.) At WBGTs above the lower line, the work/rest schedule should be changed to allow the workers to cool off periodically, such that at Line 4 they should be working only 15 minutes out of every hour. As an alternative to allowing such long rest periods, an adequate individual monitoring program can assure individual safety while allowing workers to work closer to their capacity. However rest periods should be instituted every hour, both to allow the workers to cool down and to allow for the monitoring. On the three days the WBGT exceeded the maximum for continuous work at about 10:35 a.m., 9:45 a.m., and 10:15 a.m., respectively. In addition on the third day it exceeded the line for 75% rest, 25% work per hour at about 1:00 p.m., making individual monitoring the only safe way to continue work. Because of the difficulties with measuring WBGTs, dry bulb temperatures are more likely to be available. These are also plotted on the graphs. On the three days the dry bulb temperatures were between 95^{o} and 100^{o}F when the WBGTs exceeded the maximum for continuous work. Except for high humidity days, unlikely in Tucson, a dry bulb reading of over 95^{o}F should serve as a fairly good guide to the existence of an overly hot environment requiring work modification, although WBGT readings would be preferable. Temperatures taken in the building confirm that it is a good cooling off place. Outside, even in the shade, may not be.

Wearing an impervious suit robs the body of its major method of eliminating excess heat--evaporation of sweat. The more complete the seal, the greater the problem. Most monitoring was done while at least part of the suits were being worn. Nevertheless, for those periods when regular work clothes were being worn, only one worker (on the third day) increased his beginning of rest pulse to over 110 beats per minute. At the time the WBGT equaled or exceeded the continuous work line. Individual monitoring results are shown in Figures V through VII.

There were eight instances where a worker wearing a full "slicker" suit was monitored, and one for the light-weight suit. In six instances involving the slickers at least one of the pulses at the beginning of a rest period exceeded 110 beats per minute. The lowest WBGT associated with an excessive pulse rate was 25^{o}C with a dry bulb temperature of 95^{o}F. The highest WBGT associated with a slicker-wearer showing no excessive increase in pulse was 29.5^{o}C with a dry bulb temperature of 101^{o}F. For the light weight suit there was no excessive pulse rate although the maximum WBGT was 29^{o}C with a dry bulb temperature of 107^{o}F. It was observed that the worker wearing the light weight suit appeared to be considerably more sweat soaked than did the wearers of the slickers.

There were six instances where a worker wearing only the slicker pants was monitored. In only two instances were there excessive beginning of rest period pulses. The lowest WBGT associated with this was 26°C with a dry bulb temperature of 96°F. The maximum WBGT temperature not associated with an excessive pulse was 31°C, and the maximum dry bulb temperature was 103°F.

Thus it appears that the full suit is more likely to lead to an excessive beginning of rest period pulse than is the use of the pants only. Also excessive pulses are first observed at WBGT temperatures which would be considered safe for continuous work in regular work clothes. Although in the one instance of excessive pulse the dry bulb temperature associated with the WBGT temperature of 25°C was 95°F, over the three days temperatures of 90 to 95°F were associated with 25°C WBGT.

The skin monitoring showed that most workers on whom the tests were successful had episodes where skin temperature equaled or exceeded core temperature. Under these circumstances not only was the body prevented from loosing the heat generated internally, but it also gained heat from the environment. As a monitoring method, however, skin temperatures appear less sensitive than pulse and considerably harder to obtain. Also, with current instrumentation, pulse allows an immediate readout and, therefore, immediate corrective action. Skin temperatures do not. If one were to go to continuous pulse monitoring, it should be remembered that during the work activities one would expect the pulse to rise above 110 beats per minute, possibly for prolonged periods of time. However on ceasing activity (beginning of rest pulse), it should rapidly drop below this level.

VII. CONCLUSIONS

Based on environmental criteria workers at this facility were subject to heat stress all three days of the study beginning in midmorning. Biologic monitoring suggested that the wearing of a full impervious suit increased the stress, with the wearing of the pants only causing less increase in stress than the full suit. Current work practices allow enough flexibility to make serious heat stress problems unlikely although there have been a few instances of more minor heat stress illnesses. Fluid replacement appeared adequate except where beer was used as the replacement fluid. There is a possibility of interaction between heat coping mechanisms and medications (particularly diuretics). The individual's physician should be made aware of the possibility. Because most of the older workers are eligible for medical care from the Air Force, it would seem appropriate for the local Air Force medical facility to draw up guidelines.

Environmental sampling for lead, chrome, methyl ethyl ketone (MEK), methylene chloride, and total hydrocarbons showed none to pose a health problem as used. Low levels of exposure to all chemicals monitored was due to good work practices and because work was performed outside with plentiful ventilation.

VIII. RECOMMENDATIONS

1. During hot weather work should be done as early in the day as possible. It would help if the starting time be moved up sufficiently that the workers are able to be out on the wash rack starting work as soon as light permits.

2. When only part of the impervious suit is needed for protection, only wear the necessary part.

3. During hot weather all workers should have a baseline pulse, oral temperature, and weight at the start of the shift. If oral temperature exceeds 99.6°F (37.6°C), they should not be permitted to work without medical clearance that day. If the initial pulse exceeds 110 beats per minute and does not come down on rest, the worker should receive medical clearance that day before being allowed to work. If the pulse does come down, use the lower pulse rate as the baseline. Workers should be weighed again, comparably clothed, at the end of shift. If weight loss over shift exceeds 1.5% of beginning weight, the worker should be informed, and encouraged to more adequately replace sweat loss. Beer is not a good replacement fluid because of the diuretic effect of the alcohol.

4. When monitoring is required, work periods should not exceed one hour at a time. Pulse should be taken as soon as possible after coming in to rest. Oral temperature should be taken some time during the rest period, but not immediately after a drink, hot or cold, or smoking. If the pulse rate exceeds 110 beats per minute or the oral temperature exceeds 99.6°F (37.6°C), the work period should be shortened before the next rest and the worker should not be permitted back to work until his pulse and temperature are below these levels. If a baseline has not already been established, pulse and temperature should be taken at the <u>end</u> of the first rest period after it has been determined monitoring will be necessary. After a few months of monitoring the results may indicate that oral temperatures (other than baseline) are only needed if the pulse exceeds 110 beats per minutes.

5. For workers wearing the impervious suits, monitoring should be started any day it is anticipated that the outside temperature will exceed 90°F (32°C). It is particularly important that these workers have baselines established, preferably before they start working in the suits.

6. For workers not wearing the suits, monitoring need not start until the outside temperature exceeds a WBGT of 26.7°C; if only a dry bulb temperature is available, any time it exceeds 95°F (35°C), unless it is a very humid day (in which case use a lower temperature).

7. There should be a procedure posted for handling a possible heat stroke victim which includes rapid cooling of the worker, obtaining medical assistance, and establishing the core (rectal) body temperature. The rectal temperature may be of help in less severe heat cases as well. The supervisor is the most logical person to be in charge of such emergencies, but several of the more experienced workers should be ready to take charge in his absence.

8. Workers on medications, particularly diuretics or other heart or blood pressure medications, should inform their doctor that they work in a hot environment so appropriate modifications in medication and salt intake can be made. The Base medical facility should draw up guidelines which can help the individual physicians make appropriate modifications.

9. For the oral thermometer, an electronic thermometer would prove much more satisfactory than trying to maintain enough sterile glass thermometers. It would also reduce the time necessary to take the temperature. A glass rectal thermometer should prove adequate and should be available in the office area. Pulse could be more easily obtained utilizing an electronic meter, but could be done almost as well, after a little practice, counting the radial pulse for 30 seconds (and multiply by 2) using a watch with an adequate seconds readout. WBGTs should be obtained using a direct reading monitor, such as the Wibget WBGT.

IX. REFERENCES

1. Criteria for a Recommended Standard...Occupational Exposure to Hot Environments. DHEW Publication (NIOSH) 72-10269.

2. Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1981. ACGIH, Cincinnati, Ohio, 1981.

3. Procedures for Heat Stress Surveillance . . . Dukes-Dobos and Janerfeldt. Personal communication April 27, 1981.

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6. "Chrome Pigment", Current Intelligence Bulletin 4 (October 8, 1976) from Reprints - Bulletins 1 through 8. DHEW (NIOSH) Publication No. 78-127.

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9. Ibid., pp. 342-343.

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11. Gilman's The Pharmacological Basis of Therapeutics, 6th edition. MacMillan Publshing Company, New York, 1980, p. 381.

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Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Information Resources and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Service (NTIS), Springfield, Virginia. Information regarding its availability through NTIS can be obtained from NIOSH, Publications Office, at the Cincinnati address.

Copies of this report have been sent to:

1. Davis Monthan Air Force Base.
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3. American Federation of Government Employees.
4 U.S. Department of Labor/OSHA - Region IX.
5. NIOSH - Region IX.
6. Arizona State Department of Health.
7. State Designated Agency.

For the purpose of informing affected employees, a copy of this report shall be posted in a prominent place accessible to the employees for a period of 30 calendar days.

TABLE 1

Breathing Zone Air Concentrations of
Chromium and Lead
on Aircraft Preservation Servicers

Davis Monthan Air Force Base
Tucson, Arizona

August 27-28, 1981

Sample Number	Sampling Time	Chromium (mg/M³)	Lead (mg/M³)
100	6:54 AM - 10:25 AM	*	*
101	8:40 AM - 9:40 AM	0.01	*
102	8:45 AM - 10:05 AM	*	*
106	9:35 AM - 12:45 PM	0.05	*
200	7:10 AM - 10:20 AM	*	*
EVALUATION CRITERIA		0.05	0.05
LABORATORY LIMIT OF DETECTION mg/filter		0.002	0.001

* = below laboratory limit of detection

TABLE 2

Breathing Zone Air Concentrations of
Methyl Ethyl Ketone (MEK), Methylene Chloride (MCL), and Total Hydrocarbons
on Aircraft Preservation Servicers

Davis Monthan Air Force Base
Tucson, Arizona

August 27-28, 1981

Sample Number	Sampling Time	mg/M^3 MEK	MCL	Total Hydrocarbons
1	6:30 AM - 1:30 PM	*	*	22
2	6:39 AM - 1:30 PM	*	*	299
3	8:37 AM - 1:40 PM	*	*	65
4	8:40 AM - 1:45 PM	*	*	8
5	6:45 AM - 8:30 AM	*	*	*
6	6:45 AM - 1:30 PM	*	*	14
7	6:50 AM - 1:00 PM	*	*	33
8	6:50 AM - 1:10 PM	*	*	*
9	6:54 AM - 2:15 PM	64	3	6
EVALUATION CRITERIA		590	360	525**
LABORATORY LIMIT OF DETECTION mg/sample		0.01	0.01	0.1

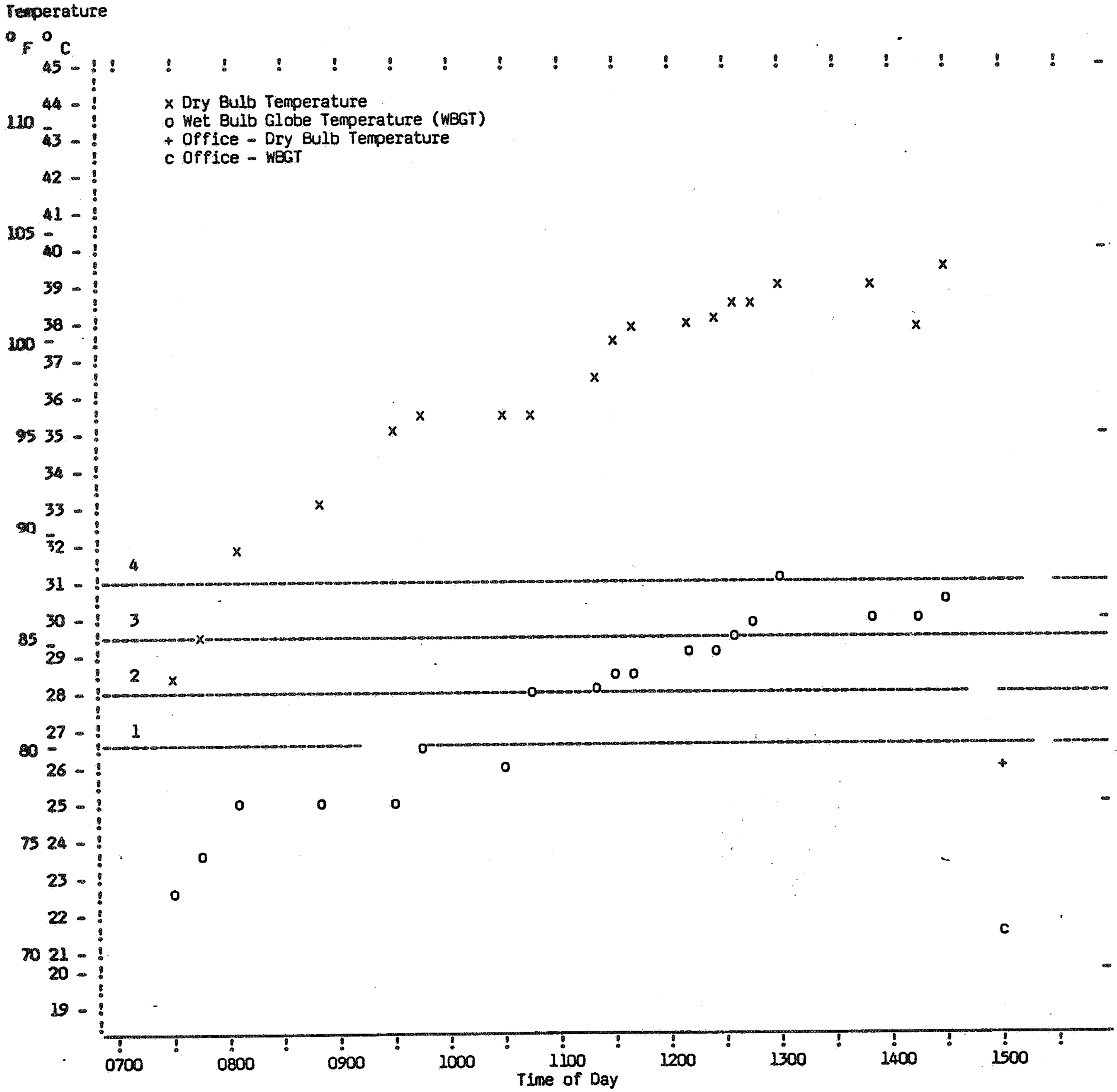
* = below laboratory limit of detection

** = this solvent was very similar to Stoddard and, therefore, the 1981 TLV for Stoddard was used as the evaluation criteria.

FIGURE I

Environmental Temperatures

Davis Monthan Air Force Base
Tucson, Arizona
August 25, 1981



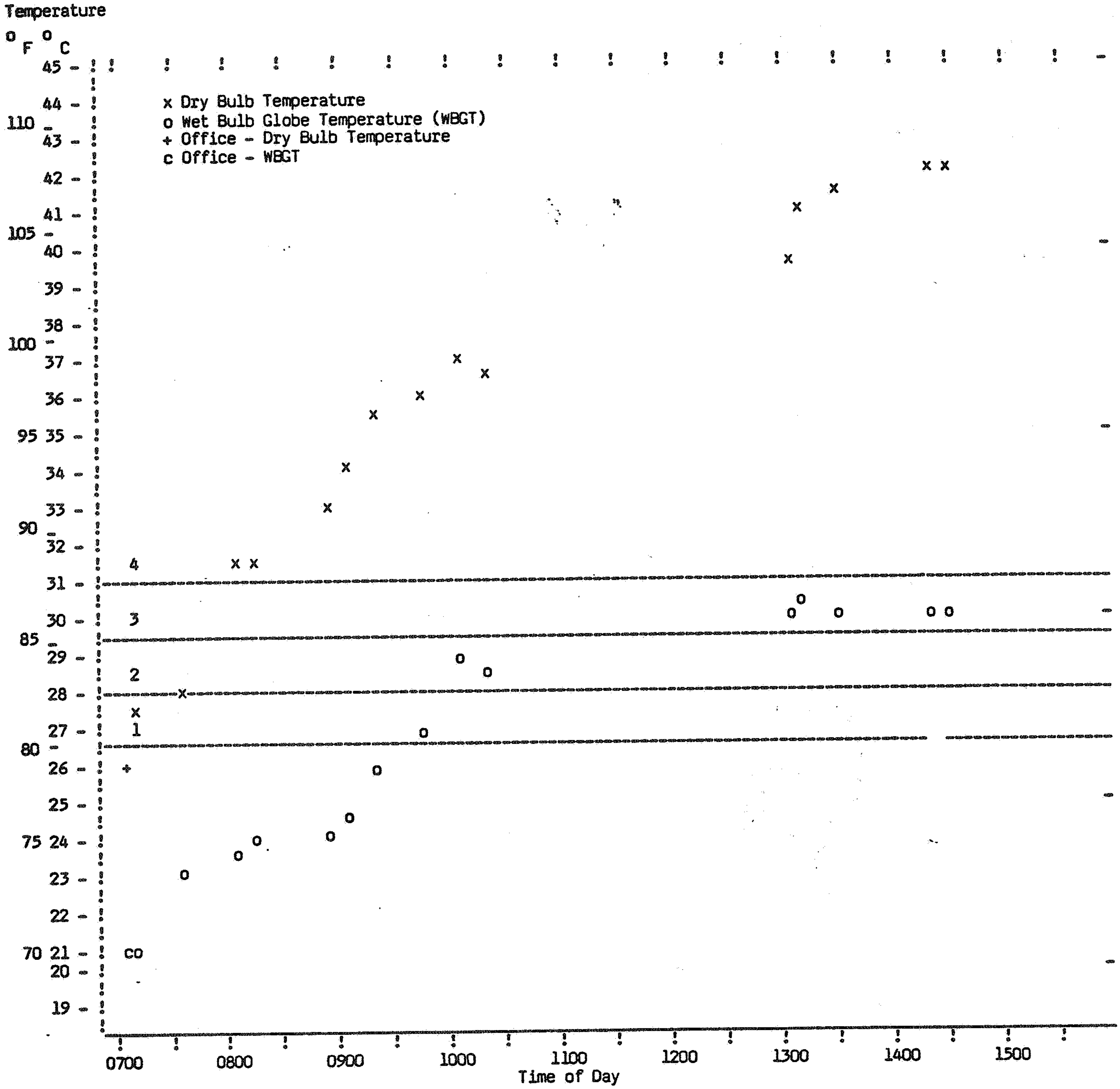
Line 1	Threshold Limit Value (TLV) for Continuous Work, Moderate Work Load	26.7°C WBGT
2	TLV 75% Work, 25% Rest, Each Hour, Moderate Work Load	28.0°C WBGT
Line 3	TLV 50% Work, 50% Rest, Each Hour, Moderate Work Load	29.4°C WBGT
Line 4	TLV 25% Work, 75% Rest, Each Hour, Moderate Work Load	31.1°C WBGT

TLVs taken from Table 1, page 59, Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1981. ACGIH, Cincinnati, Ohio, 1981.

FIGURE II

Environmental Temperatures

Davis Monthan Air Force Base
Tucson, Arizona
August 26, 1981



Line 1 Threshold Limit Value (TLV) for Continuous Work, Moderate Work Load 26.7°C WBGT

Line 2 TLV 75% Work, 25% Rest, Each Hour, Moderate Work Load 28.0°C WBGT

Line 3 TLV 50% Work, 50% Rest, Each Hour, Moderate Work Load 29.4°C WBGT

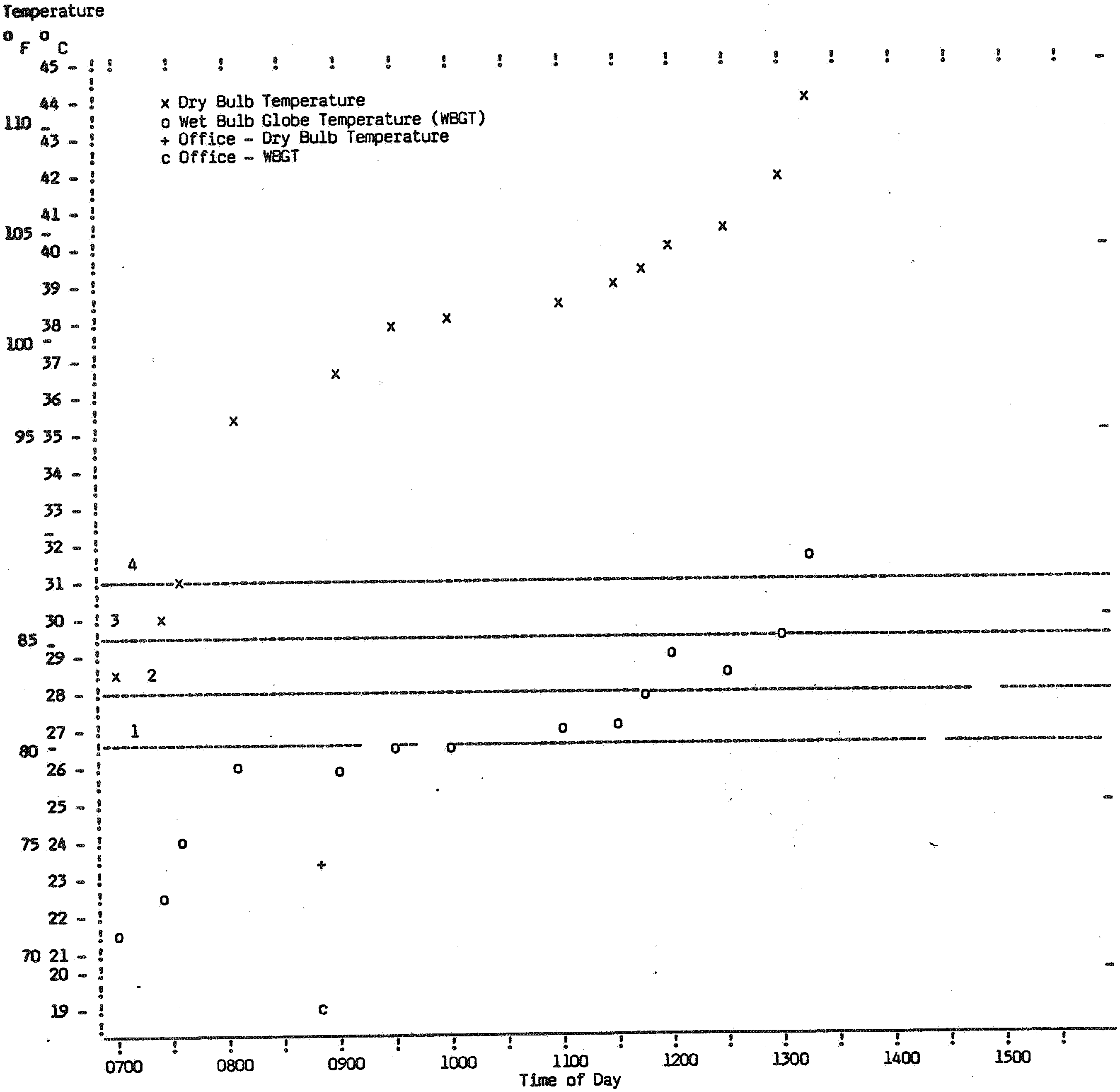
Line 4 TLV 25% Work, 75% Rest, Each Hour, Moderate Work Load 31.1°C WBGT

TLVs taken from Table 1, page 59, <u>Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1981</u>. ACGIH, Cincinnati, Ohio, 1981.

FIGURE III

Environmental Temperatures

Davis Monthan Air Force Base
Tucson, Arizona
August 27, 1981



Line 1 Threshold Limit Value (TLV) for Continuous Work, Moderate Work Load 26.7°C WBGT

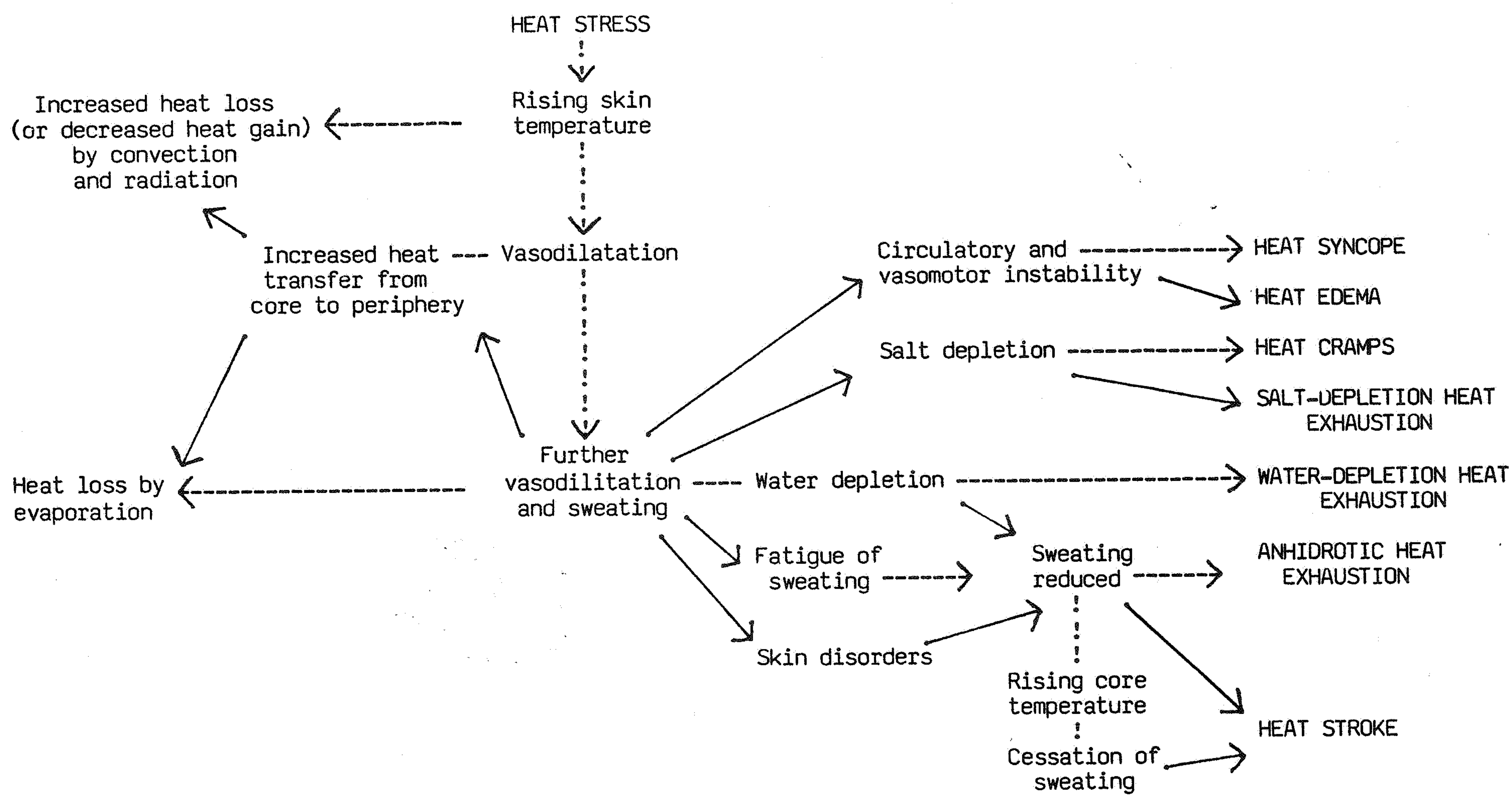
Line 2 TLV 75% Work, 25% Rest, Each Hour, Moderate Work Load 28.0°C WBGT

Line 3 TLV 50% Work, 50% Rest, Each Hour, Moderate Work Load 29.4°C WBGT

Line 4 TLV 25% Work, 75% Rest, Each Hour, Moderate Work Load 31.1°C WBGT

TLVs taken from Table 1, page 59, Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1981. ACGIH, Cincinnati, Ohio, 1981.

FIGURE IV
Heat Stress and Heat Disorders



Reference: Figure 3. Heat Stress and Heat Disorders, Criteria for a Recommended Standard . . . . Occupational Exposure to Hot Environments. NIOSH, HEW Publication No. HSM 72-10269, 1972.

FIGURE V

Individual Worker Monitoring

Davis Monthan Air Force Base
Tucson, Arizona
August 25, 1981

Worker # 1 — Weight loss over shift 1.6%

Clothing: X........................Full Suit.........................X
Pulse: 66 80 84 103 103 115 109 96
Skin Monitor: X.............Good..............X
Skin Temp. Equals or Exceeds Core Temp.: XX X

Worker # 2 — Weight loss over shift 1.9%

Clothing: X....................Full Suit........................X.......Pants Only........X
Pulse: 85 95 95 113 96 114 115 118 116
Skin Monitor: X.............Poor.............X
Skin Temp. Equals or Exceeds Core Temp.: None

Worker # 3 — Weight gain over shift 0.9%

Clothing: X.Full SuitX..Pants only much of time.X
Pulse: 75 126 93 101
Skin Monitor: X.No RecordX

Worker # 4 — Weight loss over shift 0.0%

Clothing: X.............Full Suit.............X
Pulse: 85 115 114
Skin Monitor: X..............Good...............X
Skin Temp. Equals or Exceeds Core Temp.: XX

Worker # 5 — Weight loss over shift 0.0%

Clothing: X..........Pants Only...........X
Pulse: 75 91 101
Skin Monitor: No

0700 0800 0900 1000 1100 1200 1300 1400 1500
Time of Day

FIGURE VI

Individual Worker Monitoring

Davis Monthan Air Force Base
Tucson, Arizona
August 26, 1981

Worker # 1 — Weight loss over shift 2.4%
Clothing — Regular Work Clothes
Pulse 79 — 65 62 81 84 78 92 69
Skin Monitor — No

Worker # 2 — Weight loss over shift 0.9%
Clothing — Regular Work Clothes
Pulse 104 — 74 78 85 81 81
Skin Monitor — No

Worker # 3 — Weight loss over shift 1.2%
ClothingX..........Pants Only..........X
Pulse 78 — 82 84 85 81 89 75 80 83
Skin Monitor — No

Worker # 4 — Weight loss over shift 1.2%
ClothingX.......................Full Suit........................X
Pulse 68 — 80 96 82 108 93 85 92 90
Skin Monitor — X..............Good...............X
Skin Temp. Equals or Exceeds Core Temp. — XXX XXXXXX XXX

Worker # 5 — Weight loss over shift 0.0%
Clothing — X...Full Suit....X
Pulse 76 — 64 72 66 68 87 113 91 82 84 64 77
Skin Monitor — X......Poor......X
Skin Temp. Equals or Exceeds Core Temp. — X X X

0700 0800 0900 1000 1100 1200 1300 1400 1500
Time of Day

Individual Worker Monitoring

Davis Monthan Air Force Base
Tucson, Arizona

FIGURE VI (continued)
August 26, 1981

Worker # 6 — Weight loss over shift 0.3%

Clothing X..........Pants Only..........X........................Full Suit........................X

Pulse 80 110 119 104 125 115 133 107 117 103 114 99

Skin Monitor X...........Good...........X

Skin Temp. Equals or Exceeds Core Temp. XXXX XX

Worker # 7 — Weight loss over shift 0.5%

Clothing X.Full Suit..X

Pulse 87 87 102 121 101 97 114 146 120

Skin Monitor X.No Record..X

0700 0800 0900 1000 1100 1200 1300 1400 1500

Time of Day

FIGURE VII
August 27, 1981

Worker # 4 — Weight loss over shift 0.0%

Clothing X..............Light Weight Suit...............X

Pulse 70 89 93 83 99 90 104 80

Skin Monitor X...................Good...................X

Skin Temp. Equals or Exceeds Core Temp. X X

Worker # 7 — Weight loss over shift 1.1%

Clothing X.............Full Suit.............XPantsX

Pulse 80 85 82 92 86 90 94 88

Skin Monitor X...............No Record...............X

0700 0800 0900 1000 1100 1200 1300 1400 1500

Time of Day

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