Heat Stress Management

Pavel CASTULIK

CB 050 Vojenská chemie, toxikologie ochrana před vysoce toxickými látkami

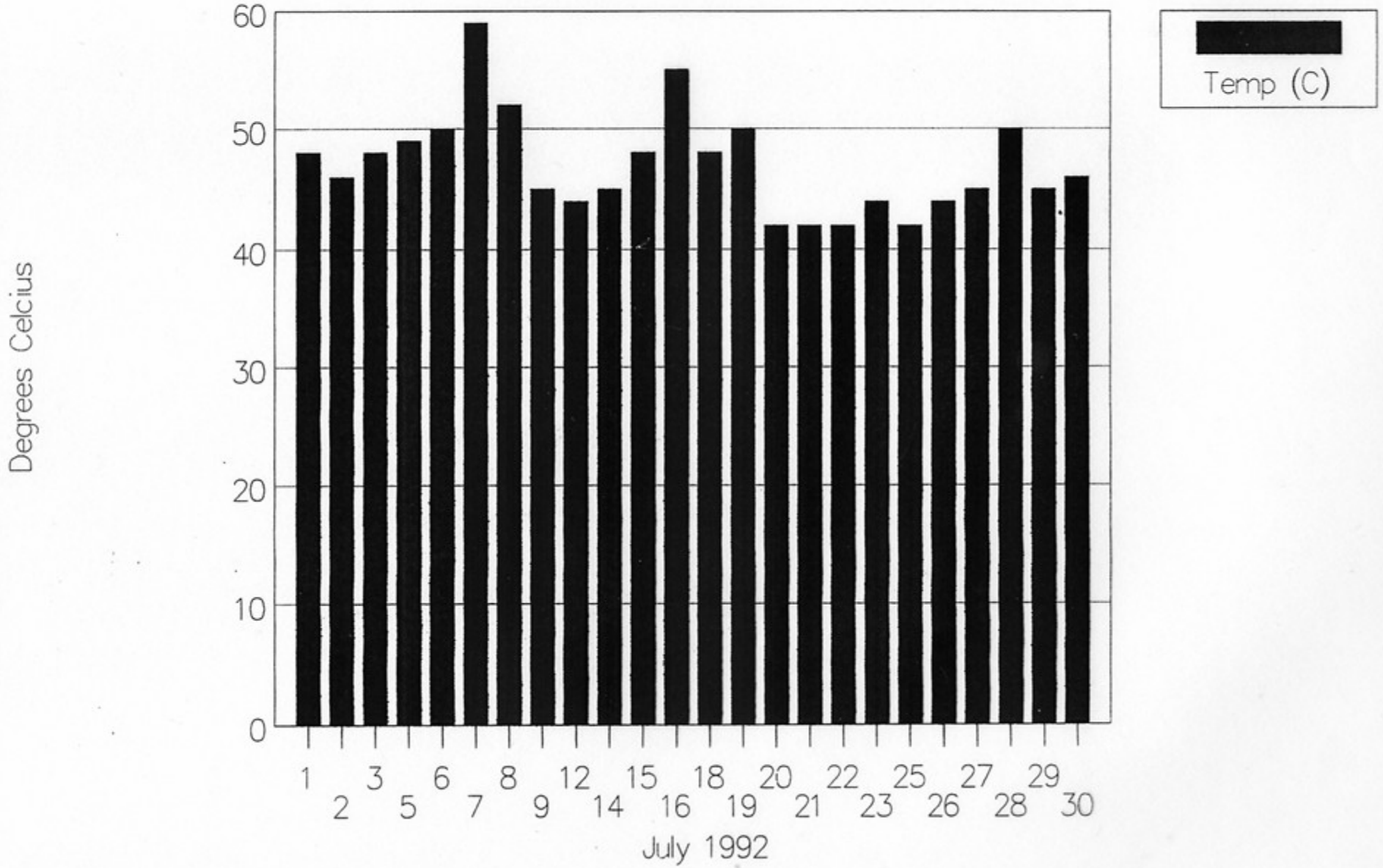
Přírodovědecká fakulta Masarykovi university Brno

Jaro 2011

Heat Exhaustion

Heat Stress

Al Muthanna


Temp (C)
Degrees Celcius
60
50
40
30
20
10
0
1 2 3 5 6 7 8 9 12 14 15 16 18 19 20 21 22 23 25 26 27 28 29 30
July 1992

Body temperature

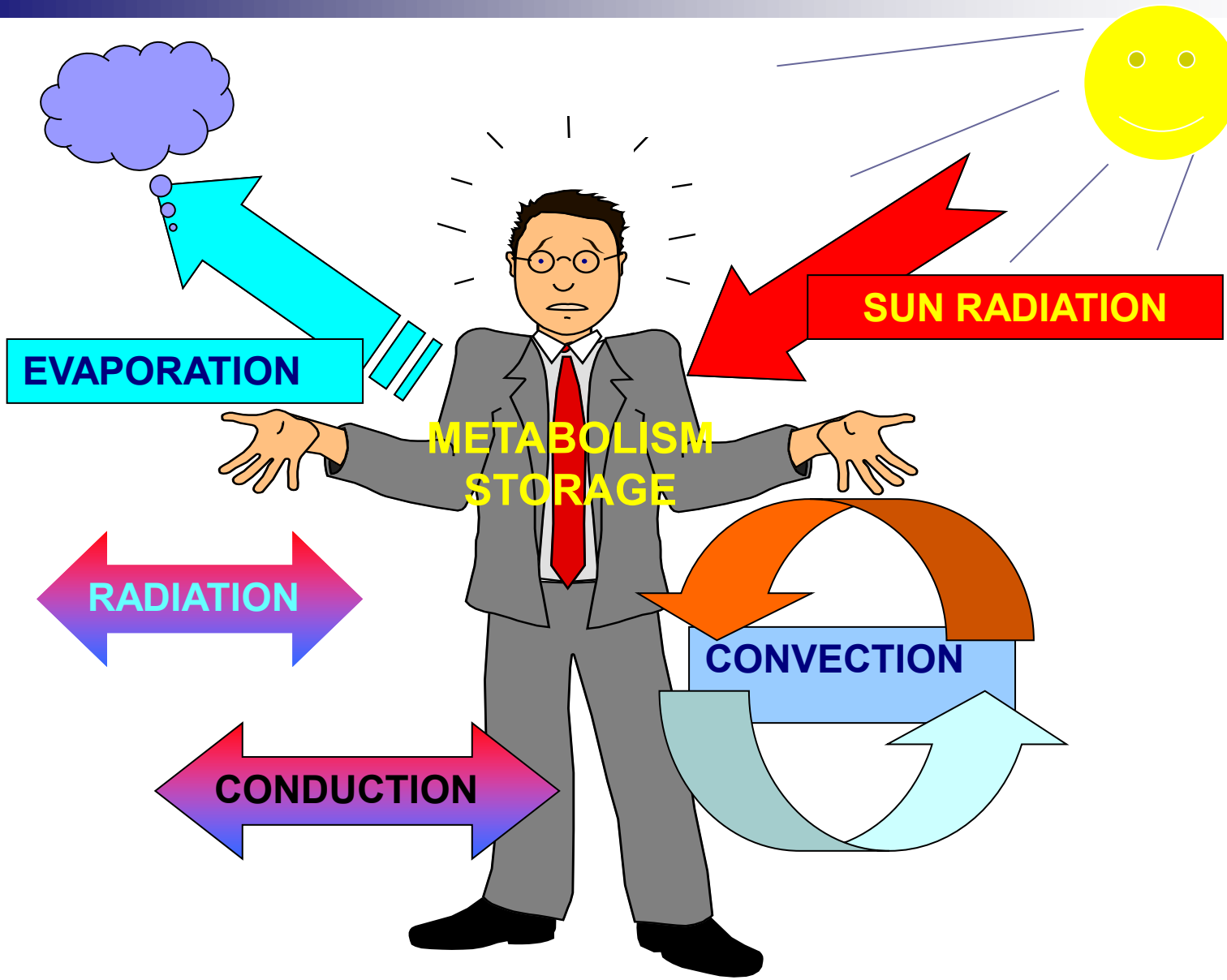
- Body temperature must be maintained within very narrow limits for optimum physical and mental performance.
- The man has to maintain thermal balanced exchanges with outside environment, permitting him to maintain his body temperature on non-dangerous level.
- The man's core body temperature can not exceeds 38,5°C, and the difference between core temperature and skin temperature cannot be less than 1°C to have correct thermal exchange.

Metabolic Heat

- The body produces heat due to metabolic process.
- The overall man's metabolic rate consists of basal metabolic rate plus work metabolic rate depend on his current activity.
- The body produces more heat during work than rest. At body rest it is lowest with a value of about 115 Watt with the standard man sitting or about 160 Watt when standing. Thus total thermal metabolic rate has to be kept in balance with environment not to exceed optimal core body temperature.

Thermal balance

- Thermal balance of a man is influenced biochemical process of
- basal metabolic rate plus work metabolic rate,
- evaporation of sweat, and
- heat energy transfer by radiation, conduction, convection and sun radiation


EVAPORATION
SUN RADIATION
METABOLISM
STORAGE
RADIATION
CONVECTION
CONDUCTION

Heat Energy Transfer

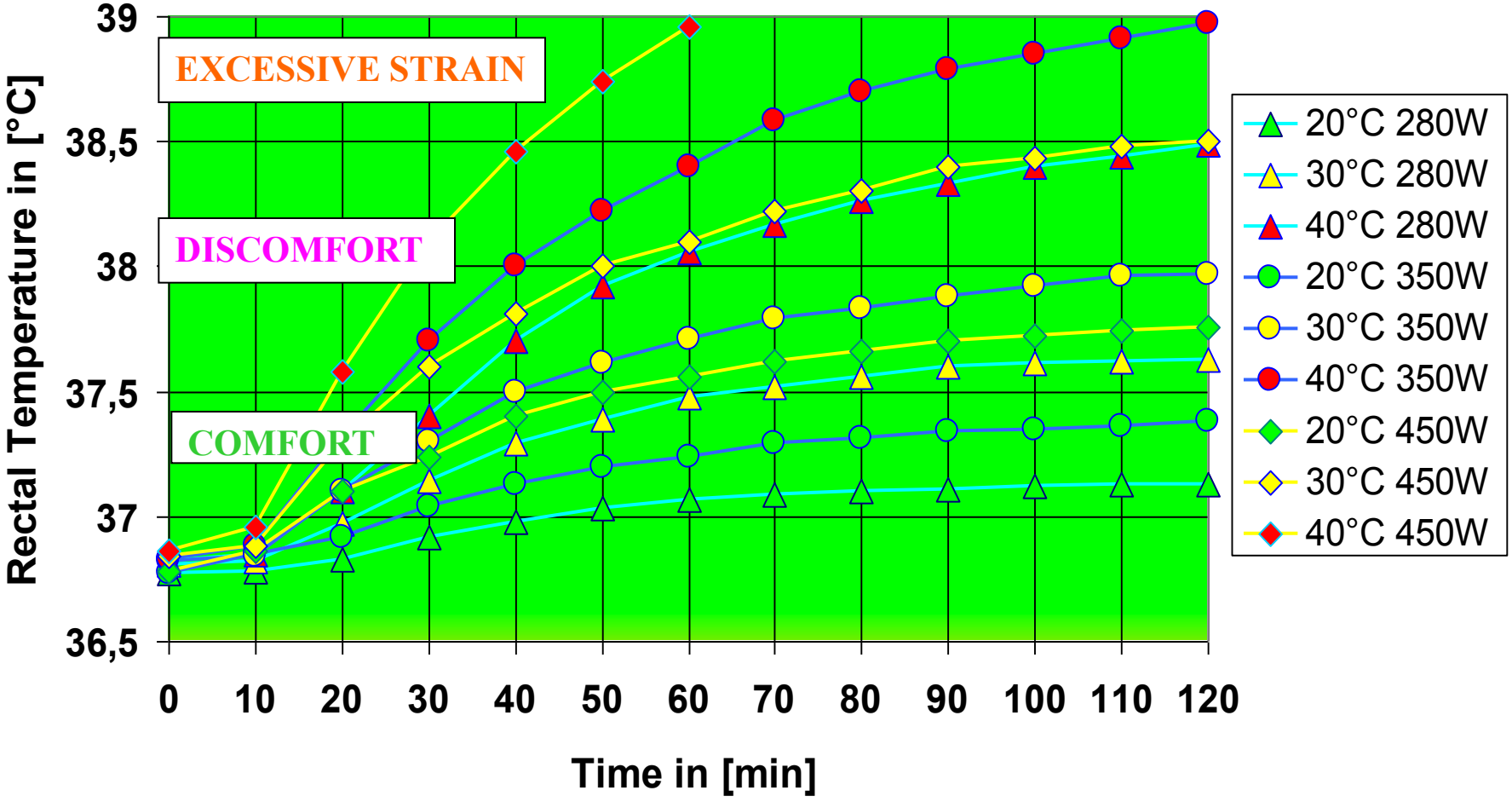
- **Evaporation** represents nature way of cooling wet surfaces. Liquids during their evaporation consume heat energy resulting in cooling surface or environment.
- **Sun Radiation** represents transmitting of heat energy by infrared radiation and its absorption on surface, resulting increasing temperature of a subject. Direct sun radiation is eliminating by covers or shade.
- **Conduction** represents transmission of heat energy through a substance from a region of higher temperature to a region of lower temperature. Region/objects have to be physically in direct contact.
- **Convection** represents transfer/exchange of heat energy a solid surface in gas or liquid media by upward movement of the heated and less dense medium.
- **Radiation** represents emission of energy as electromagnetic waves.

Heat Stress Environment

- Normally, the body cool itself be evaporation of sweat and radiation of heat at the skin's surface.
- The combination to solar and non-solar radiant energy or enclosed areas with high temperature and high humidity, metabolic heat production, and the used of impermeable (which prevents evaporative cooling) as well air permeable protective clothing place an individual/responder at high risk for heat injury.
- Adding layers over the standard cloth of workers increase the risk of heat stress even in moderate environmental temperatures and work intensity

Time-pattern of Rectal Temperature

Standard Man v=1.0 m/s 30% r.h.



Factors to Predispose Heat Stress

- Lack of physical fitness
- Obesity
- Dehydration
- Lack of acclimatization
- Age
- Sunburn
- Diarrhea
- Infection
- Chronic disease
- Alcohol, tobacco and drug use

Heat Stress Symptoms

- **Heat Rash** results from continuous exposure to heat or humid air
- **Heat Cramps** are caused by heavy sweating with inadequate fluid intake

Warning signs vary but may include the following:

- Muscle spasm
- Pain in the hands, feet, and abdomen

Heat Stress Symptoms

- **Heat Exhaustion** is a **milder form** of heat-related illness

- Heavy sweating
- Paleness
- Muscle Cramps
- Tiredness
- Weakness
- Dizziness
- Headache
- Nausea or vomiting
- Fainting
- Skin: may be cool and moist
- Pulse rate: fast and weak
- Breathing: fast and shallow

Heat Stress Symptoms

- **Heat Stroke** is the most serious **heat-related illness**.
- Body temperatures rise to 41°C or higher within 10 to 15 minutes. Heat stroke can cause death or permanent disability if emergency treatment is not provided

- An extremely high body temperature above 39,5°C
- Red, hot, and dry skin (no sweating)
- Throbbing headache
- Lack of perspiration
- Nausea
- Dizziness and confusion
- Rapid, strong pulse
- Coma

First Aid to Heat Illness

- Get the person to a shady area and if possible, seek an air-conditioned environment
- Drink cool, nonalcoholic, non-caffeinated beverages (avoid extremely cold liquids because they can cause cramps)
- Get medical assistance as soon as possible

First Aid to Heat Illness

- Cool the person rapidly, using whatever methods you can. For example:
- Immerse the person in a tub of cool water;
- Place the person in a cool shower or spray the person with cool water from a garden hose;
- Sponge the person with cool water;
- Wrap the person in a cool, wet sheet and fan him vigorously (if the humidity is low)

First Aid to Heat Illness

- Monitor body temperature and continue cooling efforts until the body temperature drops to 38,5°–39°C
- Monitor heart pulse rate and blood pressure
- Rest and do not engage in strenuous activities

Factors with Using PPE

- PPE restricts heat loss mechanisms because of its high insulation and low permeability to water vapor.
- In addition, physical work tasks require more effort when individuals wear protective clothing because of added weight, and restricted movement
- PPE restricts vision and hand operation capabilities
- This results in more body heat to be dissipated than normal and body temperature tends to rise quickly

Hand operation capabilities

Hand operation capabilities

Factors with Using PPE

- Encapsulated suits increase the heat strain associated with most environments and work rates by creating a microenvironment of small volume around worker's body.
- The impermeability to vapor of the suit crates high local humidity, restricting evaporative cooling and conductive/convection cooling.
- In effects, the suit creates an environment (tropical conditions) at the body surface hotter and wetter under almost any circumstances than the environment outside the suite.

Factors with Using PPE

- The amount and type of personal protective equipment worn is directly related to reduce work tolerance and the risk of heat stress. Protective clothing and equipment add weight and bulk, and diminish or prevent liquid and vapor exchange is resulting into:
- Severely reduce the body's normal heat exchange mechanism by evaporation, convection, and radiation.
- Increases energy expenditure by about 1.2 percent for every kilogram of added weight.
- A bulky suit can increase by 2 to 4 times the energy ordinarily needed to perform task.

Recommendation

- Therefore, when selecting protective equipment, carefully evaluate each item's health benefit against its potential for increasing heat stress risk. Once protective equipment is selected, determine the length of the work period based on:
- Work rate
- Ambient temperature
- Sun radiation and other environmental factors
- Type of protective ensemble
- Individual worker characteristics

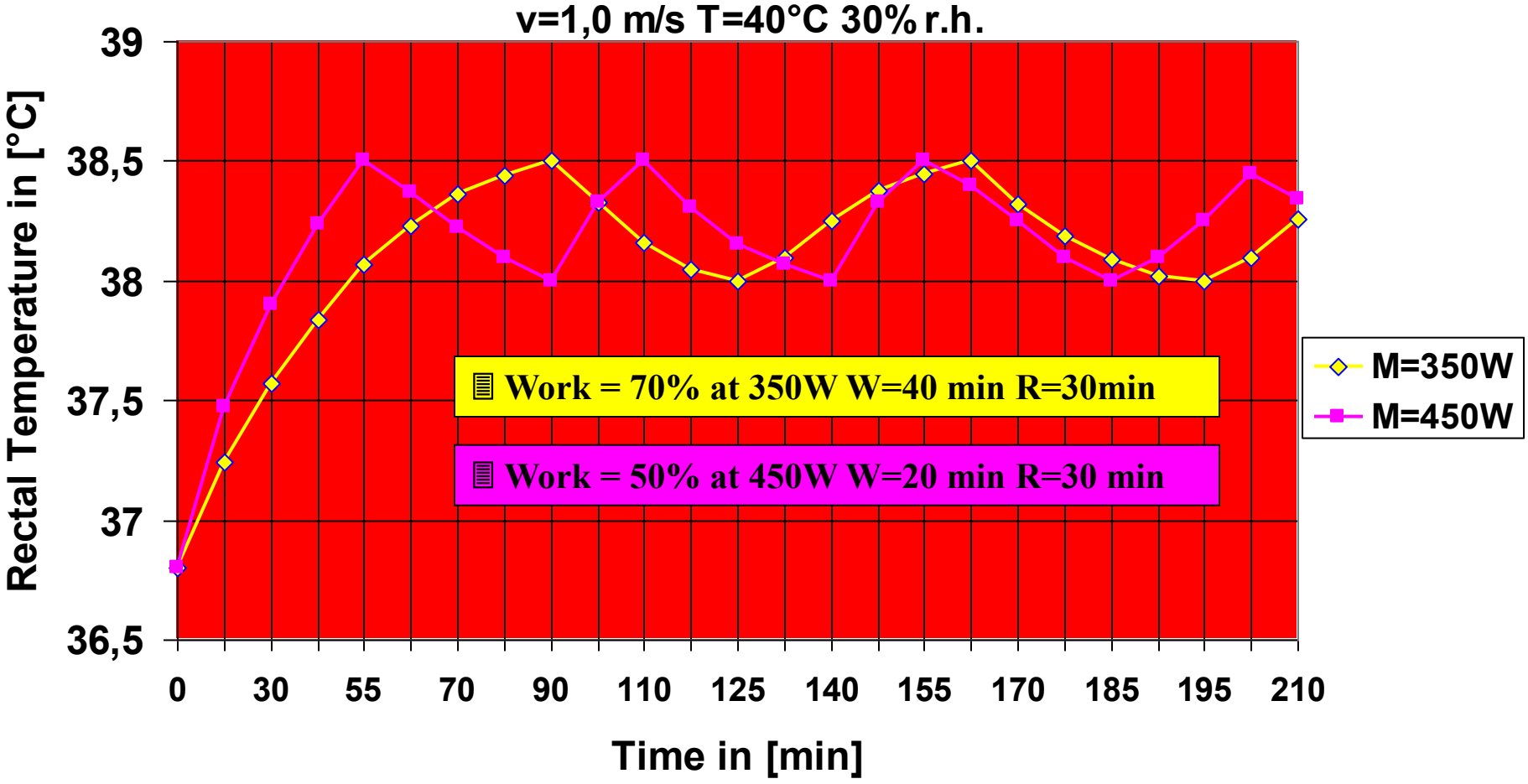
Work Intensity Factors

Work Intensity	Work Activity	Metabolic Rate [W]
Very Light	Sitting, Laying, Standing, Driving Truck	105-175
Light	Observing, Walking Hard Surface 3.6 km/h, load 0-30kg	175-325
Moderate	Walking Reconnaissance, Fitness Exercise Walking Hard Surface 5.6 km/h, 20kg load	325-400
Heavy	Pick and Shovel, Decontamination	400-500
Very Heavy	Carry casualty on stretches Walking Hard Surface 5.6 km/h, 30kg load	500 and above

“work-rest”

- Regime of cycles “work-rest” has to carefully planed and executed.
- Recommended work-rest schedule should be for example, 10-15 minutes of work and 50 minutes of rest.
- Note that continuous work under these conditions may lead to heat casualties after 49 minutes, see Graph #1.

Time-pattern of Rectal Temperature in regime Work & Rest



Physiological and Psychological Factors

- **Physiological** factors directly affect worker ability to function using PPE include:
- *Physical condition*
- *Acclimatization level*
- *Training and conditioning*
- *Age*
- *Weight*
- *Dehydration, nutrition, and*
- *Sex*

Physical Condition

- This is the most important factor, the higher degree of fitness, a fit person will have:
- Less physiological strain
- A lover heart rate
- A lower rectal temperature, which indicates less retained body heat (a rise in internal temperature precipitates heat injury)
- A more efficient sweating mechanism
- Slightly lower air consumption
- Slightly lower carbon dioxide production

Acclimatization

- An acclimatized individual will generally have a lower heart rate and body temperature than an individual who is unaccustomed to working in the heat.
- The acclimatized person also begins to sweat sooner and sweats more.
- Sweat composition also becomes more diluted with acclimatization so less salt is lost in the sweat.

Acclimatization

- Acclimatization can occur after just a few days of exposure to a hot environment. There is recommendation a progressive 6-days acclimatization period for the un-acclimatized worker before allowing him to do full work on a hot job. Begin the first day with 50% of the anticipated workload and exposure time and add 10 % each day through day 6.
- With fit or trained individuals, the acclimatization period may be shortened 2 or 3 days

Training and Conditioning

- Well-prepared individuals suffer less stress when in PPE than those who are less prepared.
- Well-prepared individuals are those who are in good physical condition and have trained extensively in PPE.
- Physically fit individuals are more resistant to physical and psychological fatigue and acclimatized more quickly to climate heat or the heat associated with PPE wear than less fit individuals.

Training and Conditioning

- CBR Response Teams that anticipate deployment to response operations have to have augment physical training programs and increase their state of heat acclimatization.
- To optimize heat acclimatization, individuals should progressively increased the duration and intensity of exercise in wearing PPE in heat, reaching 6-8 hours of continuous wearing over 1 to 3 consecutive weeks.
- Finally, individuals are required to routinely work in PPE, it is important to practice also good hygiene, keep skin clean to avoid developing heat rash that can dramatically reduce the ability to regulate temperature

Weight

- The ability of a body to dissipate heat depends on the ratio of its surface area to its mass (surface area/weight).
- Heat loss (dissipation) is a function of surface area.
- Heat production is dependent on mass.
- Heat balance is determined by the ratio of the two.

Weight

- Obese and stocky individuals produce a lot of heat, but do not have a proportionately large surface area. Hence they are not capable of rapidly dissipating the heat they produce and are susceptible to heat illness.
- In comparison, thin individuals have less weight and nearly the same amount of surface area as an obese person, and are able to dissipate heat much more rapidly.

Weight

- Therefore, it has been suggested that anyone exceeding his standard weight by 15 % or more be excluded from working in a hot job. The use of height-weight tables is not recommended. More valid procedures are skin fold measurements, anthropometry, and hydrostatic weighing.

Dehydration

- Because of higher body temperatures, individuals in PPE sweat considerably more than usual, often more than 1.4 liter of water every hour during work.
- Water must be consumed to replace lost fluids or dehydration will follow. Even a slight degree of dehydration impairs the body's ability to regulate its temperature and, nullifies the benefits of heat acclimatization and physical fitness increasing the susceptibility to heat injury, and reduce work capacity, appetite, and alertness

Dehydration

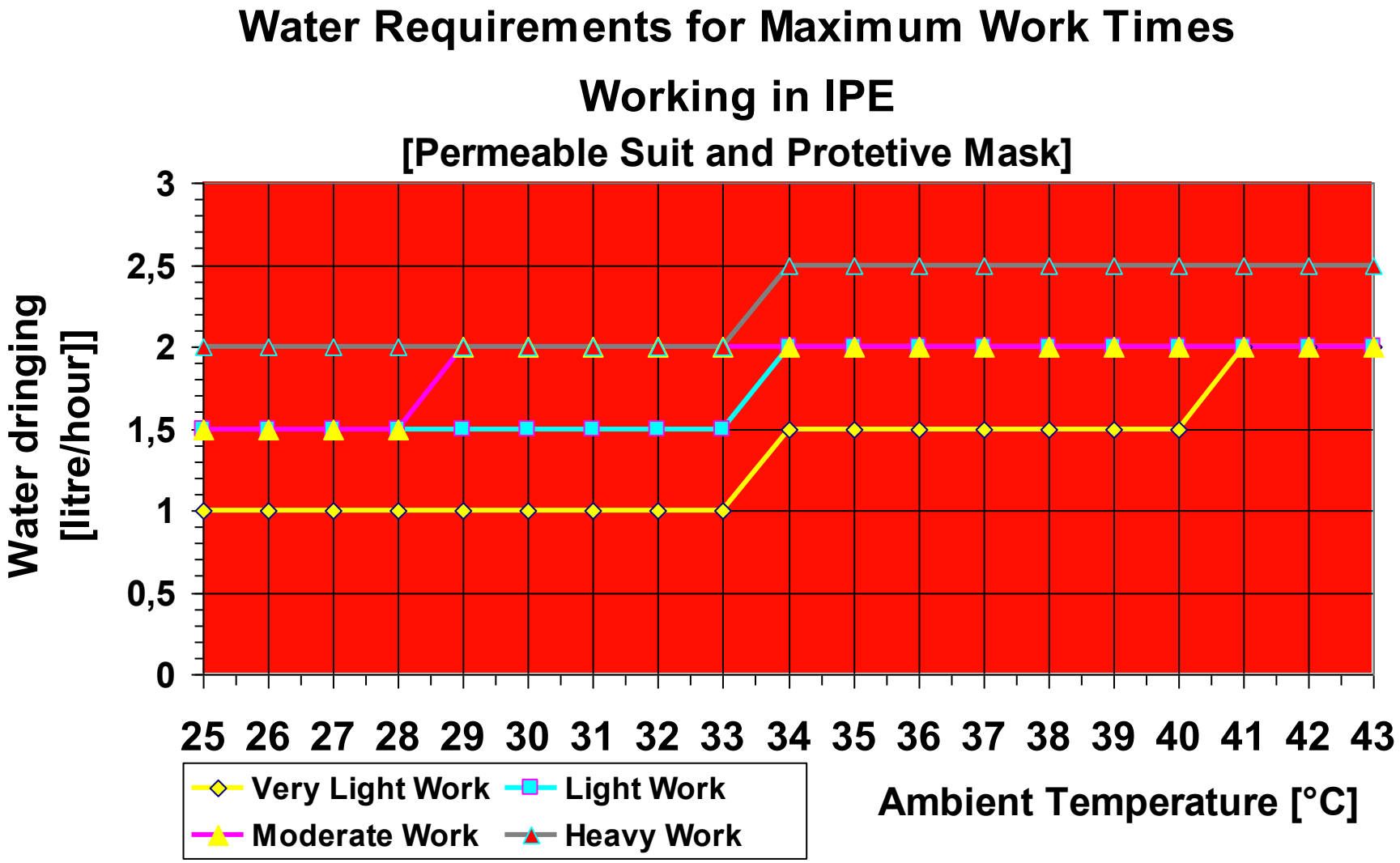
- The difficulty of drinking in PPE increases the likelihood of dehydration. Thirst is not an adequate indicator of dehydration because individuals will not sense when they are dehydrated and will fail to replace body water losses, even when drinking water is readily available.
- Chain of command must take responsibility for enforcing regular and timely fluid replacement in individuals.

Dehydration

- Individuals should drink as much as possible before donning PPE, and frequent drinking while working is more effective in maintaining hydration than waiting upon rest periods of drink. Water requirements should be estimated using the guidelines provided in Graph #6.

Nutrition

- In addition to bodily requirements for electrolyte (salt) replacement caused by sustained and excessive sweating, the higher work intensities typical of operations in PPE lead to increased demand for energy/calories.
- Lack of adequate energy supplies can lead to decrements in both physical and mental performance.
- It advisable to have responder teams field feeding menus to provide adequate amount both of salts and calories to support operations in PPE.


Water Requirements for Maximum Work Times
Working in IPE
[Permeable Suit and Protetive Mask]
Water dringing [litre/hour]]
3
2,5
2
1,5
1
0,5
0
25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43
Very Light Work
Light Work
Moderate Work
Heavy Work
Ambient Temperature [°C]

Monitoring to Prevent Heat Stress

- Because the occurrence of heat stress depends on a variety of factors, all workers, even those not wearing protective equipment, should be monitored
- For worker wearing semi-permeable or impermeable encapsulating ensembles, monitor when ambient temperature is above 21°C. It may be also necessary to monitor at lower temperatures if humidity is high

Frequency of Physical Monitoring

Temperature	Semi-permeable Suit	Impermeable Suit
32 or above °C	After 45 minutes	After 15 minutes
31-32	60	30
28-31	90	60
25-28	120	90
22-25	150	120

Monitoring to Prevent Heat Stress

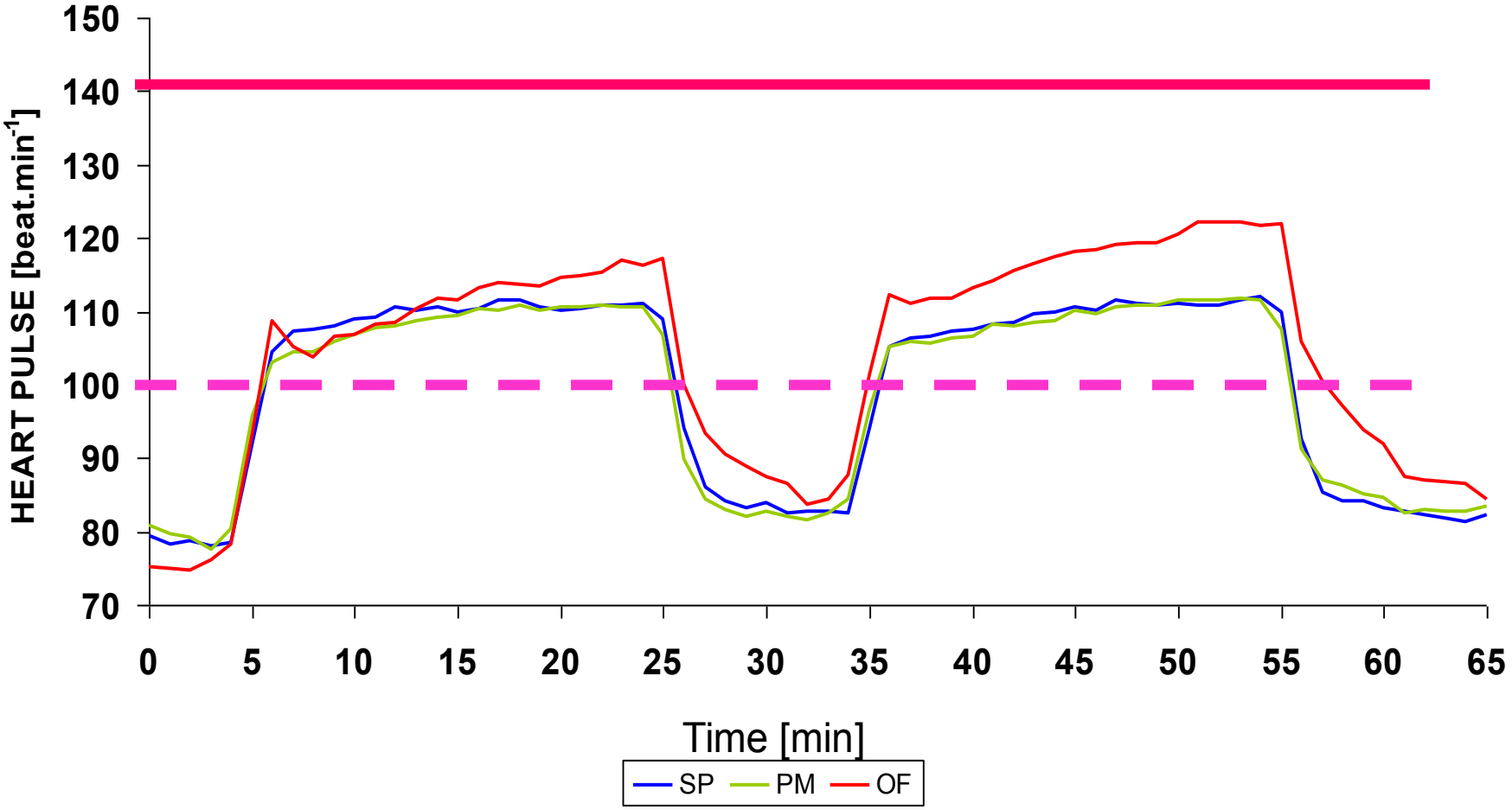
- To monitor individual it is recommended to measure:
- Heart Rate
- Oral or Ear temperature
- Skin temperature
- Body Weight

Heart Rate

- Count the radial pulse during a 30-second period immediately following the end of a work period.
- If the heart rate exceeds 140 beats per minute at the end of a work period and 100 beats per minute at the end of a rest period, shorten the next work cycle by 1/3rd or lengthen the rest period.
- If the heart rate still exceeds 140 beats per minute at the end of the next work cycle, shorten the following work cycle by 1/3rd or lengthen the rest period by 1/3rd

TIME-pattern of HEART PULSE

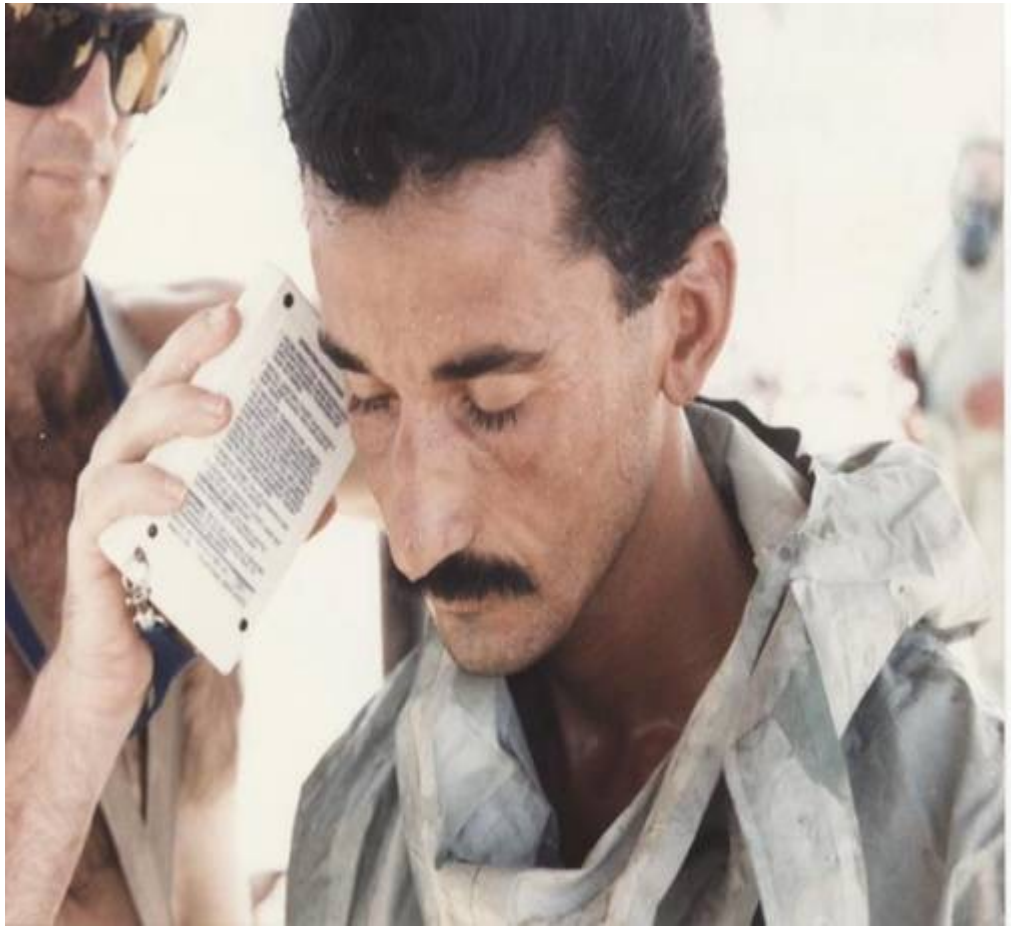
in Climatic Chamber at 25°Celsia



Oral or Ear Temperature

- Use a clinical thermometer 3 minutes under the tongue or ear infrared thermometer for reading core temperature within few seconds.
- If oral/ear temperature exceeds 37,5 °C, shorten the next work cycle by 1/3rd or lengthen the rest period by 1/3rd.
- If oral/ear temperature still exceeds 37,5 °C, shorten the following work cycle by 1/3rd or lengthen the rest period by 1/3rd.
- Do not permit a worker to wear a semi-permeable or impermeable protective suit when his oral/ear temperature exceeds 38-38,5 °C.

Ear Temperature



Ear Thermometer

Ear Thermometer

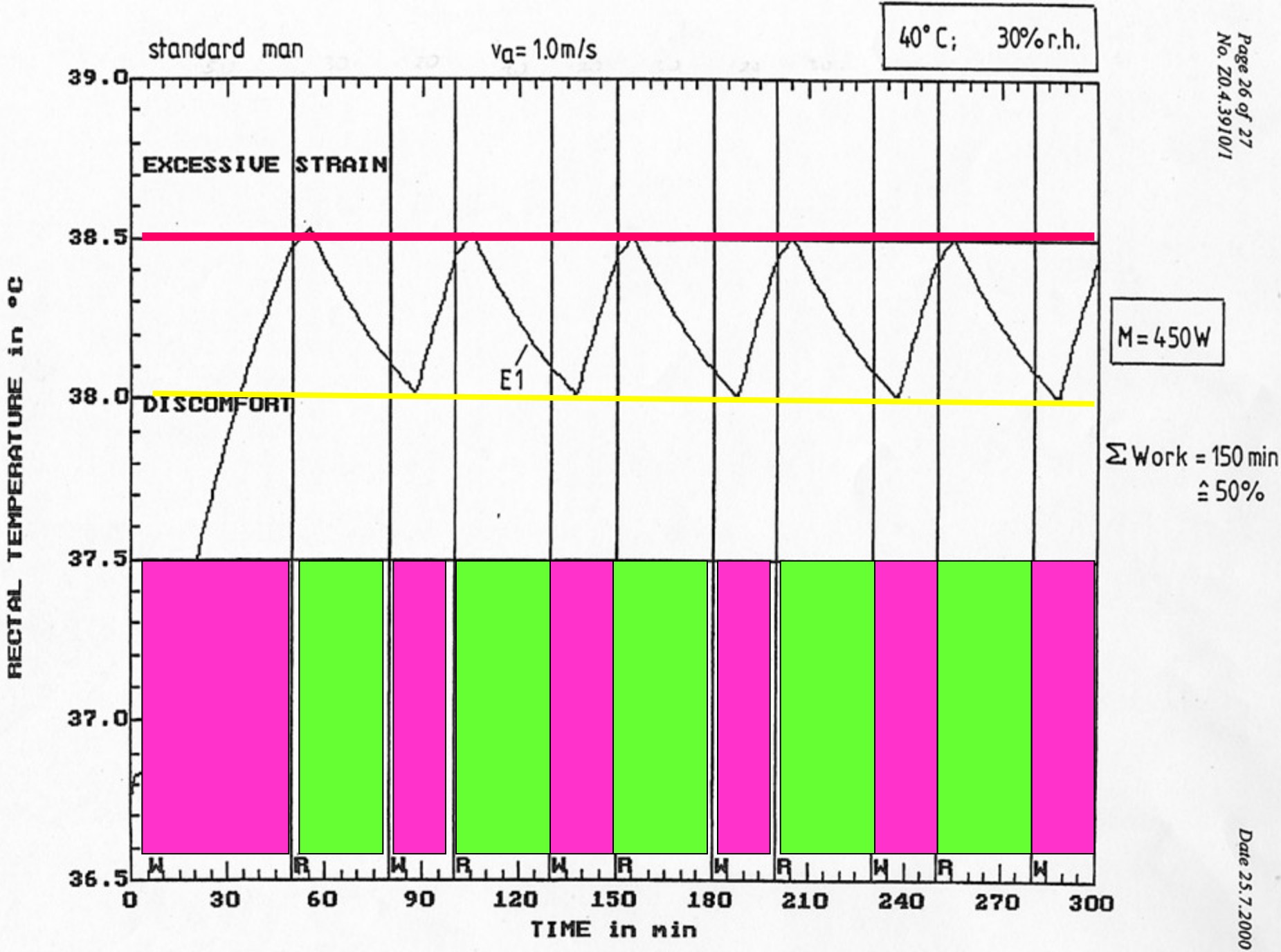


Figure 12 : Time - pattern of rectal temperature - Ensemble E1

Body Weight

- It is recommended if possible measure body weight at the beginning and end of each work day to see enough fluids are being taken to prevent hydration.
- Do not allow more than a 1.5 % body weight loss a working day.

Measures to Prevent Heat Stress

- Proper training and preventative measures will help avert serious illness and loss of work capability.
- Preventing heat stress is particularly important because once someone suffers from heat stroke or heat exhaustion, that individual is predisposed to additional heat injuries.
- To avoid heat stress, management should take the following steps:
- Moderating the heat strain associated with an encapsulating ensemble is accomplished in the following ways:

Work Schedule

- Modify work/rest schedules according to monitoring requirements – generally, for every hour of work, and allow 30 minutes rest.
- Work-rest cycles to permit cooling and re-hydration, and examination.
- Mandate work slowdowns as needed.
- Rotate personnel: alternate job functions to minimize overstress or overexertion at one task.
- Perform work during cooler hours of the day if possible

Monitoring of Temperature and Wind

Provide Shaded Area for Responders

Drinking regime

- A worker in impermeable suit performing a moderately intense task at an adjusted temperature exceeding +27-30°C could lose as much as 1 liter per hour working according the work/rest schedule or 2 liter per hour if working continuously.
- This should represent deficiency water of 7-8 liter per 8 hours. More water may be required depending on the ambient temperature and humidity.
- The individuals working in hot environment will excrete also significant amount of salt during sweating.

Drinking regime

- When heavy sweating occurs, encourage the worker to drink more. Use following strategies:

- Maintain water temperature at 10-17 °C.
- Include also drinks enriched with minerals/salts to adjust electrolyte balance in body.
- Provide small disposable cups that hold about 0.2 liter (2 dcl) of water.
- Have workers drink 2-4 cups (0.4-0.5 liter) of fluid-preferable water or diluted drinks, before beginning work.
- Urge workers to drink 1 or 2 cups every 15 to 20 minutes, or at each monitoring break.
- Weight workers before and after work to determine if fluid replacement is adequate.

Physical Fitness

- Provide an aerobic and/or other exercise program
- Acclimatize workers to site work conditions: temperature, protective equipment, and workload
- Urge workers to maintain normal weight levels.
- Discourage smoking and drugs consumption during off hours.

Training

- Train workers to recognize and treat heat stress.
- As part of regular acclimatization and PPE performance training,
- identify also the symptoms of heat stress, and
- providing heat illness first aid.

Microclimate Cooling

- Provide cooling devices to aid natural body ventilation during prolonged work or severe heat exposure.
- Reduce body temperature by increasing the temperature gradient across the suit:
- shielding individual from radiant heat source,
- cooling the work space or, in dry environments,
- wetting the surface of the suit with field showers or hose sprayers.
- Loose fitting cotton or integrated fabric underwear and/or clothing to help absorb moisture and protect skin from direct contact with heat-absorbing protective clothing.

Microclimate Cooling

- Microclimate cooling systems in which an air or liquid cooled vest/jackets, suits worn under or above PPE removes heat away from skin.
- Another principle is based on forced ventilation of body space under PPE, when cleaned ambient air helps evaporate sweat from skin and reduce humidity inside of protective suit. Forced evaporation of sweat provides natural cooling effect.

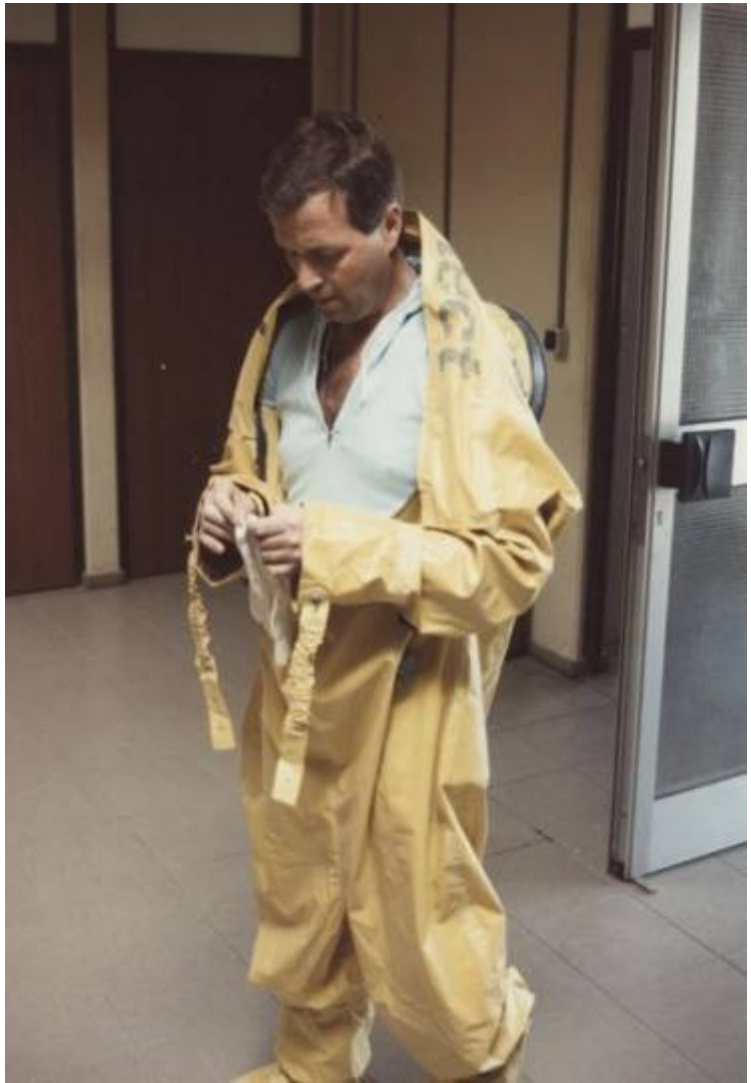
Wet Cooling Coverall

Provide Cooling Shower

Cooling Vest

Cooling Underwear

Ventilation Suit

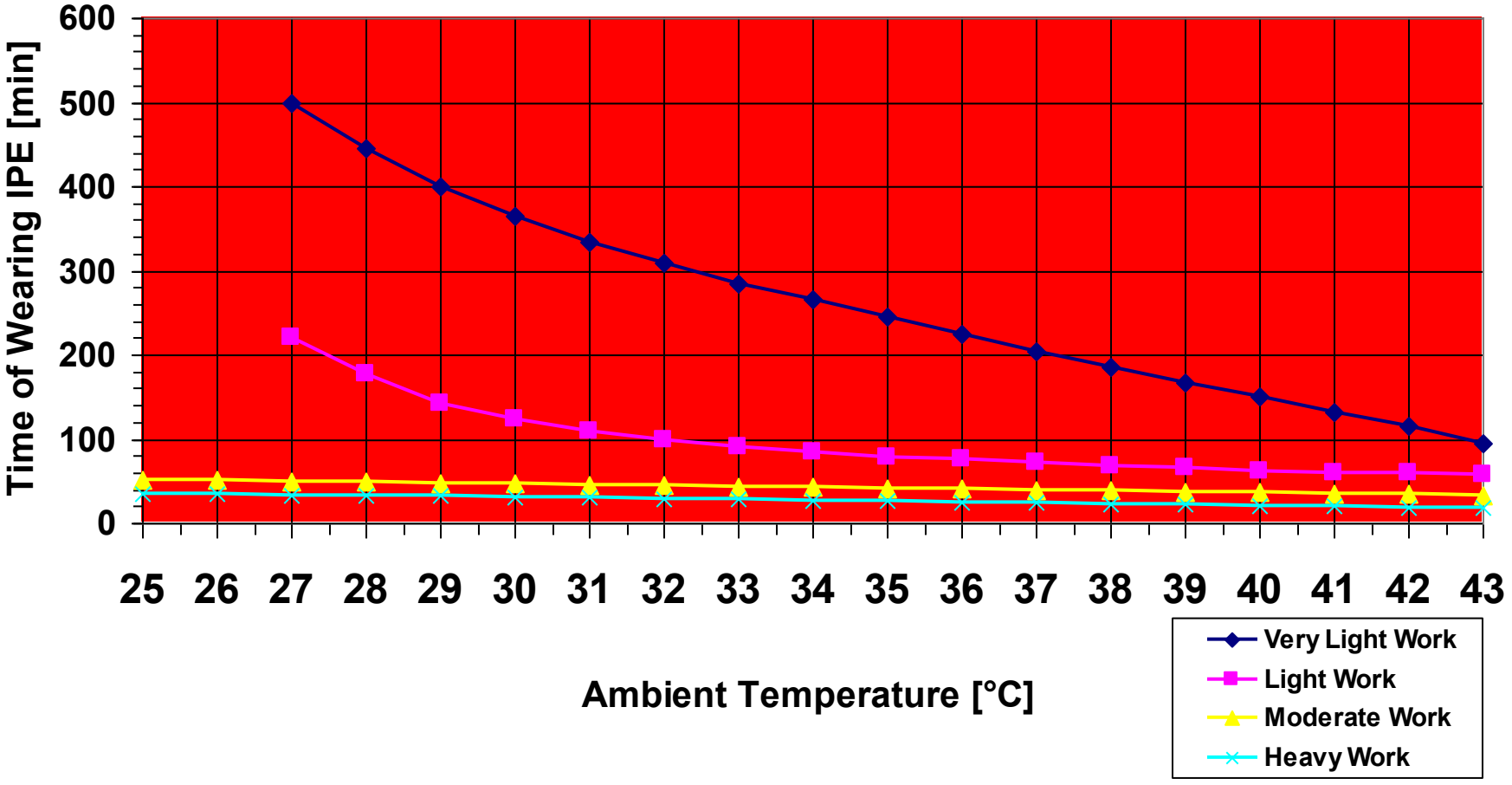


Ventilation Suit

Cooling Filtration-Ventilated Unit

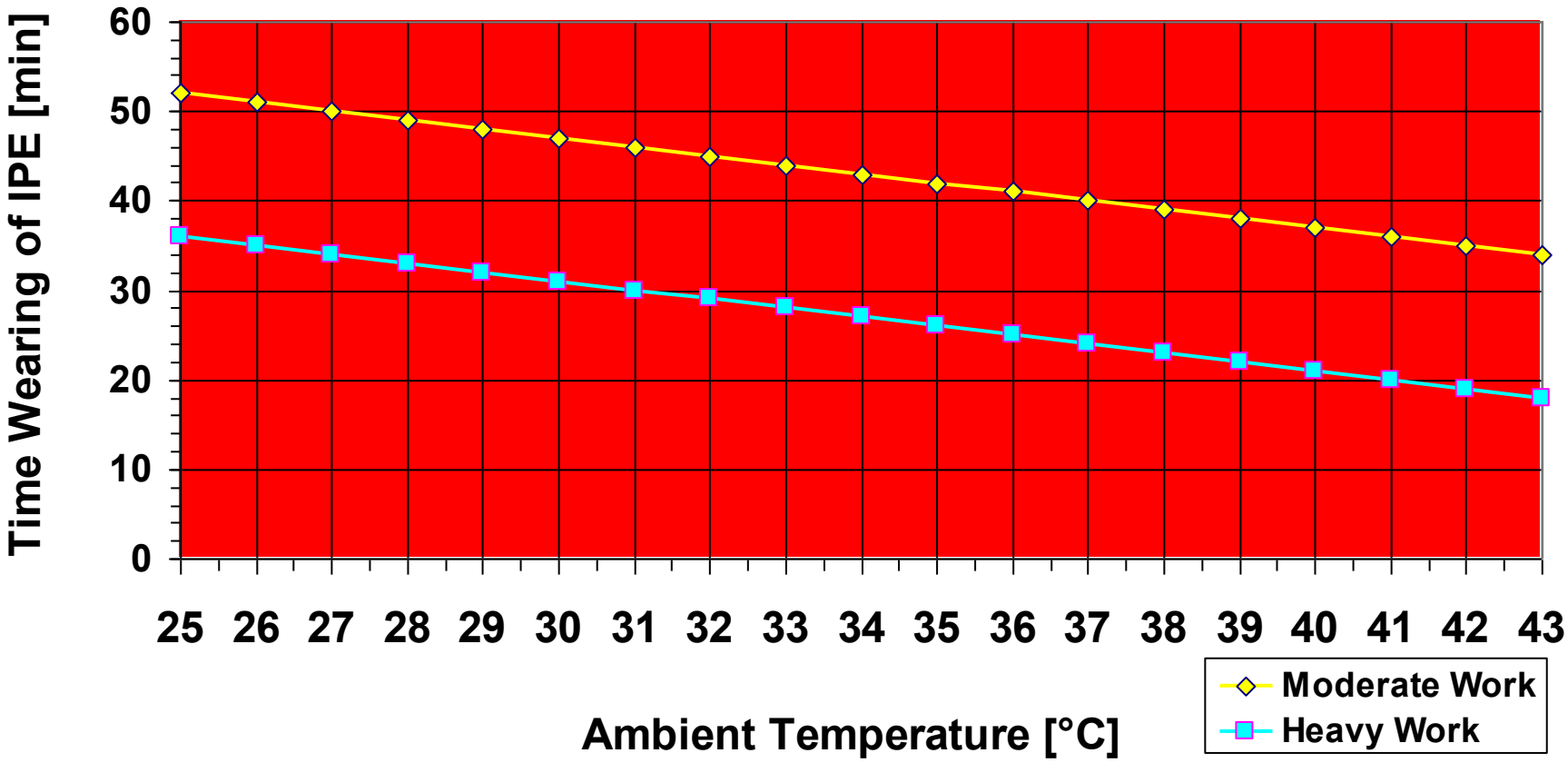
Maximum Work Times in IPE

[Permeable Suit with Protective Mask]



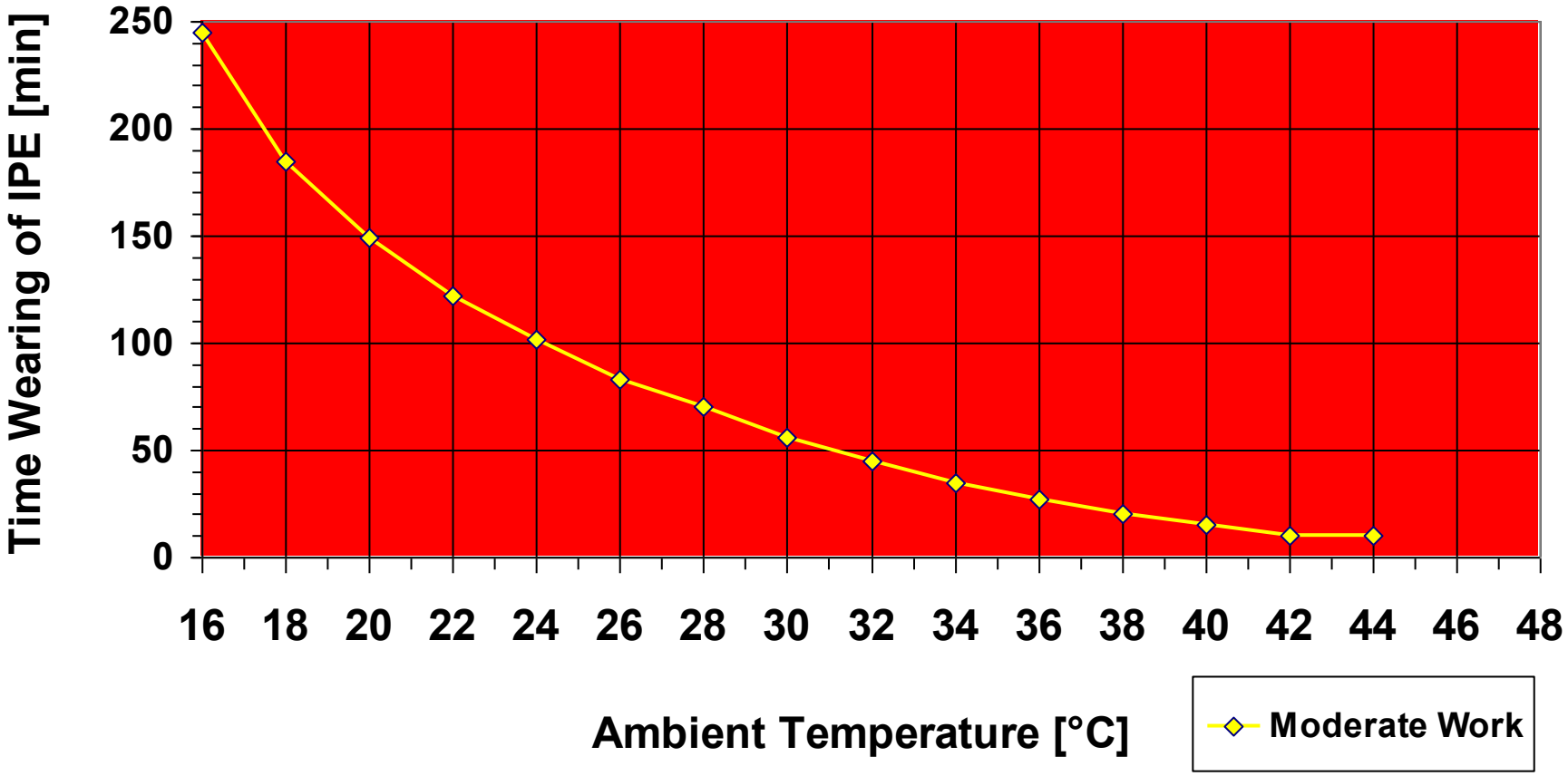
Maximum Work Times Working in IPE

[Permeable Suit and Protetive Mask]



Maximum Work Times Working in IPE

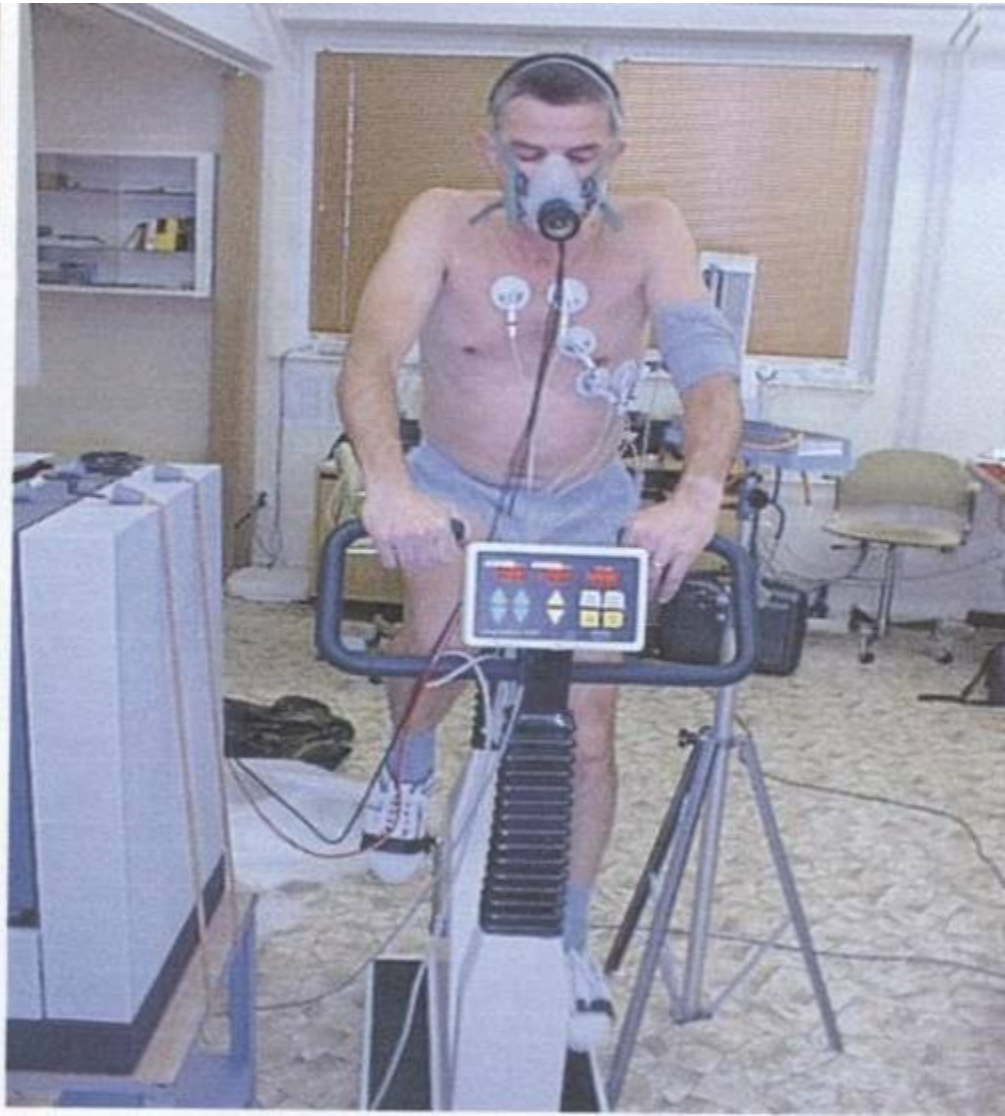
[Impermeable Suit and Protetive Mask]



Medical Surveillance

- Medical surveillance is the systematic collection, analysis, and dissemination of disease data on groups of workers. It is designated to detect early signs of work-related illness.
- A hazardous material work site medical program should provide the following surveillance:
- **Pre-placement screening**
- **Periodical medical examination** (with follow-up examinations, when appropriate), and
- **Termination examination**

Medical Testing Program



pcastulik@yaahoo.co.uk