# Predicted Heat Strain (PHS) MODEL
## Its use in practice


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## Summary

- The BIOMED research: development of PHS
  - Improvement of the SWreq standard
  - Validation
  - Comparison PHS – SWreq
  - Comparison PHS – WBGT



## ISO 7933 " interpretation of thermal stress using the Required Sweat Rate"

Main criticisms concerned:

- The prediction of the skin temperature
- The influence of the clothing on convection, radiation and evaporation
- The increase of core temperature linked to the activity
- The prediction of the sweat rate in very humid conditions
- The limiting criteria and in particular the "alarm" and "danger" Stage
- The maximum water loss allowed.



## Partners in the BIOMED research:

8 European labs

G. Alfano, universita di Napoli, Italy

H. Gebhardt, ASER, Germany

B. Griefahn, P. Mehnert, IFADO, Germany

G. Havenith, E. Den Hartog, TNO, The Netherlands

I. Holmér, Arbetsmiljöinstitutet, Sweden

B. Kampmann, institut für arbeitswissenschaften, G.

J. Malchaire, catholic university of Louvain, Belgium

K. Parsons, Loughborough university, UK

# 1. Predicted skin temperature (1/4)

*ISO 7933 algorithm*

- *Based on a limited set of data*
- *For mainly nude subjects.*
- *Skin temperature decreased with the clothing*

- **Material and Methods**
  - **HEAT database**
  - **Selection of data points in steady state conditions**
  - **Only data from MALE subjects**
- **$T_{SK}$ database: 1999 data points (from 1399 conditions with 377 male subjects)**
  - **Separate analysis for nude ($\leq$ 0.2 clo) and clothed (0.6 $\leq$ Icl $\leq$ 1.0) subjects**
  - **Multiple linear regression technique**



# 1. Predicted skin temperature (2/4)

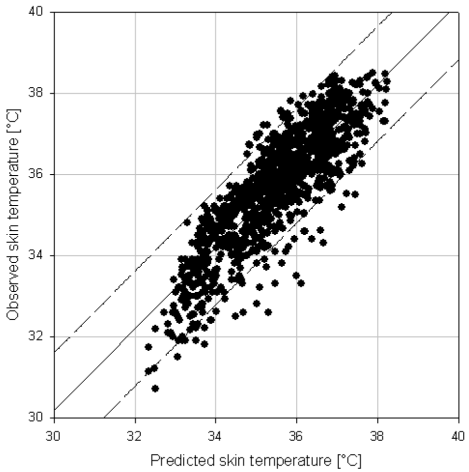
| Ranges of validity of the Tsk model | | |
|---|---|---|
| | Min | Max |
| $t_a$ °C | 15 | 50 |
| $P_a$ kPa | 0 | 4.5 |
| $t_r$-$t_a$ °C | 0 | 60 |
| $v_a$ m/s | 0 | 3 |
| M W | 100 | 450 |
| $I_{cl}$ clo | 0.1 | 1.0 |



# 1. Predicted skin temperature (3/4)

## Prediction model: nude subjects

$$t_{sk} = 7.19+0.064\, t_a + 0.061 t_r + 0.198 p_a - 0.348 v_a + \underline{0.616 t_{re}} + 0{*}M$$

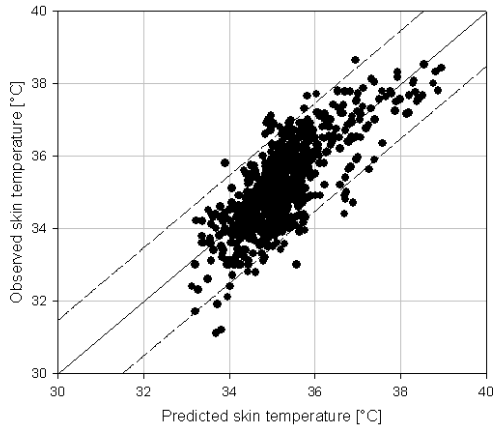





# 1. Predicted skin temperature (4/4)

## Prediction model: clothed subjects

$$t_{sk} = 12.17+0.020\, t_a+0.044\, t_r+0.194\, p_a- 0.253\, v_a+0.003\, M+\underline{0.513\, t_{re}}$$



## 2. Prediction of $t_{re}$ from the core temperature (1/2)

- Rectal temperature remains, with heart rate, the easiest physiological parameter to record at the work place

- The core temperature $t_{co}$ is the mean of
  - the rectal temperature: characteristic of the muscle mass
  - the oesophageal temperature: characteristic of the blood and influencing the hypothalamus.

$$T_{co} = (T_{oe} + T_{re}) / 2$$

$$T_{re} = 2\,T_{co} - T_{oe}$$



## 2. Prediction of $t_{re}$ from the core temperature (2/2)

**Edwards et al.:** $t_{oe} = 0.962\, t_{re} + 7.03\, dt_{re} + 1.31$

$$t_{re} = t_{re0} + \frac{2\, t_{co} - 1.962\, t_{re0} - 1.31}{9}$$

$$t_{re} = 0.782\, t_{re0} + 0.222\, t_{co} - 0.146$$

- $t_{re}$: rectal temperature at time *i*
- $t_{re0}$: rectal temperature at time *i-1*



## 3. Skin - core temperature weighting

- *$SW_{req}$ assumes constant weighting 30% – 70%*

**PHS:**

$\alpha = 0.3$ for $t_{co} \leq 36.8°C$

$\alpha = 0.1$ for $t_{co} \geq 39°C$

$\alpha$ varies between 0.3 and 0.1 according to

$$\alpha = 0.3 - 0.09\,(t_{co} - 36.8)$$

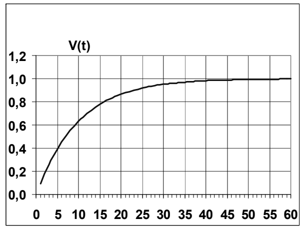


## 4. Evolution of $t_{sk}$ and SW with time

- *Main limitation of the ISO 7933 standard:*
  - *Assume that a steady state is reached instantaneously.*
  - *Impossible to predict in case of intermittent exposure*

$$V(t) = V_{max}\,(1 - \exp(-t/\tau))$$

$$V_i = V_{i-1}\, k + V_{max}\,(1 - k)$$




where

| | |
|---|---|
| $V_i$ | is the value at time *i* |
| $V_{i-1}$ | is the value at time *(i-1)*, $\Delta t$ min before |
| $V_{max}$ | is the target value |

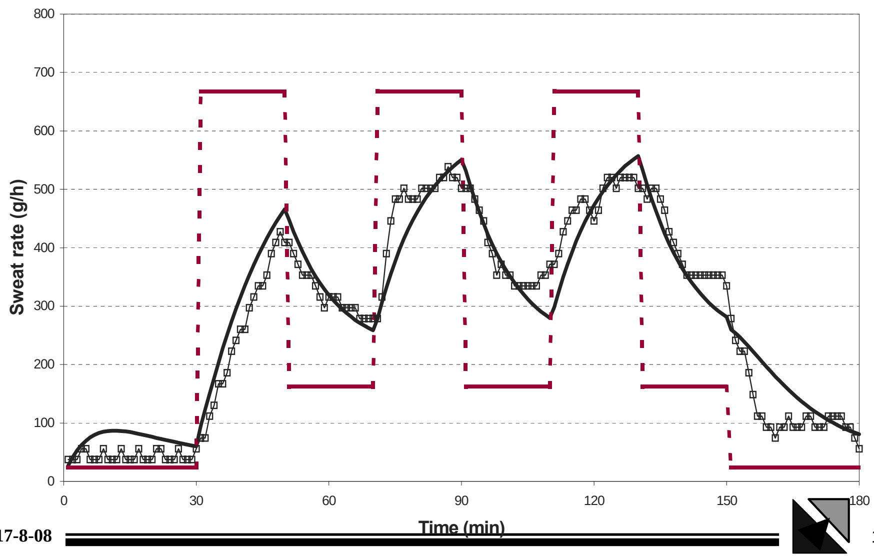
$k = \exp(-\Delta t / \tau)$

$\tau$ is the time constant (in minutes)

- 3 minutes for the skin temperature
- 10 minutes for the sweat rate

# 4. Evolution of tsk and SW with time

**Observed and predicted SW (using ISO 7933 and PHS)**






# 5. Increase in $t_{co}$ associated with M

- *SWreq does not take into account the normal increase in core temperature due to activity even in moderate and neutral climate.*

## PHS:

**Saltin (1966), in a neutral condition:**

$T_{cor\ eq} = 0.002M + 36.6$ (M in watts)

$T_{co}$ reaches $t_{co\ eq}$ with a time constant of about 10 minutes.

➔ $t_{co,i} = t_{co\ i-1} \cdot k + t_{co\ eq} \cdot (1 - k)$

➔ **Heat storage associated with this increase:**

$$dS_R = c_{sp}\ (T_{co\ i} - T_{co\ i-1})\ (1-\alpha)$$

**The body does not attempt to loose this stored heat**



# 6. Maximum sweat rate: $SW_{max}$

- *ISO 7933 assumes constant values of maximum sweat rate for acclimatised and unacclimatised subjects*

## PHS:

$SW_{max} = 2.6\ (M - 58)$ g/h

- **for M < 300 watts : 650 g/h**
- **limited to 1000 g/h for unacclimatised subjects**

**For acclimatised subjects:**

- **maximum capacity increase by 25%**
- **sweating in a given environment can be greater by a factor 2**



# 7. Limit criteria

- *ISO 7933 limits for acclimatised and unacclimatised subjects*
  *2 Stages of protection:*
  - *"alarm" Stage: to protect the entire population*
  - *"danger" Stage: to protect most of the workers.*

  *Criteria too vague and too stringent.*

## PHS:

**For $T_{re}$: limit of 38°C**

**For $SW_{tot}$:**

- **for the "average" subject**
- **for percentile 95%**

## 8. Max dehydration and water loss (1/2)

- *ISO 7933 limit values questioned in the field, and particularly in mines*

**PHS:**

**Szlyck (1989): threshold for thirst: 2% loss of body weight**
**Candas et al. (1985): at 3% dehydration:**

- increased heart rate
- depressed sweating sensitivity.

➔ **maximum dehydration in industry** (not army or sports):

**3% of body mass**

to be considered only in less severe conditions
where the limitation of exposure is for dehydration and not for excessive $T_{co}$



## 8. Max dehydration and water loss (2/2)

**Kampmann et al.(1995):**

**with exposure 4 to 8 hour**

- average rehydration rate of 60%
- rehydration rate greater than 40% for 95% of the subjects

**Maximum water loss**

- 7.5% of the body mass for an average subject
- 5% of the body mass for 95% of the working population



## 9. Limit of internal temperature

*WHO document 1969: Limit of 38°C*

*"It is inadvisable for deep body temperature to exceed 38°C in prolonged daily exposure to heavy work."*

*commonly adopted and implicitly adopted in ISO 7933*
*Document often quoted and altered*

**PHS:**

$$t_{re\ max} = 38°C$$



## 9. Limit of internal temperature

**Maximum rectal temperatures:**

- 42°C : the maximum internal temperature to avoid physiological damages
- 39.2°C : Wyndham et al. (1965). "may rapidly lead to total disability in most men with excessive, often disturbing, physiological changes"

**Maximum probabilities:**

- for 42°: $< 10^{-6}$ : <1 heat stroke every 4 years among 1000 workers (250 days/year)
- for 39.2°: $< 10^{-3}$ : <1 person at risk among 1000 work shifts.

# VALIDATION



## Database: 1113 experiments

Primary parameters: $t_a$, $p_a$, $t_r$, $V_a$,
Work parameters: M, $I_{cl}$
Physiological factors: $t_{re}$, sweat rate

| | Number of experiments |
|---|---|
| Lab experiments | 67% |
| Field experiments | 33% |
| Men | 91% |
| Women | 9% |
| Not acclimatised | 40% |
| Acclimatised | 60% |
| Nude experiments | 22% |
| Clothed experiments | 78% |



## BIOMED database

Means, standard deviations and 95% confidence interval for the 6 parameters, 672 lab experiments, 95689 points

| | | m | s | 95% confidence interval |
|---|---|---|---|---|
| air temperature | $t_a$ (°C) | 30.85 | 9.14 | 12.94 - 48.75 |
| humidity | $p_a$ (kPa) | 1.95 | 1.26 | 0 - 4.42 |
| radiation | $t_r$-$t_a$(°C) | 15.42 | 21.80 | 0 - 58.15 |
| air velocity | $v_a$ (m/s) | 0.40 | 0.25 | 0 - 0.90 |
| metabolic rate | M (W) | 243 | 114 | 20 - 467 |
| clothing insulation | (clo) | 0.38 | 0.34 | 0 - 1.05 |



## Ranges of validation

| Ranges of validity of the PHS model | | | |
|---|---|---|---|
| | | Min | Max |
| $t_a$ | °C | 15 | 50 |
| $P_a$ | kPa | 0 | 4.5 |
| $t_r$-$t_a$ | °C | 0 | 60 |
| $v_a$ | m/s | 0 | 3 |
| M | W | 100 | 450 |
| $I_{cl}$ | clo | 0.1 | 1.0 |

## Data selection for the validation

| | SW | $t_{re}$ |
|---|---|---|
| Lab experiments | 672 | 1927 |
| Field experiments | 237 | 1028 |

## Validation in lab experiments: SW (1/4)

| SW | Lab experiments |
|---|---|
| N | 672 |
| Observed (m±s) | 424 ± 172 |
| Predicted (m±s) | 451 ± 154 |
| Slope | 0.848 |
| Intersection | 41 |
| R | 0.7601 |

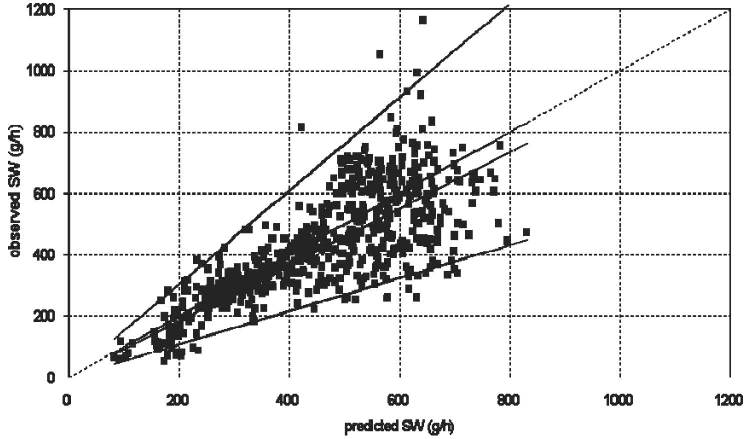
- Predicted values: in average 27 g/h greater
- Standard deviation smaller

- $SW_{obs} = 0.848 * SW_p + 41$  R=0.76
- $SW_{obs} = 0.918 * SW_p$



## Validation in lab experiments: SW (2/4)

Observed and predicted sweat rates  95% confidence interval




$SW_{obs} = 0.848 * SW_p + 41$  R=0.76
$SW_{obs} = 0.918 * SW_p$



## Validation in lab experiments : $t_{re}$ (3/4)

| $t_{re}$ | Lab experiments |
|---|---|
| N | 1937 |
| Observed (m±s) | 37.45 ± 0.47 |
| Predicted (m±s) | 37.46 ± 0.47 |
| Slope | 0.664 |
| Intersection | 12.57 |
| r | 0.6585 |

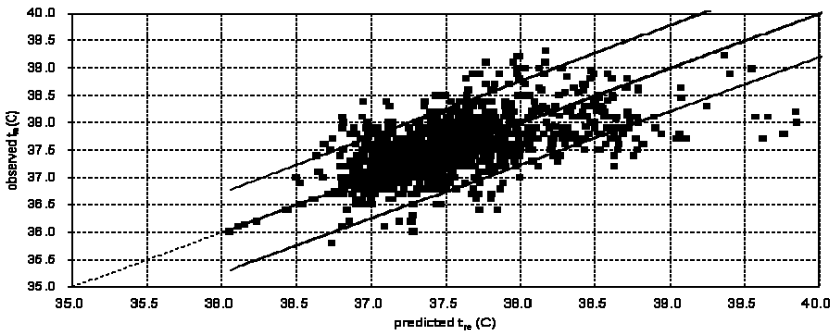
Means and standard deviations of observed and predicted values about equal.

$t_{re\ obs} = 0.664\ \ t_{re\ p} + 12.57$  R = 0.66
$t_{re\ obs} = 1.000 * t_{re\ p}$



## Validation in lab experiments: $t_{re}$ (4/4)

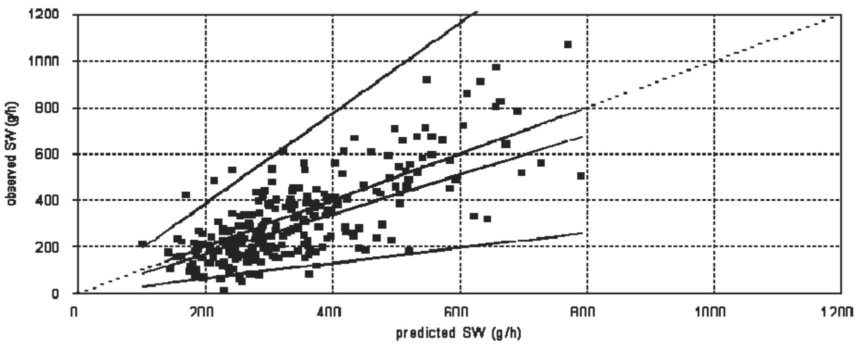
Observed and predicted rectal temperature  95% confidence interval




$t_{re\ obs} = 0.664\ \ t_{rep} + 12.57$  R = 0.66
$t_{re\ obs} = 1.000 * t_{rep}$

# Validation in <u>field</u> experiments:SW

Observed and predicted sweat rates 95% confidence interval



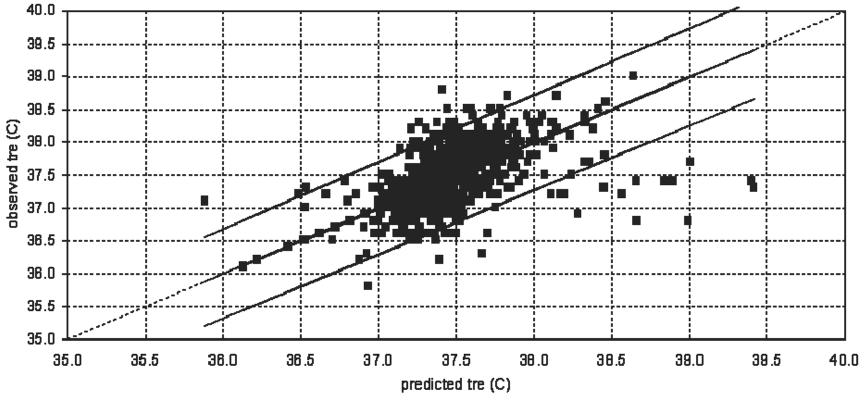

$SW_{obs} = 1.056 \quad SW_p - 46 \quad R = 0.74$

$SW_{obs} = 0.851 * SW_p$



# Validation in field experiments: $t_{re}$

Rectal temperature 95% confidence interval




$t_{re\ obs} = 0.770 \quad t_{re\ p} + 8.60 \quad R = 0.59$

$t_{re\ obs} = 1.000 * t_{re\ p}$



# PHS model validation: conclusions

good correlation between observed and predicted

In view of the inter-individual differences



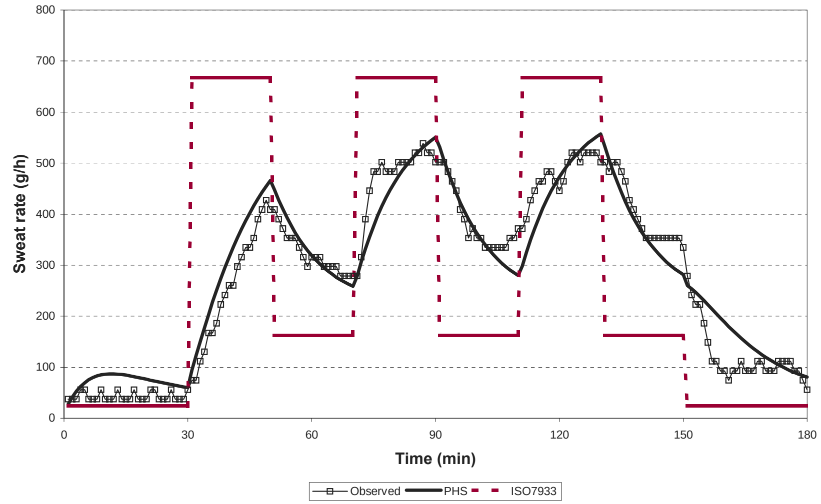
## COMPARISON BETWEEN PHS MODEL AND ISO7933

# Predicted sweat rate

| | LAB EXPERIMENTS (n = 672) | | | FIELD EXPERIMENTS (n = 237) | | |
|---|---|---|---|---|---|---|
| | Slope | Inters | r | Slope | Inters | r |
| $SW_{ISO}$ | 0.757 | 75 | 0.744 | 0.663 | 52 | 0.523 |
| PHS model | 0.848 | 41 | 0.760 | 1.056 | -46 | 0.745 |



# Comparison of PHS and ISO 7933






# COMPARISON BETWEEN PHS MODEL AND WBGT INDEX



# $DLE_{PHS}$ vs. WBGT

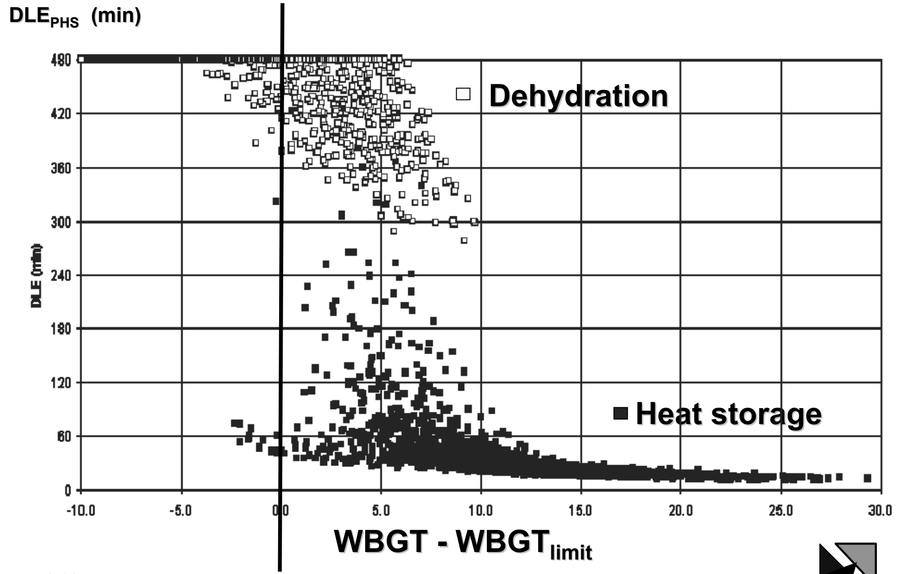
DLE computed in 3680 sets of conditions:

| | Range | Step | Number of values |
|---|---|---|---|
| Air temperature (°C) | 20 - 50 | 5 | 7 |
| Relative humidity (%) | 20 - 80 | 20 | 4 |
| ($t_r$ – $t_a$) (°C) (but $t_r$ limited at 60°C) | 0 - 40 | 10 | <5 |
| Air velocity ( $ms^{-1}$) | 0.01 - 2 | 0.5 | 5 |
| Metabolic rate (W) | 100 - 450 | 50 | 7 |
| Clothing insulation (clo) | 0.6 | - | 1 |

WBGT according to ISO 7243

$WBGT_{limit}$ = 34.3 - M / 35.5 (with M in W).

## $DLE_{PHS}$ Vs ($WBGT$ - $WBGT_{limit}$)






## Conclusion

WBGT imposes work duration limitations even in cases where, according to the PHS model, work would still be permitted for 8 hours continuously.

OK: WBGT screening method



# Example

# and

# ?



**Predicted Heat Strain model**

according to the ISO standard ISO 7933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Français English Espanol

## Entry of the exposure data

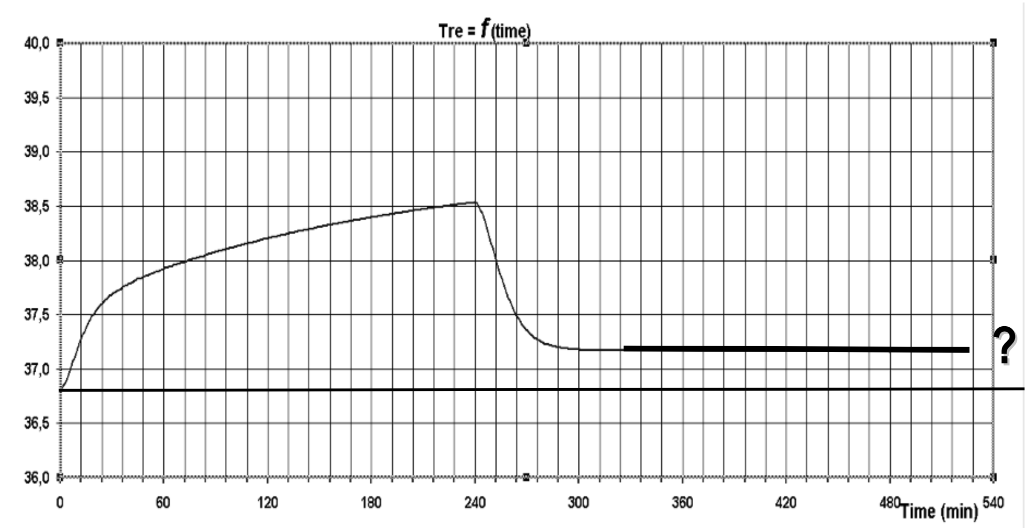
| | |
|---|---|
| Subject | azerty |
| Weight (kg) | 75 |
| Height (m) | 1,8 |
| Acclimatisation state | 100 |

| | Phase duration | Air temperature | Globe Temperature | Mean Rad Temp. | Relative Humidity | Partial vapor Pres | Air velocity | Metabolic rate | Posture 1 standing 2 sitting 3 crouching | clothing insulation | fraction of the body surface covered by the reflective clothing | emissivity of the reflective clothing dimensionless (by default: Fr=0,97) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ta °C | Tg °C | Tr °C | HR % | Pa kPa | Va m/s | M Watts | Post | Clo | Ap | Fr |
| Phase 1 | 240 | 40 | 44 | 49,62485 | 40 | 2,9488 | 0,6 | 350 | 2 | 0,5 | 0 | 0,97 |
| Phase 2 | 120 | 25 | 25 | 25 | 50 | 1,5831 | 0,6 | 100 | 1 | 0,5 | 0 | 0,97 |
| Phase 3 | 0 | - | - | - | - | - | - | - | - | - | - | - |
| Phase 4 | 0 | - | - | - | - | - | - | - | - | - | - | - |
| Phase 5 | 0 | - | - | - | - | - | - | - | - | - | - | - |
| Phase 6 | 0 | - | - | - | - | - | - | - | - | - | - | - |
| Phase 7 | 0 | - | - | - | - | - | - | - | - | - | - | - |
| Phase 8 | 0 | - | - | - | - | - | - | - | - | - | - | - |
| Total | 360 | | | | | | | | | | | |



| Ta °C | Tg °C | Tr °C | HR % | Pa kPa | Va m/s | M Watts |
|---|---|---|---|---|---|---|
| 40 | 45 | 51,92314 | 40 | 2,9488 | 0,6 | 400 |
| 25 | 25 | 25 | 50 | 1,5831 | 0,6 | 100 |

## PHS ISO




## PHS:

$E_{req}$ = Met - Work - $C_{res}$ - $E_{res}$ - Conv - Rad

Accum = $E_{req}$ - $E_p$

→ $T_{re}$

## PHS modified:

Heat stored = $c_{sp}$ ($T_{co}$ – $T_{co\ eq}$) (1-α)

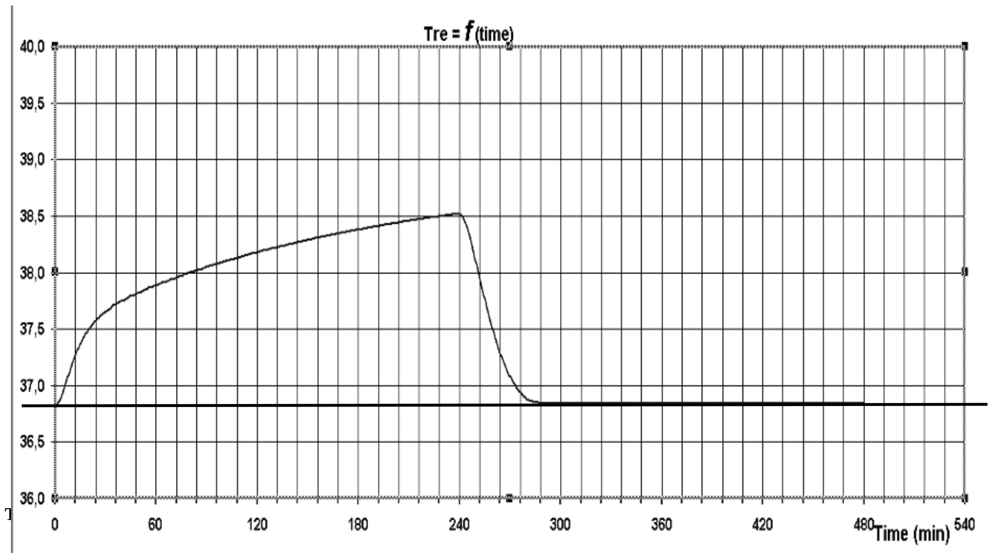
$E_{req}$ = Met - Work - $C_{res}$ - $E_{res}$ - Conv – Rad + Heat stored

Accum = ($E_{req}$ – Heat stored) - $E_p$

→ $T_{re}$



| Ta °C | Tg °C | Tr °C | HR % | Pa kPa | Va m/s | M Watts |
|---|---|---|---|---|---|---|
| 40 | 45 | 51,92314 | 40 | 2,9488 | 0,6 | 400 |
| 25 | 25 | 25 | 50 | 1,5831 | 0,6 | 100 |



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あなたの注意をありがとう

***Thank you***



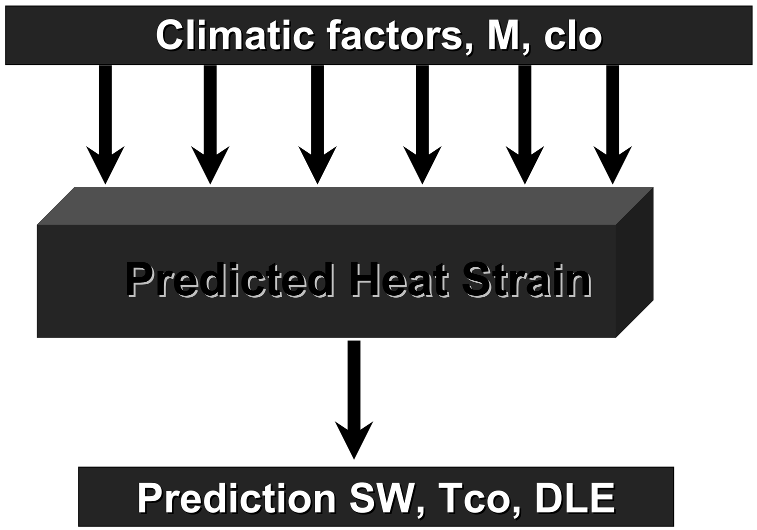
## Strategy for the management of the thermal working conditions



## Summary

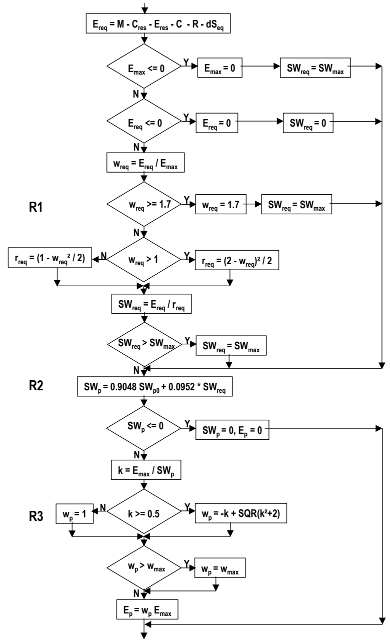
- The SOBANE strategy
  - The basic principles
  - The 4 stages of intervention
- Application to climatic conditions of work
  - Procedure
  - Stage 1, *Screening*
  - Stage 2, *Observation*
  - Stage 3, *Analysis*
  - Stage 4, *Expertise*



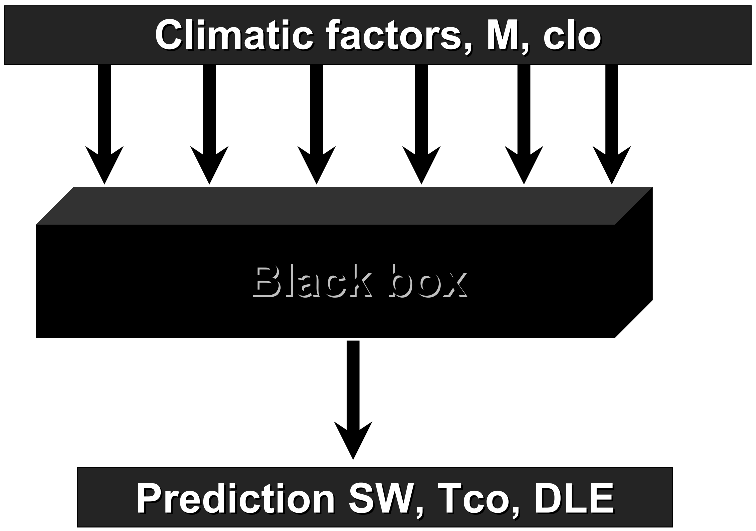


| Symbol | Term | Unit | Symbol in the program |
|---|---|---|---|
| - | code =1 if walking speed entered, 0 otherwise | - | defspeed |
| - | code =1 if walking direction entered, 0 otherwise | - | defdir |
| $\alpha$ | fraction of the body mass at the skin temperature | dimensionless | - |
| $\alpha_i$ | skin-core weighting at time i | dimensionless | TskTcrwg |
| $\alpha_{i-1}$ | skin-core weighting at time (i-1) | dimensionless | TskTcrwg0 |
| $\varepsilon$ | emissivity of the bare skin | dimensionless | - |
| $\tau$ | time constant | min | - |
| $\theta$ | angle between walking direction and wind direction | degrees | Theta |
| $A_{Du}$ | Dubois body surface area | square metre | Adu |
| $A_p$ | fraction of the body surface covered by the clothing | dimensionless | Ap |
| $A_r$ | effective radiating area of the body | dimensionless | Ardu |
| C | heat flow by convection at the skin surface | Watts per square metre | Conv |
| $c_e$ | water latent heat of evaporation | Joules per kilogram | - |
| $C_{orr,cl}$ | correction for the dynamic clothing insulation for totally clothed subjects | dimensionless | CORcl |
| $C_{orr,Ia}$ | correction for the dynamic boundary layer insulation | dimensionless | CORia |
| $C_{orr,tot}$ | correction for the dynamic clothing insulation as a function of the actual clothing | dimensionless | CORtot |
| $C_{orr\ E}$ | correction for the dynamic permeation rate | dimensionless | CORe |
| $c_p$ | specific heat of dry air at constant pressure | Joules per kilogram of dry air | - |
| $C_{res}$ | heat flow by respiratory convection | Watts per square metre | Cres |
| $c_{sp}$ | specific heat of the body | Watts per square meter per degree celsius | spHeat |
| $D_{lim}$ | allowable exposure duration | min | Dlim |
| $D_{lim\ tre}$ | allowable exposure duration for heat storage | min | Dlimtre |
| $D_{limloss50}$ | allowable exposure duration for water loss, mean subject | min | Dlimloss50 |
| $D_{limloss95}$ | allowable exposure duration for water loss, 95% of the working population | min | Dlimloss95 |
| $D_{max}$ | maximum water loss | grams | Dmax |
| $D_{max50}$ | maximum water loss to protect a mean subject | grams | Dmax50 |
| $D_{max95}$ | maximum water loss to protect 95% of the working population | grams | Dmax95 |
| $dS_i$ | heat stored during the last time increment | Watts per square metre | dStorage |
| $dS_{eq}$ | body heat storage rate for increase of core temperature associated with the metabolic rate | Watts per square meter | dStoreq |










# 7 fundamental principles

1. **The qualifications of the partners : workers, management, OH practitioners, experts are complementarity**
2. **The OH resources limited**
   **A strategy to use them adequately**
3. **The worker is ACTOR and not assisted**
   **Participative approach**
4. **All OH problems are linked:**
   **Global approach**
5. **Prevention > Compliance**
   **Not only comply with the legal values**
   **But search for the optimal stage**
6. *Methods designed for SMEs and not only for the large companies*

# Principle 7:
# Management vs measurements

???

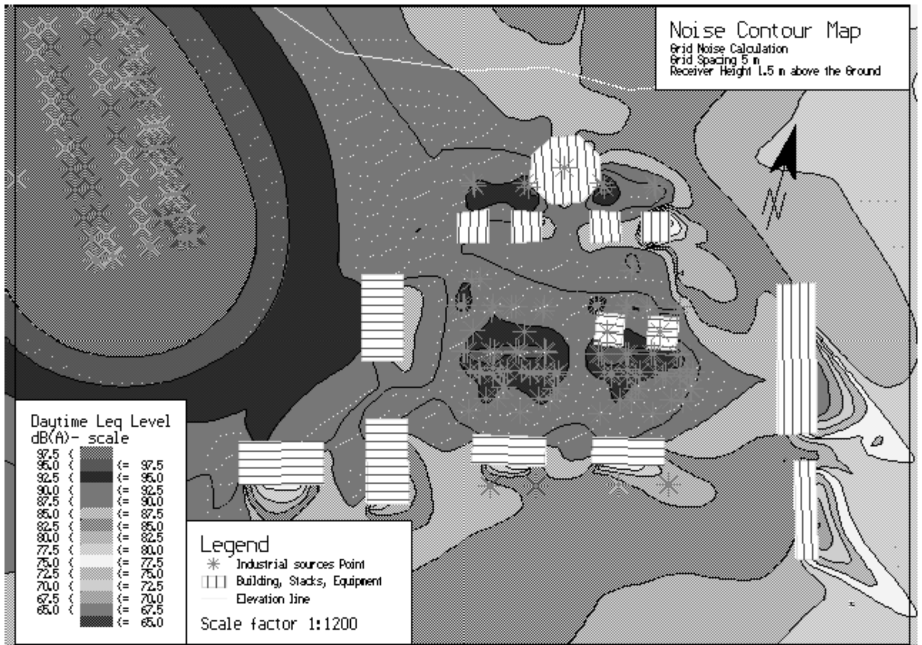


## Example

The temperature is 35°C
- When? day, hour…
- What weather outside: sunny, raining…
- Level during what period of time?
  - instantaneous value,
    - average on 1, 5, 60, 480 min.
- In what working conditions?

REPRESENTATIVENESS?








# Why so many measurements?

## False excuses

**"What is not quantified does not exist"**
- "Engineers… ask us for quantitative data"

**"Quantitative evaluation leads to solutions"**
- How much? vs Why? and how?
- The global vs the details

**"It is necessary to measure and quantify to determine whether there is a risk"**
- Legalistic vs preventive approach

**"It is necessary to measure to objectify the "subjective" complains of the workers"**
- Recognize explicitely the qualification and the integrity of the workers anf their local management

# True reasons

## Industry:

Delaying measurements

## Occupational Health Practitioners:

have been trained mainly to measure

It is easy, fast, little expensive and quite "prestigious"



# Quantification when it is indispensable for:

- Scientific research
- Dose - effect - response relationships
- Compensations
- Court
- (Compare before – after)
- To go deeper on a particular point
- To optimize costly and sophisticated solutions



# Conclusions:

## Evaluation of the exposure in quantitative terms

- Very complicated
- Long, expensive
- Little necessary at the beginning
- Little used in the field in a representative way

## To be done AFTER improvement to evaluate the residual risk



"The cost to measure the exposure correctly is greater that what several developing countries spend for health per capita per year"

Paul Oldershaw
Control Banding

"It is not unusual to see more attention given to exposure assessment and monitoring than to risk prevention and control.

The fascination exerted by sophisticated equipment and by numbers is, for some reason, greater than the interest in designing pragmatic solutions to prevent exposure"

B. Goelzer (1996)

➔No measurements a priori
costly
long and difficult
not representative

**Prevention** >>> measurements

**Management** >>> assessment



- Decrease the importance of the metrologists
- Develop personal enhanced value through
  - prevention
  - its management

  rather than through
  - measurements (less intruments)
  - descriptive studies
  - reports that are not read…
- Train people to take actions rather than measure
  prevention rather than evaluation

➨ **Modify the training programmes**



## Conclusion:

New approach with:

- Participation of the workers
- Start from a comprehensive approach
- Progressive approach
- Based on the people in the field
- Objective: the best possible conditions
- **Measurements after,** not before

## How??????

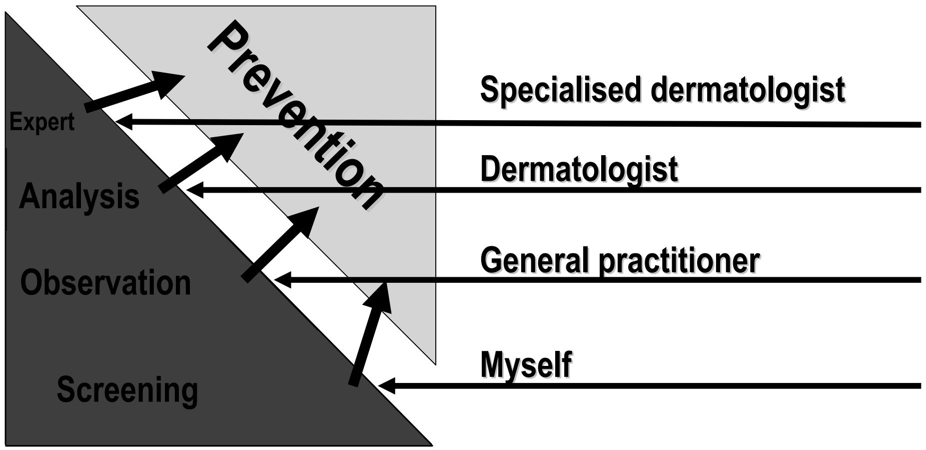


## A strategy

- Coordination of the actors
  - Artillery, Tanks, Infantry
  - Workers, OH practitioners, experts
- in time ( in sequence)
- to reach the goal in the way
  - easier
  - faster
  - more economical

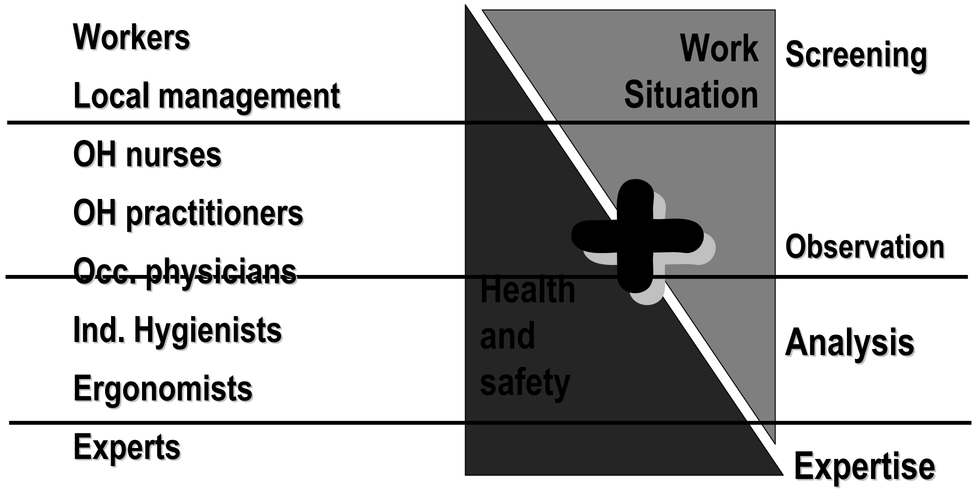
≠ method

# Management of public health



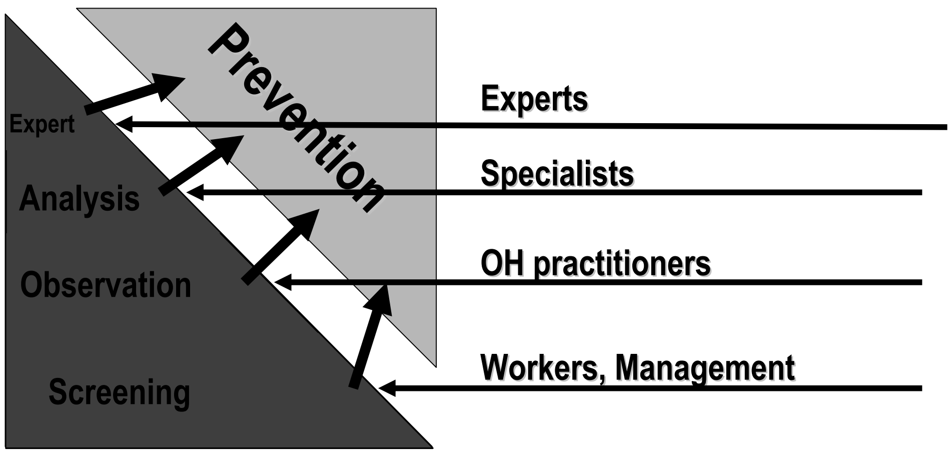



# People involved





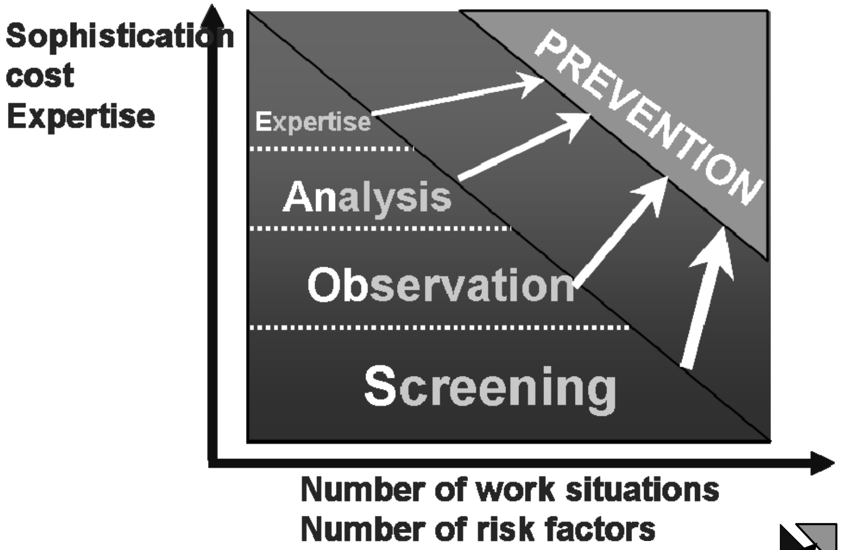

# Management of occupational health






| | Stage 1 *Screening* | Stage 2 *Observation* | Stage 3 *Analysis* | Stage 4 *Expertise* |
|---|---|---|---|---|
| • When? | Systematically | When a "problem" is detected | More complicated Cases | Very complex cases |
| • How? | Opinions | Qualitative observations | Ordinary measurements | Specialised measurements |
| • Cost? | Very low | Low | Average | High |
| • Duration | 10 min | 2 hours | 1 day | A few days |
| • By whom? | Workers + company management | Workers + company management | Same + specialists | Same + specialists + experts |
| • Knowledge - working conditions - Hygiene | Very high<br>Low | High<br>Average | Average<br>High | Low<br>Specialised |

## Prevention Strategy SOBANE






| | Screening | Observ. | Analysis | Expertise |
|---|---|---|---|---|
| S C R E E N I N G | Areas | | | |
| | Work organization | Work organization | Work organization | |
| | Machines | | | |
| | Safety | | | |
| | --- | | | |
| | Heat | Heat | Heat | |
| | Chemicals | Chemicals | Chemicals | Chemicals |
| | --- | | | |
| | Work content | Work content | | |
| | Psycho environm. | | | |



1: Social facilities
2: Safety (accidents, falls…)
3: Machines and hand tools
4: Electricity
5: Fire and explosion
6: Lighting
7: Work on VDUs
8: Noise
9: Thermal environment
10: Chemical agents
11: Biological agents
12: Musculoskeletal disorders
13: Whole body vibration
14: Hand-arm Vibration
15: Psychosocial factors



## The SOBANE strategy for the prevention of heat stress

"Operationally validated" in 20 small companies:

- understood and readily operational
- not too long, not too short
- leads to solutions at short, medium, long term
- optimizes the intervention of the O.H.
- saves time and € or ￥

## General procedure

1. Information by the direction on the aims and commitment to take account of the results
2. Definition of a small group of workstations forming a unit, a " work situation" (10 to 15)
3. Designation of a coordinator
4. Adaptation of the tools to the work situation
5. Constitution of a working group (4 to 7 people) with
   key operators designated by their colleagues
   at least 1 man and 1 woman if mixed group
   supervisory staff
6. Meeting of the group in a quiet room close to the working situation



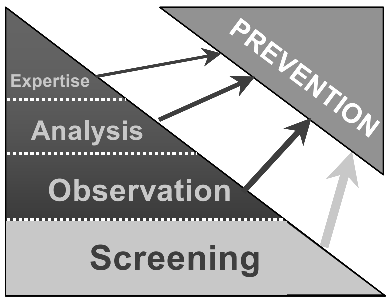
## Procedure

7. Discussion following a guide
   - not to carry a score

   but to determine
   - what can be made to improve the situation
   - what needs to be discussed ("Observation") more specifically
8. Synthesis by the coordinator
   - The list of the detailed solutions considered
   - The points that need to be studied more in detail
   - Who does what and when?
   - The short term action plan
9. Implementation of the action plans at short, medium and long terms
10. Periodically, repetition of the operation
11. Revaluation of the situation and modification of the action plans



## Stage 1, Screening






| Situation of work: |
|---|
| 1. Work areas |
| *2.* Technical organization between stations |
| 3. Sites of work |
| 4. Risks of accident |
| 5. Orders and signals |
| 6. Tools and materials |
| 7. Repetitive work |
| 8. Handling operations |
| 9. Mental load |
| 10. Lighting |
| 11. Noise |
| 12. Thermal environments |
| 13. Chemical and biological risks |
| 14. Vibration |
| 15. Relationships between employees |
| 16. Local and general social environment |
| 17. Work content |
| 18. Psychosocial environment |

## 12.Thermal environments

| To be discussed | Who can do what in practice and when? |
|---|---|
| • **Temperature**<br>Neither too warm nor too cold, no significant variations<br>• **Humidity :** not too dry nor too humid<br>• **No draughts:** by the windows and the doors<br>• **Cold, heat and humidity sources**<br>Removed: water, vapour, machines, sun...<br>•**Clothing**<br>Comfortable: overalls, laboratory apron...<br>•**Protective clothing**<br>If necessary (insulating, water-proof, anti-radiations...)<br>Quality, appropriate and comfortable<br>•**Drinks:** available in case of conditions too hot or too cold | |

| Aspects to study more in detail | |
|---|---|
| | ☹ |
| | 😐 |
| | ☺ |



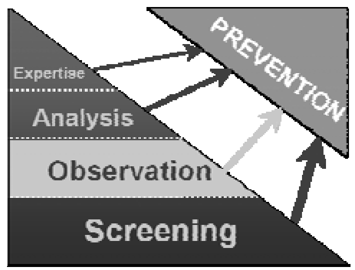
| Situation of work: Synthesis of *the Déparis* | |
|---|---|
| 1. Work areas | ☹ |
| *2.* Technical organization between stations | 😐 |
| 3. Sites of work | 😐 |
| 4. Risks of accident | ☹ |
| 5. Orders and signals | ☺ |
| 6. Tools and materials | ☹ |
| 7. Repetitive work | ☺ |
| 8. Handling operations | 😐 |
| 9. Mental load | 😐 |
| 10. Lighting | 😐 |
| 11. Noise | 😐 |
| **12. Thermal environments** | ☹ |
| 13. Chemical and biological risks | ☺ |
| 14. Vibration | 😐 |
| 15. Relationships between employees | ☺ |
| 16. Local and general social environment | 😐 |
| 17. Work contents | ☺ |
| 18. Psychosocial environment | ☹ |



| N° | WHO? | WHAT? | WHEN? Projected | WHEN? Carried it out |
|---|---|---|---|---|
| 1 | Operators | Store the pallets of boxes in the room next to the workshop | / | / |
| 2 | Operators | Range the transpallet | / | / |
| 3 | Maintenance | Reduce the stock of solvents to 3 bottles | / | / |
| 4 | Direction | Regulate the access to the workshop so that only the operators have access | / | / |
| | | | | |
| 9 | OH practit. | Look for a cutter with retractable blade | To analyze before / | |
| | | | | |
| 11 | OH practit. | Provide gloves<br>• to protect from the chemicals<br>• resistant to heat for the interventions near the furnace | To analyze before / | |



# Stage 2, Observation




## Objectifs

**To study the work situation**

**in general**

and not on a specific day

**concerning the climatic exposure conditions**

# Stage 2, Observation: how?

**Procedure similar to the Screening stage**

coordinator and working group

2-hour meeting

discussion of the items, concentrating on:

- Checking how the work is done and the problems encountered
- What can be made directly, in practical terms to improve the situation
- by whom and when
- What aspects require the assistance of an OH practitioner at stage 3, *Analysis*



# Stage 2: OBSERVATION

1. Describe the working condition known to or likely to raise a thermal problem
2. Evaluate the situation for each of the six parameters separately
   - What is the situation, on a scale of discomfort ?
   - What could be done immediately to improve the situation?
   - What is going to be the situation afterwards?



# Temperature Scale Solutions

| | |
|---|---|
| -3 | • Generally freezing |
| -2 | • Generally between 0 and 10°C. |
| -1 | • Generally between 10 and 18°C |
| 0 | • Generally between 18 and 25°C |
| 1 | • Generally between 25 and 32°C |
| 2 | • Generally between 32 and 40°C |
| 3 | • Generally greater than 40°C |

- Locate the sources of heat or cold in the periphery
- Eliminate the sources of hot or cold air
- Insulate the hot surfaces
- Exhaust hot or cold air locally
- Ventilate without draughts
- Use clothes with lower or higher insulation
- …



# Humidity Scale Solutions

| | |
|---|---|
| -1 | - Dry throat/eyes after 2-3 hours |
| 0 | - Normal |
| 1 | - Moist skin |
| 2 | - Skin completely wet |

- Eliminate the leaks of vapour and water
- Enclose all evaporating surface
- Use clothes waterproof but permeable to vapour
- …

## Radiation Scale Solutions

| | |
|---|---|
| -1 | - Cold on the face after 2-3 minutes |
| 0 | - No radiation discernible |
| 1 | - Warm on the face after 2-3 minutes |
| 2 | - Unbearable on the face after > 2 minutes |
| 3 | - Immediate burning sensation |

- Reduce the radiating surfaces
- Use reflecting screens
- Insulate or treat the radiating surface
- Locate workstations away from radiating surfaces
- Use special protective clothes reflecting radiation
- …



## Air movement Scale Solutions

| | |
|---|---|
| -2 | . cold strong air movements |
| -1 | . cold light air movements |
| 0 | . no air movements |
| 1 | . warm light air movements |
| 2 | . warm strong air movements |

Reduce or eliminate air draughts
Use screens to protect locally against draughts
Locate workstations away from air draughts
...



## Work load Scale Solutions

| | |
|---|---|
| 0 | . office work: easy low muscular constraints, |
| 1 | occasional movements at normal speed. |
| 2 | . Moderate work with arms or legs |
| | . Intense work with arms and trunk |
| 3 | . very intense work at high speed: stairs, ladders |

Reduce the movements during work
Reduce displacements
Reduce the speed of movements
Reduce the efforts, use mechanical assistance…
Improve the postures…



## Clothing Scale Solution

| | |
|---|---|
| 0 | - light, flexible, not interfering with the work |
| 1 | - long, heavier, interfering slightly with the work |
| 2 | - clumsy, heavy, special for radiation, humidity |
| 3 | - special overalls with gloves, hoods, shoes |

Improve the design of the clothing
Select more suitable materials
Look for lighter materials
…

## Workers opinion scales

| | | |
|---|---|---|
| -3 | - | shivering, strong discomfort for the whole body |
| -2 | - | strong local discomfort overall sensation coolness |
| -1 | - | slight local cool discomfort |
| 0 | - | no discomfort |
| 1 | - | slight sweating and discomfort thirst |
| 2 | - | heavy sweating, work pace modified |
| 3 | - | excessive sweating, special clothing |



## Stage 2: *Observation*

3. Determine globally how acceptable the situation is

| | -3 | -2 | -1 | 0 | 1 | 2 | 3 |
|---|---|---|---|---|---|---|---|
| Air temperature | | | | | | | O |
| Humidity | | | | | | O | |
| Radiation | | | | | O | | |
| Air movements | | | | O | | | |
| Work Load | | | | | | O | |
| Clothing | | | | | | | O |



## Stage 2: *Observation*

4. Determine globally how acceptable the situation might be afterwards:

| | -3 | -2 | -1 | 0 | 1 | 2 | 3 |
|---|---|---|---|---|---|---|---|
| Air temperature | | | | | | X | O |
| Humidity | | | | | X | O | |
| Radiation | | | | | = | | |
| Air movements | | | | = | | | |
| Work Load | | | | | X | O | |
| Clothing | | | | | X | | O |



## Stage 2: *Observation*

5. Measures to be taken in the short-term:
   - Hot or cold drinks; Recovery periods
   - Work organisation; Clothing….

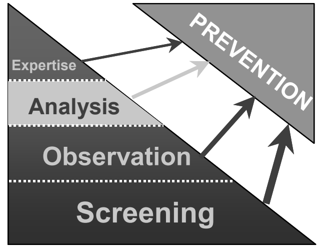
| N° | WHO? | WHAT? | WHEN? Projected | WHEN? Carried it out |
|---|---|---|---|---|
| 1 | Maintenance | Insulate all the pipes | / | / |
| 2 | Operators | Close the doors of the oven between each operation | / | / |
| 3 | OH practit | Improve the radiation shields on the left of the oven | / | / |
| 4 | Operators | Close the doors of the workshop to avoid draughts | / | / |
| | | … | | |
| 9 | Direction | Reorganise the task and the space in order to limit the displacements and reduce the emission of heat | To analyze before / | |
| | | … | | |
| 14 | OH practit. | Provide gloves resistant to heat for the interventions near the furnace | To analyze before / | |

## Stage 2: *Observation*

6. Decision whether a more detailed Stage 3, *Analysis*
   - For what specifically



## Stage 3: *Analysis*




- in specific conditions
- conducted with the assistance of an OH practitioner with adequate training
  - to find technical solutions
  - to define organisational solutions
  - and short-term protection measures
- Use common concepts and techniques and, if necessary, simple measurements
  - to identify the causes of the problems
  - and the means to solve these problems
- Useable in less than one day
- Oriented towards prevention



## *Stage 3, Analysis*: Procedure

- Analyse the sequence of activities:
  - description of the activities
  - mean and maximum durations
  - period concerned by the working situation
  - exposed workers

  during representative period(s) of time
  - measurement or estimation of the mean and maximum values
  - computation of the indices PMV-PPD, PHS



## Stage 3, *Analysis* : Synthesis

| | Activity ... | | Activity ... | |
|---|---|---|---|---|
| | mean | max | mean | max |
| $t_a$ | | | | |
| RH | | | | |
| $t_g$ | | | | |
| $v_a$ | | | | |
| M | | | | |
| Clo | | | | |
| PMV | | | | |
| PPD | | | | |
| WBGT | | | | |
| PHS / DLE | | | | |

# Stage 3, *Analysis* : interpretation

## Risk in the present situation

| | |
|---|---|
| cold constraint | PMV < -2 |
| cold discomfort | -2 < PMV < -0,5 |
| comfort | -0,5 < PMV < 0,5 |
| warm discomfort | 0,5 < PMV < 2 |
| constraint in the long term | DLE < 480 min |
| constraint in the short term | DLE < 120 min |
| immediate constraint | DLE < 30 min |



# Stage 3, *Analysis*: Procedure

- **Determine the acceptability of the working condition by comparing:**
  - the mean and maximum duration of each activity
  - with the DLEs estimated from the PHS model
- **Define prevention - control techniques**
- **Define the optimum work organisation.**
- **Determine the residual risk after implementation of these prevention - control measures.**



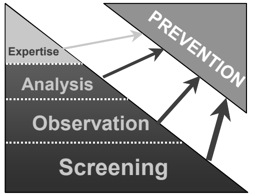
# Stage 3, *Analysis* : synthesis

| | Activity ... | Activity |
|---|---|---|
| ***3. Risk***<br>• Class of risk<br>• If heat stress<br>  • Sweating rate<br>  • Water loss per day<br>  • DLE | | |
| ***4. Acceptability*** | | |
| ***5. Prevention/control measures*** | | |
| ***6. Residual risk*** | | |
| ***7. Need for an expertise*** | | |
| ***8. Short term measures*** | | |
| ***9. Medical surveillance*** | | |



# Stage 4: *Expertise*

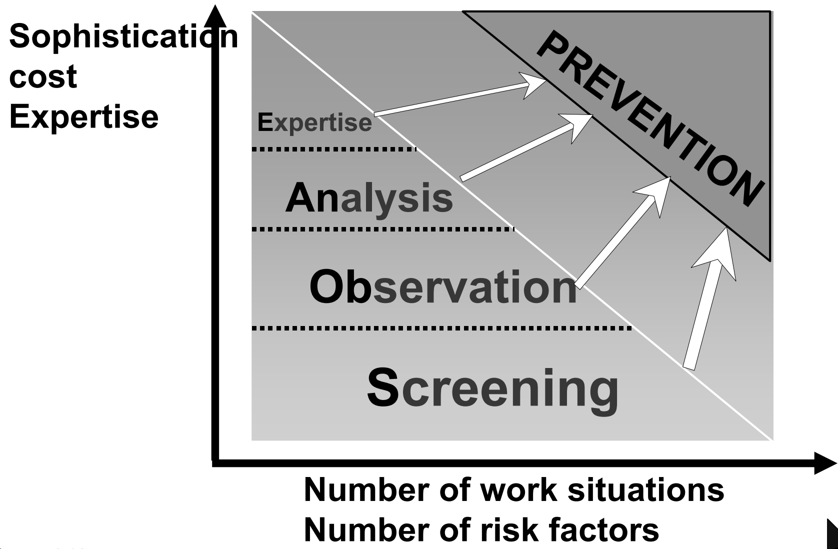
## Stage 4: *Expertise*



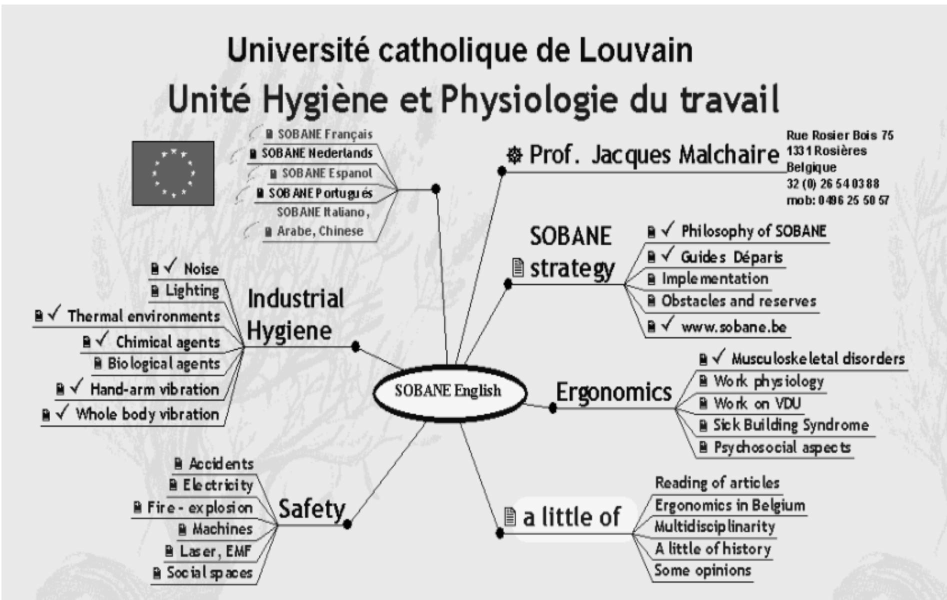

- **Better characterise some heat or cold sources and/or some unusual circumstances**
  - Specific measurements
  - Specific investigation techniques
- **Characterise the overall exposure of the workers**
- **Look for sophisticated prevention/control measures**



## Prevention Strategy SOBANE





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あなたの注意をありがとう

***Thank you***