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**

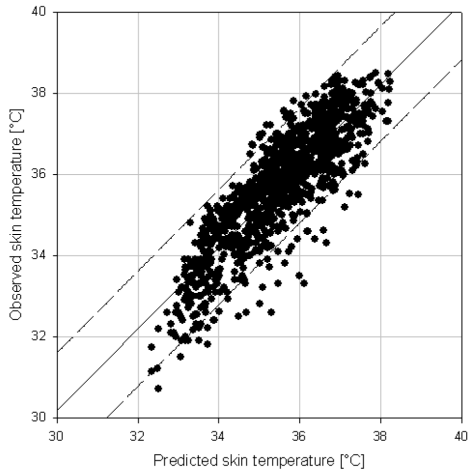
1. Predicted skin temperature (2/4)

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

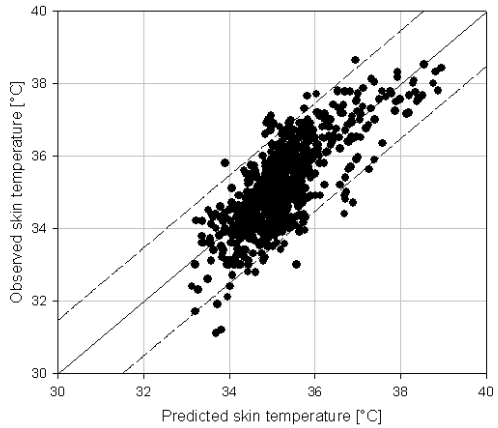
$$t_{sk} = 7.19+0.064\ t_a + 0.061 t_r + 0.198 p_a - 0.348 v_a + \underline{0.616 t_{re}} + 0*M$$



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 $t_{co} \geq 39°C$

α varies between 0.3 and 0.1 according to

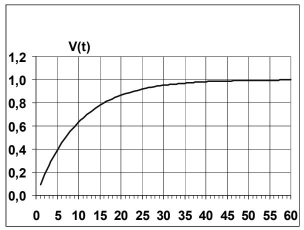
$$\alpha = 0.3 - 0.09\ (t_{co} - 36.8)$$

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)*, Δt min before

V_{max} is the target value

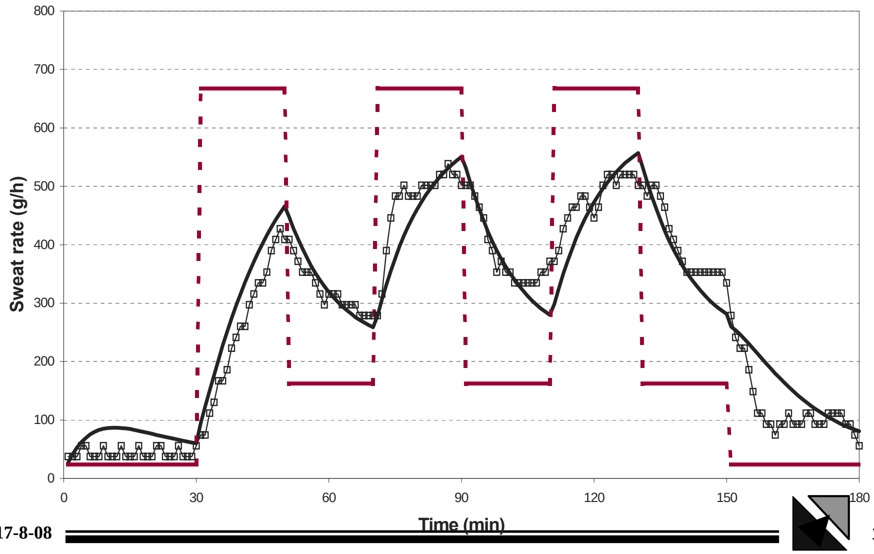
$k = \exp(-\Delta t / \tau)$

τ 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:

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

- **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)

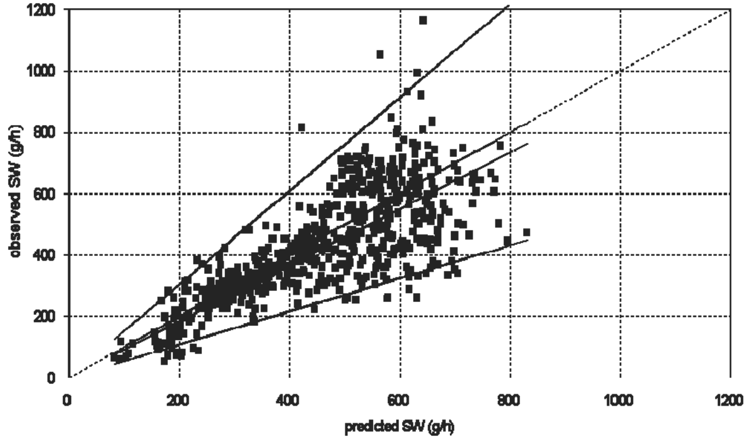
SW	Lab experiments
N	672
Observed (m±s)	424 ± 172
Predicted (m±s)	451 ± 154
Slope	0.848
Intersection	41
R	0.7601

- 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

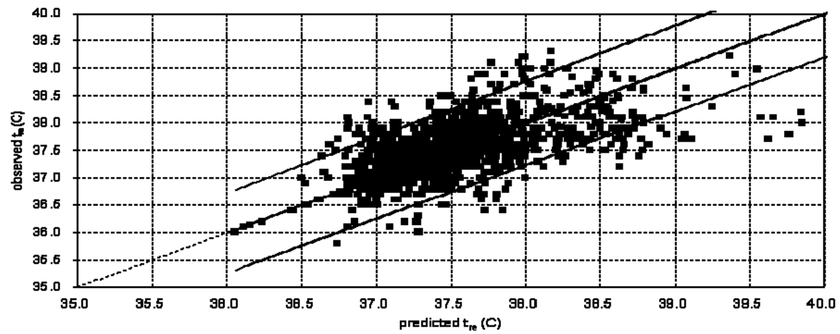
Means and standard deviations of observed and predicted values about equal.

$t_{re\ obs} = 0.664\ t_{re\ p} + 12.57$ 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

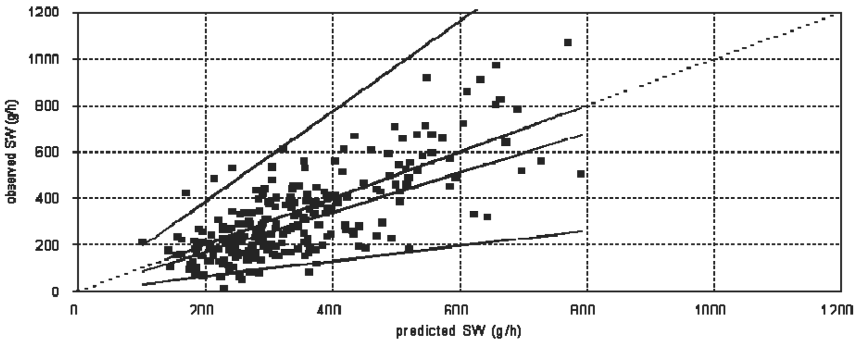


$t_{re\ obs} = 0.664\ t_{rep} + 12.57$ R = 0.66

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

Validation in field experiments:SW

Observed and predicted sweat rates 95% confidence interval

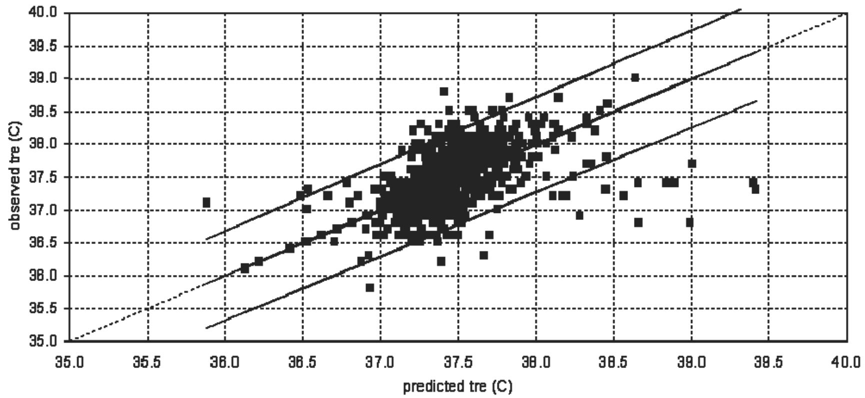


$SW_{obs} = 1.056 \; SW_p - 46 \quad R = 0.74$

$SW_{obs} = 0.851 * SW_p$

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

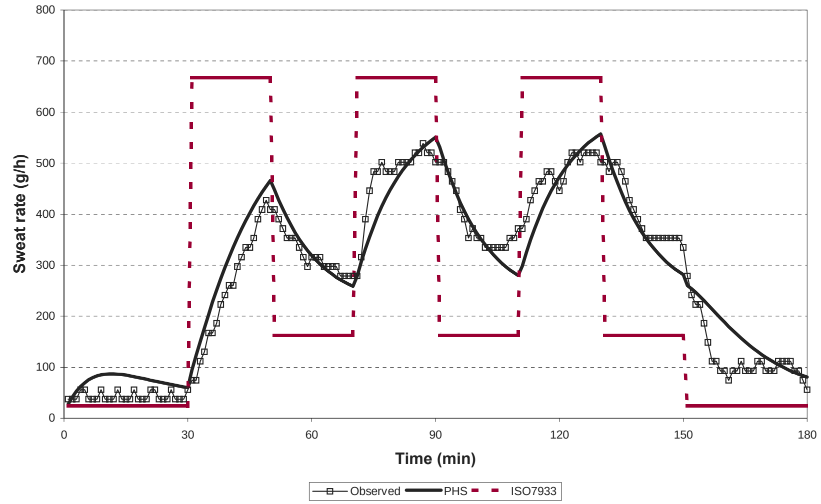
In view of the inter-individual differences

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

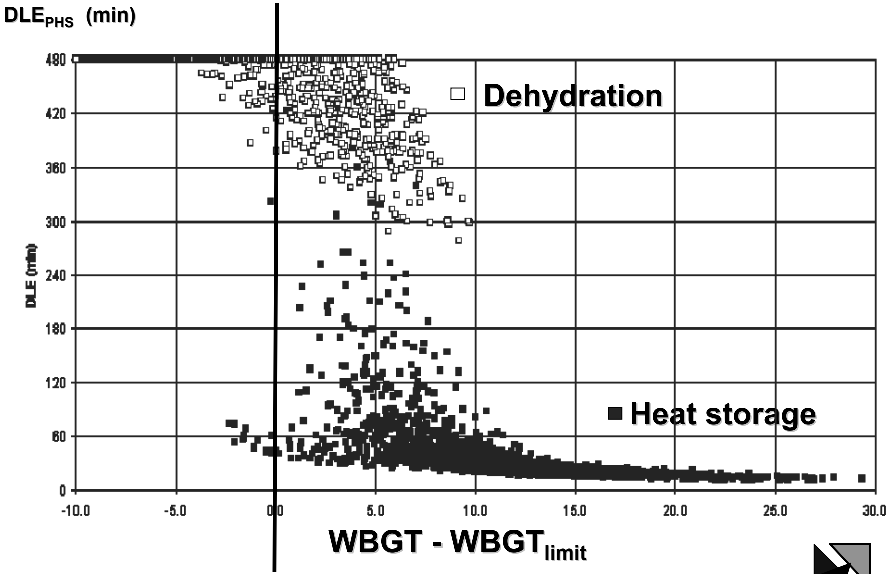
DLE computed in 3680 sets of conditions:

	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

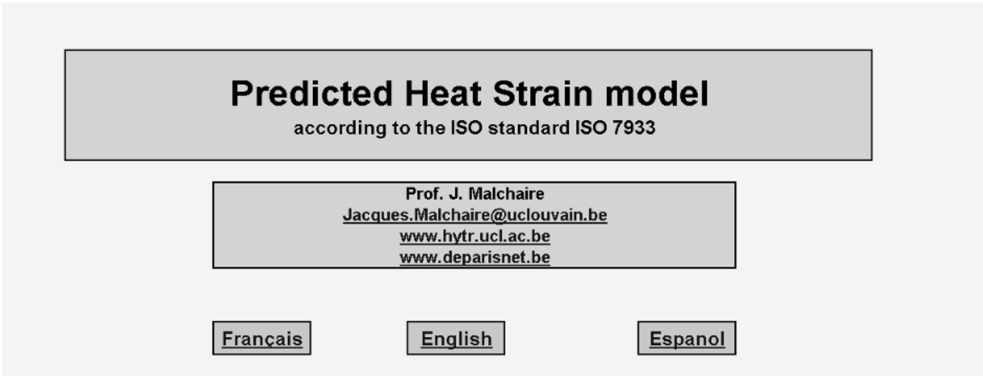
WBGT imposes work duration limitations even in cases where, according to the PHS model, work would still be permitted for 8 hours continuously.

OK: WBGT screening method

Example

and

?



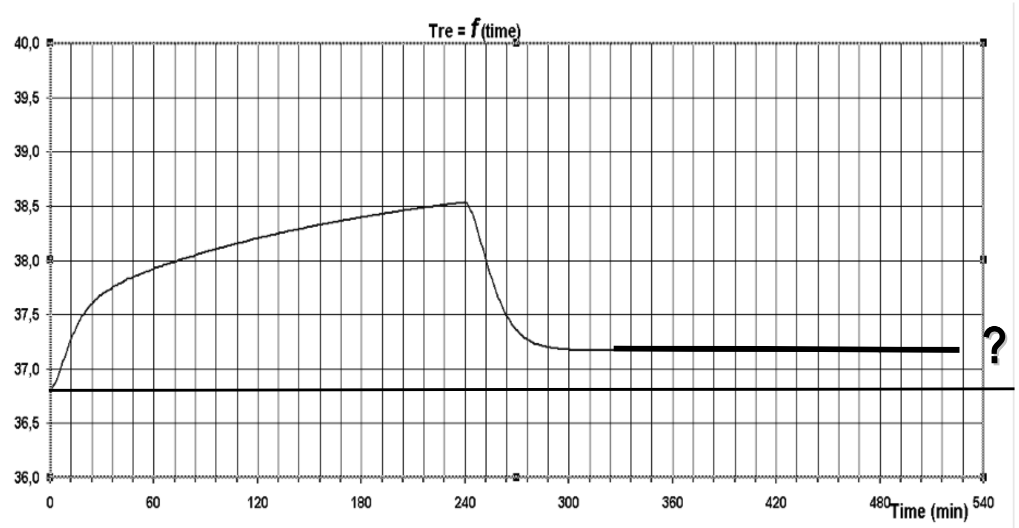
Entry of the exposure data

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:

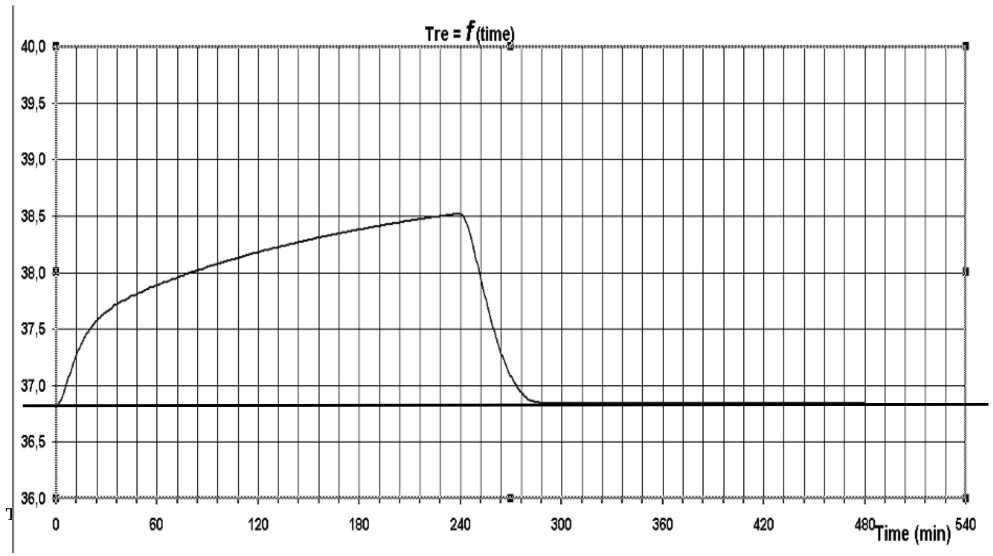
Heat stored = c_{sp} (T_{co} – $T_{co\ eq}$) (1-α)

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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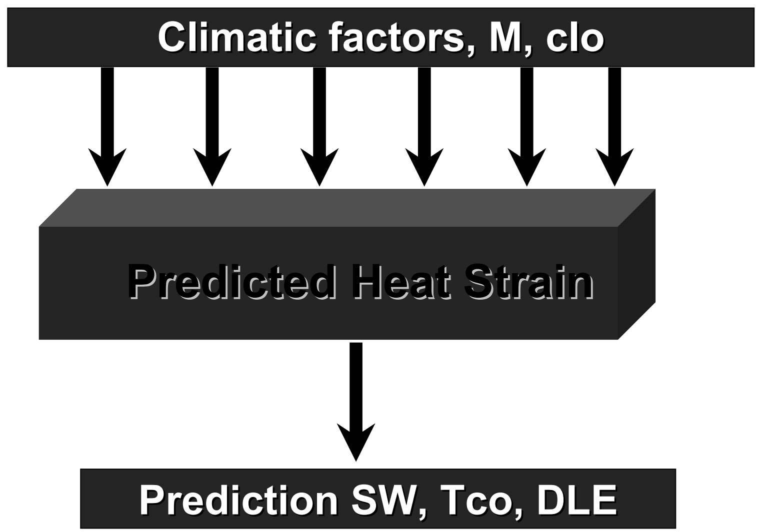
あなたの注意をありがとう

Thank you

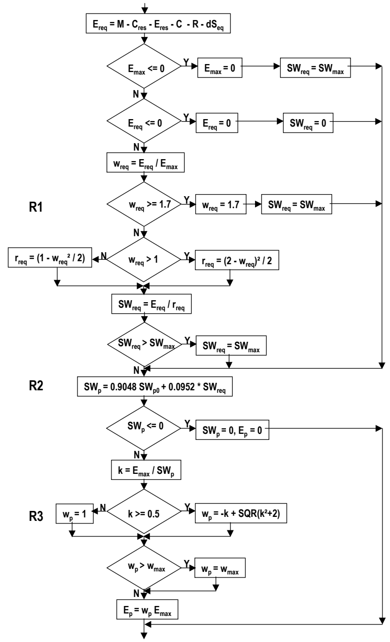
Strategy for the management of the thermal working conditions

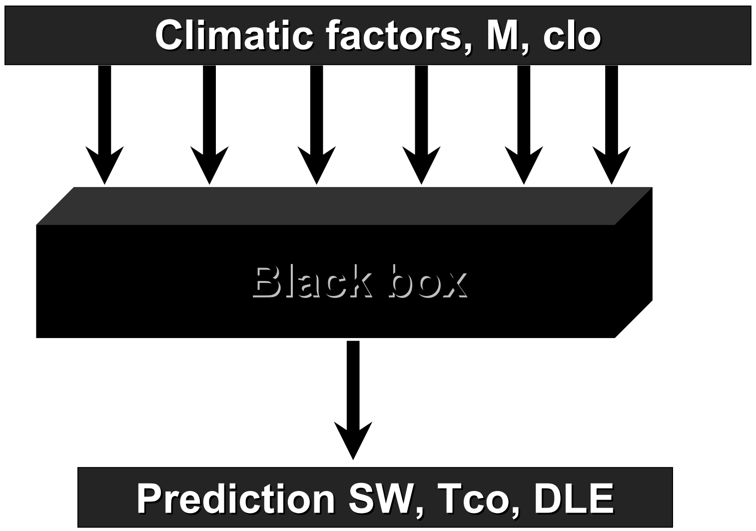
Summary

- 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
α	fraction of the body mass at the skin temperature	dimensionless	-
α_i	skin-core weighting at time i	dimensionless	TskTcrwg
α_{i-1}	skin-core weighting at time (i-1)	dimensionless	TskTcrwg0
ε	emissivity of the bare skin	dimensionless	-
τ	time constant	min	-
θ	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*

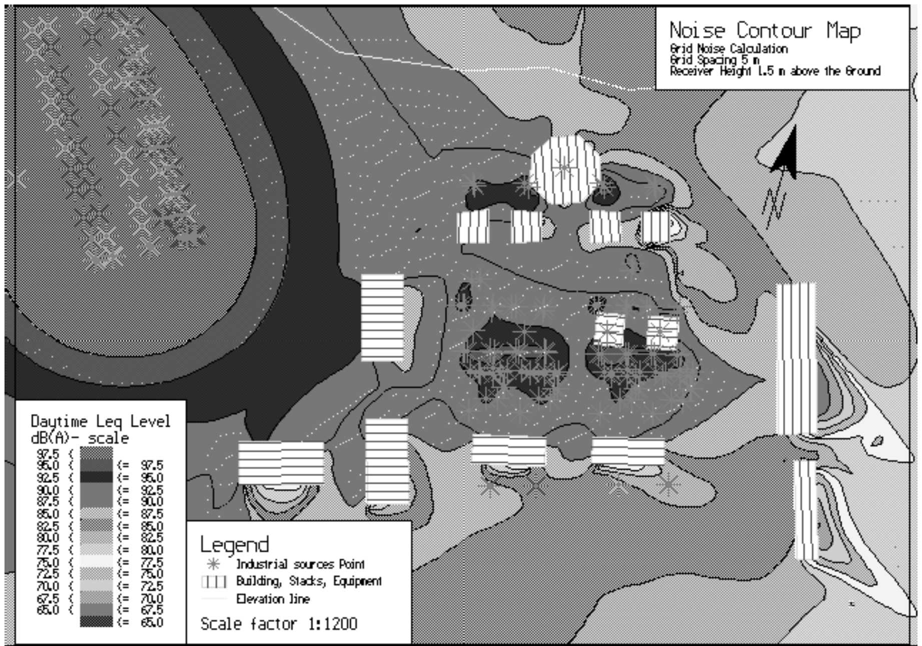
Principle 7:
Management vs measurements

???

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

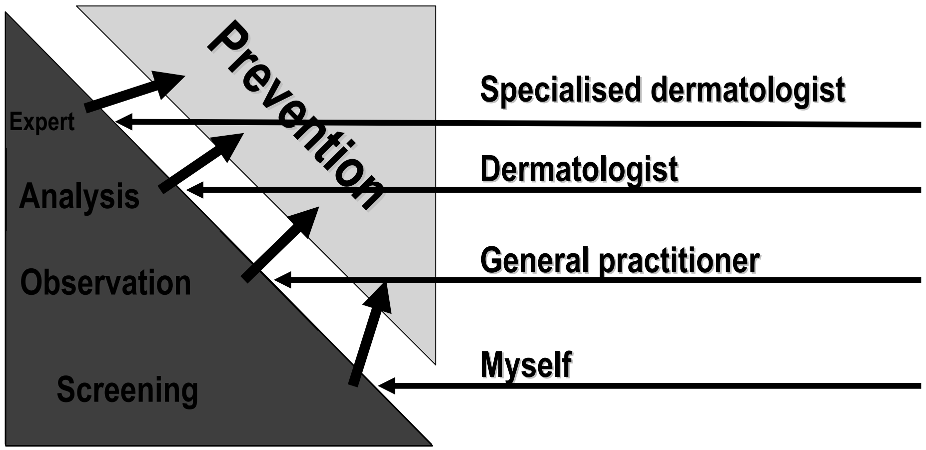
How??????

A strategy

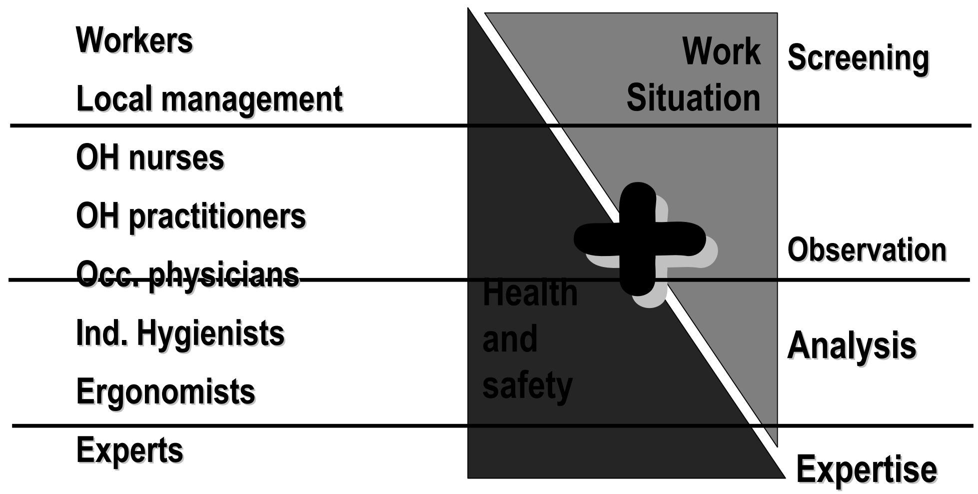
- Coordination of the actors
  - Artillery, Tanks, Infantry
  - Workers, OH practitioners, experts
- in time (in sequence)
- to reach the goal in the way
  - easier
  - faster
  - more economical

≠ method

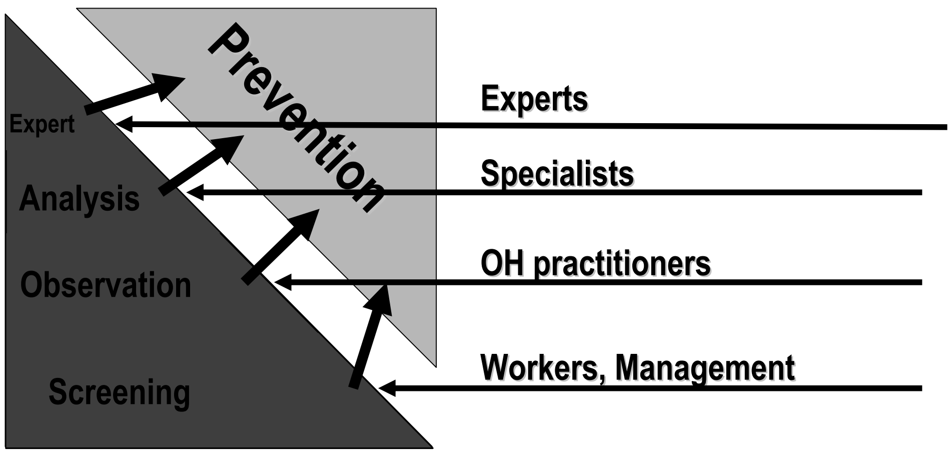
Management of public health



People involved

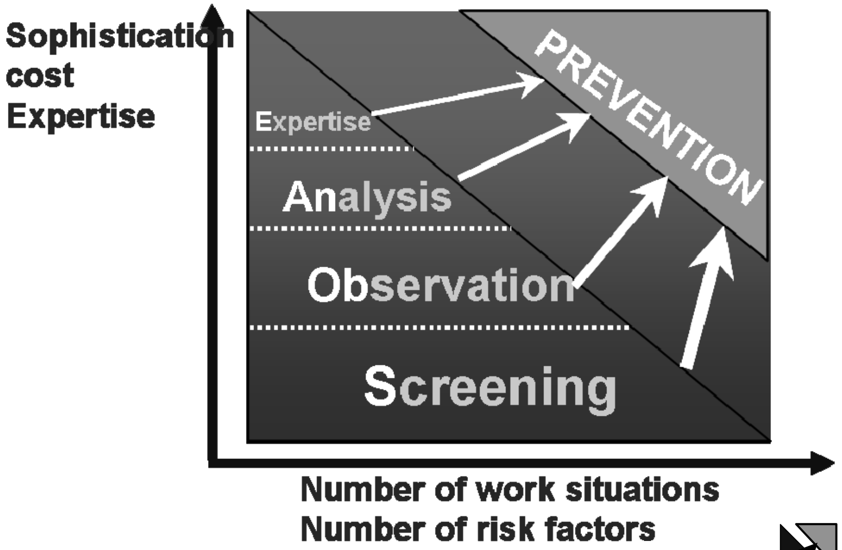


Management of occupational health



	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 Low	High Average	Average High	Low Specialised

Prevention Strategy SOBANE



Screening	Observ.	Analysis	Expertise
Areas			
Work organization	Work organization	Work organization	
Machines			
Safety			

Heat	Heat	Heat	
Chemicals	Chemicals	Chemicals	Chemicals

Work content	Work content		
Psycho environm.			

S C R E E N I N G

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

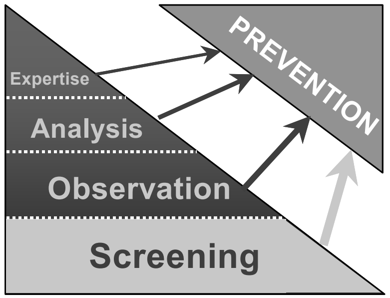
1. Information by the direction on the aims
   and commitment to take account of the results
2. Definition of a small group of workstations forming a unit,
   a " work situation" (10 to 15)
3. Designation of a coordinator
4. Adaptation of the tools to the work situation
5. Constitution of a working group (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

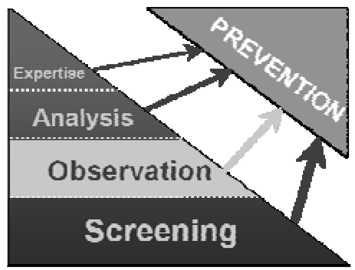
To be discussed	Who can do what in practice and when?
• **Temperature** Neither too warm nor too cold, no significant variations • **Humidity :** not too dry nor too humid • **No draughts:** by the windows and the doors • **Cold, heat and humidity sources** Removed: water, vapour, machines, sun... •**Clothing**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

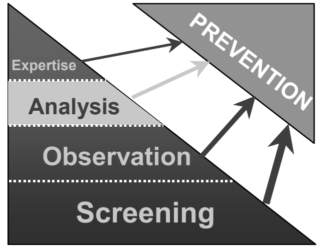
5. Measures to be taken in the short-term:
   - Hot or cold drinks; Recovery periods
   - Work organisation; Clothing….

N°	WHO?	WHAT?	WHEN?	
			Projected	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

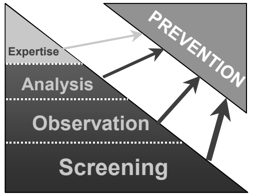
	Activity ...	Activity

3. Risk
• Class of risk
• If heat stress
  • Sweating rate
  • Water loss per day
  • 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*

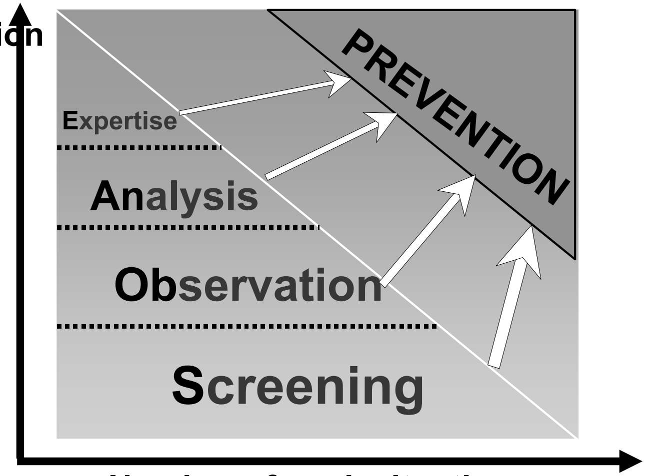
Stage 4: *Expertise*



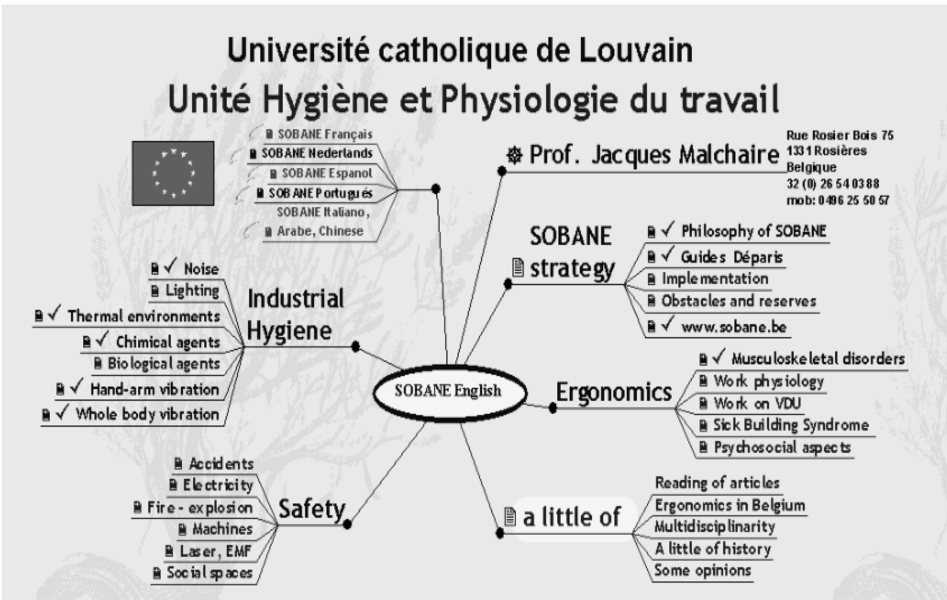
- **Better characterise some heat or cold sources and/or some unusual circumstances**
  - Specific measurements
  - Specific investigation techniques
- **Characterise the overall exposure of the workers**
- **Look for sophisticated prevention/control measures**

Prevention Strategy SOBANE

Sophistication
cost
Expertise



Number of work situations
Number of risk factors



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あなたの注意をありがとう

Thank you