Pergamon

PII: S0003-4878(99)00050-2

Ann. occup. Hyg., Vol. 43, No. 5, pp. 367–376, 1999

Printed in Great Britain.
0003–4878/99/$20.00 + 0.00

Strategy for Evaluation and Prevention of Risk Due to Work in Thermal Environments

J. MALCHAIRE*‡, H. J. GEBHARDT† and A. PIETTE*

**Catholic University of Louvain, Work and Physiology Unit, Clos Chapelle-aux-Champs* 3038, *B*-1200, *Brussels, Belgium*; †*Institute for Occupational Medicine, Safety Technology and Ergonomics, Corneliusstr*. 31, *D*-42329, *Wuppertal, Germany*

A strategy in four successive stages is described and justified for the prevention and control of thermal problems in the workplace. This should allow these problems to be approached and solved progressively in small as well as large companies by relying successively, when necessary, on the complementary competencies of the workers themselves, their technical assistance, the occupational health specialists and the experts. The criteria to fulfil at each stage are described and discussed. Appendix 1 describes in detail the methods to be used at stage 2, "*Observation*" by the workers and their assistance; at stage 3, "*Analysis*" with the help of specialists; and outlines the stage 4, "*Expertise*". © 1999 British Occupational Hygiene Society. Published by Elsevier Science Ltd. All rights reserved.

Keywords: thermal conditions; risk assessment; thermal indices; WGBT index; BIOMED programme

INTRODUCTION

Many papers have been published during the last 10 years questioning the validity of the method of analysis and interpretation of the thermal stress based on the Required Sweat Rate (ISO 7933, 1989). The criticisms concerned many different aspects, from the way the influence of clothing on evaporation exchanges was taken into account (Haslam and Parsons, 1987), to the physiologic limits used for the prediction of exposure duration limits (Kampmann and Piekarski, 1995).

Extensive research was started in 1996 in co-operation between 8 prominent expert institutions with the support of the European BIOMED Research Programme.

Significant improvements of the validity of the methods are expected. They will be discussed in future scientific papers. As an example, an algorithm was developed to take into consideration the interference between the direction of the displacement of the person and the direction of the air draught. Clearly, this will greatly increase the sophistication of the analysis and interpretation method and hopefully its validity. The question however is: is this sophistication needed? When? And by whom?

Received 15 January 1999; in final form 14 April 1999.
‡Author to whom correspondence should be addressed.

The comparison with the WBGT index which is used—or misused—in many working situations all over the world is striking. Obviously, it is unlikely that this index, trivially simple, can be a valid model of the physiological behaviour in hot climates and the reason for this "success" is this simplicity.

The comparison between the WBGT (ISO 7243, 1989) and ISO 7933 is often done in practice (Smolander *et al*., 1990). It actually does not really make much sense if the position defended by the ISO standard is adopted: the WBGT index would be the screening method and the analytical method would be ISO 7933, the method for analysis and interpretation, when the working conditions raise a thermal problem.

This position is however open to criticism for several reasons:

1. A screening method should offer a greater safety margin than the method used afterwards to verify whether there is indeed a problem. It should have a very high statistical sensitivity, to the detriment of the specificity (large number of false positives). It was shown that this is not the case for the WBGT and, at least, the present version of the analytical method (Gebhardt *et al*., 1999).
2. A screening method should be more general, more global, cheaper and faster to use. It is disputable that this is the case for the WBGT index since the specific measuring instruments are

rather expensive. One measurement takes at least 30 min and the problems of representativeness of the results, in time and in space, are, at least, the same as for the measurements made for the analytical method. The only advantage seems really to be that it does not require any calculation. This argument was decisive in the 1970s (a pocket calculator costs more than $100). It is hardly decisive in 1999 when computers are readily available.

3. The main purpose of occupational hygiene is not the analysis and interpretation of the risk for its own sake, but its prevention. Therefore, these methods must be used primarily in order to collect the information required for finding solutions, and to the extent that this information is indeed needed for identifying the most appropriate solutions. If the collected information does not lead to this identification, it is not an appropriate approach. It can be considered that this is the case for the "natural wet bulb temperature" which measures something hybrid, influenced by all climatic parameters (air temperature, humidity and velocity and radiation) and therefore does not permit a decision on what to do to reduce the most effectively the heat stress.

Based on these elements, it can be concluded that the WBGT index is not the ideal screening method.

A screening method however is needed. Indeed, the number of working situations with thermal problems remains high, particularly in southern countries and it would be utopian and not practical to study them all in details systematically. This would actually be useless since, in the majority of the cases, prevention measures can be found easily, based on simple and straightforward observations.

A strategy of analysis and interpretation of thermal working conditions was proposed by Malchaire and Mairiaux (1991). As the title indicated, this was still oriented mostly towards risk assessment instead of prevention, and it must therefore be adapted. It must also be revised, as, at the different steps of the analysis, a good understanding of the indices was required. This implicit prerequisite limited the application of the strategy to people specifically trained in this field and, probably, to working situations in fairly large companies where these people work or are employed as consultants.

Actually, statistics, for example for Germany (Hoffmann *et al.*, 1996), show that about 30% of the labour population are working in companies with less than 20 employees and more than 60% are working in companies with less than 200 employees. Accident rates (from all origins) are greater by approximately 33% in these companies compared to the accident rates in companies with 200 employees and more. It can be assumed that it is likely to be the same for the thermal problems. It is therefore essential to increase the likelihood of improvements of the working conditions in small and medium sized companies.

It is indeed true that hygienists are equipped with WBGT instruments and are using the WBGT index. However, the time needed for the measurements is rather long; the representativity of these measurements, made often at random in time, is often low and the expertise of hygienists is seldom available in SMEs. The first stage of any approach of the climatic conditions cannot therefore be realistically and systematically based on the use of the WBGT.

A strategy in four stages is described hereunder. Its ambition is to make it possible to initiate and conduct a policy of prevention in any company of any size or type, based on the expertise available inside and outside this company.

PHILOSOPHY OF THE STRATEGY

At the first stage, all, or the majority of the risk factors or "problems", have to be detected in order to get a first overview of the working conditions. A "*Screening*" method is therefore necessary. It must cover briefly the majority of the factors related to safety, health and well-being (psychosocial factors). The conclusions will be, in the context of this paper, whether there are complaints related to the climatic conditions, whether there might be "problems", and whether there is a need to investigate further.

The second stage consists of looking more closely at the climatic and working conditions over the entire year and/or in any circumstance and of searching for straightforward solutions. This "*Observation*" method has to be designed to identify the particular circumstances, the specific tasks, and the unusual working conditions where a "problem" exists and to determine what to do to reduce or eliminate this special "problem". Clearly this can only be done by or with the help of people who have a thorough knowledge of the working conditions: these are the workers themselves. Competencies in thermal physiology or measuring techniques would help. However, the method should not make these competencies indispensable. At the end of this second, "*Observation*", stage, the users should be able to decide whether the "problem" is satisfactorily controlled or not. If it is not, or if any doubt remains, the assistance of trained specialists is obviously needed.

The third stage will usually be conducted by (or preferably with the help of) occupational hygienists or persons with adequate training. It will be carried out for well-identified working conditions, where a heat stress problem remains after stage 2, "*Observation*". Therefore, it will deal with specific conditions and will usually involve measurements. Again, the objective is primarily to find technical solutions and, secondly, when exposure is unavoidable, to define organisational solutions and short-

Table 1. Characteristics of the 4 stages of the strategy

	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 (order of magnitude)	10 min	2 h	1 day	A few days
By whom?	Workers + management from the company	Workers + management from the company	Same + specialists	Same + specialists + experts
Knowledge				
Working conditions:	Very high	High	Average	Low
Ergonomics:	Low	Average	High	Specialised

term protection measures (such as drinks). At the end of this third stage, called "*Analysis*", most of the conditions should be under control. It might be, however, that in very special cases, due to unusual circumstances, an unacceptable risk of discomfort or heat stress remains.

The further assistance of an expert (stage 4) will then be required for studying these unusual circumstances, using very specific investigation techniques, such as plane radiant thermometry, clothing permeation or oxygen consumption measurements. This type of investigation, "*Expertise*", will obviously be very more costly, take longer time and require very sophisticated instrumentation and competencies.

Table 1 summarises the characteristics of the four stages of the strategy.

It is worth insisting on the fact that not all four stages are systematically performed. The procedure actually stops when adequate solutions have been implemented.

Many different methods have been proposed in the past for the first "*Screening*" stage. Examples are, in Germany, the AET (Rohmert and Landau, 1977) or the 7-point-evaluation-scale for stress factors (Müller and Hettinger, 1981), in France, the method used in the car industry (Anon., 1979; Guélaud *et al*., 1975), in Finland, the method developed by the Finnish Institute of Occupational Health (Ahonen *et al*., 1989). More recently, the European Commission (1995) published the "*Self Audit Handbook for SME*".

Although these methods aim to do much more than the screening method described above, clearly they can be used for this limited—and probably more realistic—purpose. The "*Screening*" method will therefore not be discussed in more detail.

CRITERIA FOR THE "OBSERVATION", "ANALYSIS" AND "EXPERTISE" METHODS

Work was started, inside the BIOMED research group, for the development of the materials to be used in practice, at each of the three last stages of the strategy.

A first method was developed based on the publication by Malchaire (1998). An attempt was made then to validate the second stage, the "*Observation*" method, near potential users in different types of industries and in different countries. 42 people in four countries agreed to use it candidly and gave their opinions. They were people trained in occupational health, primarily working in SMEs and confronted with climatic problems. They were invited to use the stage 2, "*Observation*" procedure in a small company of their choice and to return their "observation" to a BIOMED partner. Later, they were contacted by phone and ask a set of predetermined questions concerning usability, duration, understanding and relevancy.

The results showed that:

- the method has to be understood in < 30 min and the time to use it has to be shorter than 90 min;
- for a given workplace, it must deal, not with the working conditions in general over the entire year, but with a single specific circumstance. If necessary, it should then be repeated for different circumstances at the same workplace;
- it must be emphasised that prevention is the purpose of the operation and that the scoring scales are only means to derive solutions;
- suggestions must be made concerning the prevention measures;
- the information provided by this method is not always sufficient to demonstrate to the employer the need for investing in prevention measures.

Based on this information, the strategy was revised. It is described in Appendix 1.

The following criteria were used:

Stage 2: "*Observation*"

- it must be designed to be used by people from the company and, possibly, by the workers themselves;
- it has to be simple to understand by untrained people and, in particular, by the workers;
- it must not make reference to concepts or technical terms that are not readily understood by the general population;
- it should be easy to use, in a maximum of one hour for a specific circumstance of work;
- it must be based on simple observations;
- it should not require any measurement, since, inevitably, a measurement raises questions of representativeness;
- it must be oriented towards prevention, the reasons why the condition deviates from the optimum and the ways of correcting this;
- it must take advantage of what the users know best, that is their working conditions, the technical process, the characteristics of the heat or cold sources, the possibilities of control measures.

This method therefore acknowledges explicitly the competence and the skill of the workers and deliberately relies on them to improve the working conditions. It simply helps them to structure and systematise their approach, so that it is not solely based on perceptions and opinions.

Stage 3: "*Analysis*":

- the method must be designed to be used by occupational health specialists, that is, by occupational physicians, occupational hygienists, ergonomists, ... with a general training in the management of heat problems;
- it must still use concepts and techniques commonly used in the field, avoiding therefore more "scientific" considerations, such as evaporation efficiency, mean skin temperatures or intrinsic clothing insulation;
- if necessary for prevention, it can require measurements with instruments, cheap, easy to use, readily available in the field. Special measurement techniques, such as for the plane radiant temperature, the draught factor or the oxygen consumption, must be avoided.
- it should be possible to use it and make recommendations in less than 1 day, so that realistically, it can still be used rather systematically when a complicated problem exists;
- it must remain oriented towards prevention and therefore use measurements and indices that make possible to best identify the causes of the problems and the means to solve them.

Stage 4: "*Expertise*"

This stage will be needed in very complex cases for which satisfactory solutions could not be found even after a detailed "*Analysis*". The methodology to be used, the measurements to make, the evaluation to perform will vary depending upon the problem. In addition, this stage will be carried out with the help of experts who should be able to decide the best procedure to collect the information necessary to solve the problem.

Therefore, there does not exist one unique expertise method and none will be proposed here. Comments will be limited to the great lines of what this "*Expertise*" study should obviously include and report.

CONCLUSIONS

A strategy with four stages is proposed for the control of the working conditions with thermal problems. This strategy rests on two basic principles:

1. It is *participative*: the workers play the essential role in the dynamics of the improvement of the working conditions. Occupational health specialists and experts are there to help these workers to find the solutions.
2. It is *structured* in 4 stages which require complementary knowledge and competencies:
    - at the 2 first stages: knowledge of the company, of the workers themselves, of the working procedures, of the "normal" and "abnormal" conditions, ...;
    - at the "*Analysis*" stage: assistance of specialists with education and training about the general methodological aspects, the common measuring and evaluation techniques, the possible technical solutions;
    - at the "*Expertise*" stage, when it is absolutely necessary, assistance of highly trained experts who will bring their specific knowledge for the

identification of special solutions to particular problems.

It is then clear that the investigations are conducted with an increased degree of precision and with the participation of trained persons, to the extent that it is indeed necessary to bring about satisfactory control measures. Sophisticated indices and techniques are used when needed. The problems are neither transferred nor abandoned to nor taken over by "experts" and the whole process of searching for the solution is carried out in full partnership. It is usually considered that a "top down" approach gives better result: a trained specialist leads the analysis and brings to the people in the field the information needed at each stage. The strategy presented in this paper allows this. Indeed, in a large company, it is expected that such a specialist is available and will initiate and monitor the process. The strategy does not exclude this. However, it does not rely on it. It seems indeed utopian to base any intervention study in the field (on this matter as well as on any), on the availability of a trained specialist. The procedure wants therefore to be realistic and pragmatic. It is hoped that this bottom-up approach will make possible, at least, some improvement of the working conditions in some of the SMEs.

REFERENCES

Ahonen, M., Launis, M. and Kuorinka, T. (1989) *Ergonomics workplace analysis*, Ergonomics Section Finnish Institute of Occupational Health, Helsinki, Finland.

Anon (1979) *Les profils de poste, méthode d'analyse des conditions de travail.* Masson, Paris.

European, Commission (1995) *Self audit handbook for SME.* Office for Official Publications of the European Communities, Luxembourg.

Gebhardt, H., Kampmann, B. and Mueller, B. (1999) *Systematische Analyse aktueller Klimasummenmasse fuer Hitzearbeitsplaetze, Schriftenreihe der Bundesanstalt fuer Arbeitsschutz und Arbeitsmedizin, Wirtschaftsverlag NW*, (in press).

Guélaud, F., Beauchesne, M. N., Gautrat, J. and Roustang, G. (1975) *Pour une analyse des conditions de travail ouvrier dans l'entreprise*. Armand Colin, Aix en Provence, France.

Haslam, R. A. and Parsons, K. C. (1987) A comparison of models for predicting human response to hot and cold environments. *Ergonomics* **30**, 1599–1614.

Hoffmann, B., Butz, M., Coenen, W. and Waldeck, D. (1996) *Health and Safety at Work: System and Statistics, Hauptverband der gewerblichen Berufsgenossenschaften.* Public Relations Department, Sankt Augustin, Germany.

ISO 7933 1989 Hot environments—analytical determination and interpretation of thermal stress using calculation of required sweat rates.

ISO 7243 1989 Hot environments—estimation of the heat stress on working man based on the WBGT-index.

Kampmann, B. and Piekarski, C. (1995) Bewertung klimabelasteter Arbeitsplätze. *Sichere Arbeit* **1**, 14–21.

Malchaire, J. (1998) *Stratégie d'évaluation et de prévention des risques liés aux ambiances de travail.* Ministère de l'Emploi et du Travail, Commissariat général à la promotion du travail, Bruxelles.

Malchaire, J. and Mairiaux, P. (1991) Strategy of analysis and interpretation of thermal working conditions. *Annals of Occupational Hygiene* **35**, 261–272.

Müller, B. H. and Hettinger, T. (1981) Interpretations- und Bewertungsverfahren arbeitswissenschaftlich-ergonomischer Felddaten. *Z. Arb. wiss.* **35**, 82.

Rohmert, W. and Landau, K. (1977) *Benutzerfreundliche Weiterentwicklung des arbeitswissenschaftlichen Erhebungsverfahrens zur Tätigkeitsanalyse (AET)*, Bundesminister für Sozialordnung (Hrsg.), Bonn.

Smolander, J., Ilmarinen, R. and Korhonen, O. (1990) An evaluation of heat stress indices (ISO 7243, ISO/DIS 7933) in the prediction of heat strain in unacclimated men. *Int. Arch. Occup. Environ. Health* **63**, 39–41.

APPENDIX

Stages 2–4 of the Strategy for Control of the Risk of Thermal Stress or Discomfort

Stage 2 "Observation".

OBJECTIVES

The objectives of this stage are:

- to collect information about the work situation, in general, concerning the working conditions, the climatic conditions and the heat or cold sources;
- to define the straightforward technical measures that can be directly implemented to prevent/control the risk;
- to determine whether a more thorough "Analysis" is necessary.

PROCEDURE

(1) Describe the working condition which is known to or which is likely to raise a thermal problem. This is, for instance, "workshop A in the morning during the winter", or "when cleaning the oven, in any season"...

Work place :............................CONDITION..................................
Description (work, climate,...): ....

(2) Evaluate the situation for each of the six parameters SEPARATELY, using the scales described in Table A1. Report also the average opinion of the workers. Remember that the main point of the procedure is not the score in itself, but the analysis of the reasons for that score and the determination of how to improve it.

(3) Report the results in the Table A2

Table A1. Scoring scales for the "*Observation*" method

Score	Condition
	AIR TEMPERATURE
−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
	HUMIDITY
−1	Dry throat/eyes after 2–3 h
0	Normal
1	Moist skin
2	Skin completely wet
	THERMAL RADIATION
−1	Cold on the face after 2–3 min
0	No radiation discernible
1	Warm on the face after 2–3 min
2	Unbearable on the face after more than 2 min
3	Immediate burning sensation
	AIR MOVEMENTS
−2	Cold strong air movements
−1	Cold light air movements
0	No air movements
1	Warm light air movements
2	Warm strong air movements
	WORK LOAD
0	Office work: easy low muscular constraints, occasional movements at normal speed
1	Moderate work with arms or legs: use of heavy machines steadily walking
2	Intense work with arms and trunk: handling of heavy objects shovelling, wood cutting, walking rapidly or while carrying a heavy load
3	Very intense work at high speed: stairs, ladders
	CLOTHING
0	Light, flexible, not interfering with the work
1	Long, heavier, interfering slightly with the work
2	Clumsy, heavy, special for radiation, humidity or cold temperatures
3	Special overalls with gloves, hoods, shoes
	OPINION OF THE WORKERS
−3	Shivering, strong discomfort for the whole body
−2	Strong local discomfort; overall sensation of coolness
−1	Slight local cool discomfort
0	No discomfort
1	Slight sweating and discomfort; thirst
2	Heavy sweating, strong thirst, work pace modified
3	Excessive sweating, very tiring work, special clothing

(4) If the situation is not ideal (scores outside −1 to 1), identify the reason for this and describe the importance of the problem (sources, surfaces, location...). The scales above are designed so that the optimum situation is zero in each case. When one or several parameters deviate from this optimum, prevention measures should be taken, and, the greater the deviation, the higher the need for solutions.

Causes of the problem	**Prevention measures to implement**

(5) If the industrial process does not strictly impose the thermal parameters, look for ways to improve the situation, considering the examples of prevention measures given in Table A3.

Table A2. Table of scores for the present situation

	–3	–2	–1	0	1	2	3
Air temperature							
Humidity							
Thermal radiation							
Air movements							
Work load							
Clothing							
Opinions of the workers							

(6) Determine, if necessary, the measures to be taken in the short-term: hot or cold drinks, recovery periods, work organisation, clothing.... Short-term measures should remain temporary measures. They indicate the need for a further "*Analysis*" to solve technically the problem.

(7) Estimate what the scores might be if the situation was improved as envisaged. Judge, on the scales described in Table A1, the condition in the future, taking into account the prevention/control measures. When this prediction of the future situation is difficult to do or does not appear to be reliable, this indicates the need for a further "*Analysis*" to estimate the residual risk and identify the additional control measures.

(8) Report these scores on Table A4

(9) Decide whether a more detailed "*Analysis*" is needed to quantify and to solve the problem. For this, consider the number of scores outside the range from −1 to 1 for the anticipated situation in the future.

At the end of the "*Observation*", the user must determine whether, for this working situation, a more thorough "*Analysis*" is necessary.

Stage 3: "Analysis".

Table A3. Examples of prevention measures

AIR TEMPERATURE

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

Eliminate the leaks of vapour and water
Enclose the surfaces cooled with water or any evaporating surface
Use clothes waterproof but permeable to vapour

THERMAL RADIATION

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 MOVEMENTS

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

WORK LOAD

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

CLOTHING

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

Table A4. Table of scores for the anticipated situation

	–3	–2	–1	0	1	2	3
Air temperature							
Humidity							
Thermal radiation							
Air movements							
Work load							
Clothing							

Table A5. Evaluation of the working conditions for each activity

Activity	Duration		Exposed workers	Factors to quantify
	Mean	Maximum		

OBJECTIVES

For the conditions selected during stage 2: "*Observation*", the objectives of stage 3: "*Analysis*" are:

- to quantify the risk of thermal discomfort or constraint as a function of the minimum and maximum values of the climatic parameters;
- to determine the optimum work organisation;
- to determine whether an "*Expertise*" (Stage 4) is needed;
- to justify to the employer the cost of prevention measures identified in stage 2, if this appears needed.

PROCEDURE

(1) Analyse the sequence of activities at the work place:

- description of the activities;
- mean and maximum durations;
- period concerned by the working situation;
- exposed workers;
- factors to quantify accurately;
- air temperature: if abnormal increase or decrease;
- humidity: if different from outside;
- radiation: if exposure to sun or to very hot or cold surfaces;
- air velocity: if air draught;
- workload: if high or unknown;
- clothing characteristics: if special clothing.

The information should be reported in a form similar to Table A5.

(2) Evaluate the working situation:

- during this period, representative day(s) concerning the climatic and working conditions;
- outside climatic conditions: temperatures, humidity, sun exposure, rain…;
- measurement or estimation of the mean and maximum values during the representative day(s);
- computation of the indices (PMV/PPD, WBGT and PHS[1]).

The information should be reported in a form similar to Table A6.

[1]As an outcome of the research started in 1996 an analytical model for Predicted Heat Strain (PHS) will be presented, predicting the average mean body temperature and the average sweat rate as a basis for the determination of a exposure duration limit (DLE).

Table A6. Summary of information concerning the sequence of activities to analyse

	Activity ...		Activity ...	
	Mean	Max	Mean	Max
t_a RH t_g V_a M clo				
PMV PPD WBGT PHS/DLE				

(3) Assess the risk in the present situation using the following scale:

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**

In the last 3 cases, the following information must be derived:

- prediction of the mean water loss over the 8-h day;
- prediction of the risk of increase of the internal temperature of the body;

(4) Determine the acceptability of this working condition by comparing the mean and maximum duration of each activity to the limit exposure durations.

(5) Define prevention/control techniques for each parameter as well as the optimum work organisation.
(6) Determine the residual risk after implementation of these prevention/control measures, using the criteria of point 3 above. The acceptability can be determined by comparing the DLE predicted for each activity with the actual work duration.
(7) Decide whether there is a need for a Stage 4: "*Expertise*".
(8) Define the protection measures in the short term.
(9) Define the requirements for medical surveillance.
The results of the "*Analysis*" can be summarised in a form similar to Table A7.

Stage 4: "Expertise".
OBJECTIVES
The objectives at this stage are

- to better characterise some heat or cold sources and/or some thermal phenomena in the working environment by means of specific measurements;
- to characterise the overall exposure of the workers and look for special prevention/control measures to be implemented through a more refined analysis of the activities and the climatic parameters.

PROCEDURE

1. Determine conditions to study in great details and representative days
2. Assess the risk in the present situation:
   - for each sequence of activities, collect data concerning: duration, air temperature, humidity, radiation, air velocity, metabolic rate, clothing insulation, in the average and extreme conditions;
   - assess the risk per activity and globally using the thermal indices;
   - PMV-PPD for comfortable and discomfortable situations;
   - Predicted Heat Strain (PHS) for conditions with heat constraint.
3. Define prevention/control measures
4. search for modifications to be brought to each parameter, to the whole set of parameters, and/or to the work organisation (rest phases, etc.);
5. if required, perform detailed and specialised analyses of each heat or cold sources.

Assess the residual risk after implementation of the prevention/control measures.
Determine the personal protection measures.
Define the requirement for medical surveillance.

Table A7. Risk assessment and control measures for each activity

	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 • Class of risk • Acceptability		
7. NEED FOR AN EXPERTISE		
8. SHORT TERM MEASURES		
9. MEDICAL SURVEILLANCE		