

Community Ergonomics Action

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Working Document

ERGONOMICS DESIGN - THE CONDITIONS FOR ITS IMPLEMENTATION AND ITS CONTRIBUTION TO ACCIDENT PREVENTION
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Source : Prof. C.P. ODESCALCHI, Adviser to the Community Ergonomics Action

Author : Prof. C.P. ODESCALCHI and Coll. (Arch. L. BANDINI BUTI, Dr G. CORTILI,
Dr E. MORETTI)

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Presentation

As soon as the Commission began to take an interest in ergonomics methods of work organization - an interest which was subsequently to enable it to actively approach problems of prevention and adaptation - it became aware of the decisive role of worker participation for the success of any ergonomics action.

A workplace or tool cannot in fact be properly adapted to practical requirements without consulting the user.

It soon became apparent that three conditions must be met if worker participation is to be secured :

- 1) The union organizations must take an interest in problems of work adaptation.
- 2) Means must be available to give workers suitable training.
- 3) All practical action must be backed by objective and ongoing information of all the parties concerned (employers, workers, technicians) on risks present at the workplaces, on environmental factors and on their effects.

Closer examination of the latter problem appeared desirable in the light of the special conditions now obtaining in Italy where a number of practical means of information have been introduced at the initiative of the union organizations, on the basis of recent, innovative legislation.

The experience gained in this way, which is summarized by Professor ODESCALCHI in the following study, may well play an important role in the future of prevention in Europe.

Dr. U. VIDALI
Director

Luxembourg, March 1976

CONTENTS

	<u>page</u>
1. <u>INTRODUCTION</u>	1
1.1 Accident prevention and health protection in industry	1
1.2 Factors influencing the workload	3
1.3 The working environment in Italy	5
2. <u>ERGONOMICS</u>	9
3. <u>ERGONOMICS ACTION</u>	17
3.1 The cost of not taking ergonomics action	17
3.2 Conceptual and corrective action	17
3.3 The industrial reality must be treated as a dynamic entity	18
3.4 Resistance	18
4. <u>INSTRUMENTS OF ERGONOMICS ACTION</u>	21
4.1 Preparatory analysis	22
4.2 Ergonomics training course for engineers and workers	22
4.3 Register of environmental data	24
4.4 Health and risk register	25
4.5 Register of biostatistical data	26
4.6 Regular meetings	27
4.7 Cooperative designing	28
5. <u>CONCLUSIONS</u>	31

1. INTRODUCTION

1.1 Accident prevention and health protection in industry

The post-war years have been characterized by increasingly rapid industrial development, in particular:

- the tendency to achieve increasingly high levels of productivity both in the sectors already developed on an industrial scale and by applying industrial techniques to craft or semi-industrial sectors. This trend has been based on the "organization of work" described by TAYLOR, BARNES, GILBRETH etc.;
- programming which has failed to take coherent account of the human factors in work;
- sporadic and isolated measures to influence human factors, in small, medium and large plants, through the work of individual industrialists or local trade unions;
- extremely rapid technological development which has not been accompanied by the growth of techniques designed to improve the mental and physical well-being of man and enable the individual to achieve fulfilment in his work.

All these factors have resulted in a growing movement of opposition among workers, who feel themselves more and more oppressed by the civilization of machines and the system of work organization.

The transition from craft work to industrial operations has finally given the lie to the hypothesis that work can be self-regulating.

In craft activities a single individual who is responsible for all the phases of the process is able to regulate his own work, maintaining it at levels of overall acceptability and having regard to motivation; in industry, the increasingly sharp division between

different tasks prevents those people who have decision-making and planning powers from knowing and remembering, when work is planned and organized, the reality of the shop floor which they do not experience directly.

The results are now becoming increasingly apparent in a society which has been guided (and is still guided) solely by considerations of productivity, without regard to human limitations in respect of the mental and physical aspects of work and the content of work itself.

Statistics compiled in recent years also show a continual growth in industrial accidents and occupational diseases, despite the creation of health care structures in the company and at State level.

The characteristics of occupational diseases, understood in the traditional sense as being linked to specific causal factors, have deteriorated greatly now that the modern form of work organization has been shown to be a direct cause of severe stress on the worker.

A new form of pathology has grown up in parallel with the technological development of the industrial world, due to the characteristics of work organization: there is now a vast incidence of industrial neurosis.

To the direct and indirect cost of these phenomena to society as a whole must be added the "postponed social costs" due to the presence of a great body of workers who, instead of producing for society, represent a considerable burden on it because of their partial or total handicap.

To this specific situation of the working environment is added the aggression of environmental pollution present in the main industrial centres which tends to aggravate the overall condition of the individual and is added to the forms of aggression experienced during work.

1.2 Factors influencing the workload

The workload is defined by:

- the physical and chemical characteristics of the environment: thermal environment or micro-climate (temperature, humidity, air speed and flow of radiant heat), noise levels, type and degree of pollution (gas, vapours, fumes and dust), vibration, ionizing radiation;
- neuro-muscular activity and the man-machine relationship in its anthropometric, functional and psycho-physiological implications;
- the working rhythms and shifts;
- the possibility of accidents.

Each individual worker may be continuously or regularly exposed to many adverse and toxic factors such as:

- contact between body surfaces and liquid or solid pollutants;
- contamination of the air (by gas, vapours, fumes, dust);
- the presence of ionizing radiation;
- thermal loads well above the average capacity of physiological adaptation and close to the toleration limits;
- noise levels which may damage the organism; vibrations; jolting; abnormal conditions of air pressure and composition; lighting which is not appropriate to the requirements and efficiency of the task being performed;
- intense working rates and shifts in an organizational system which is authoritarian and provides no motivation;
- risks linked with technical safety (fire, explosions, electrical discharges, high energy sources, falling weights, collision with moving bodies), due either to the lack or inadequacy of the protection and safety systems or to the influence of the working environment on the worker's response.

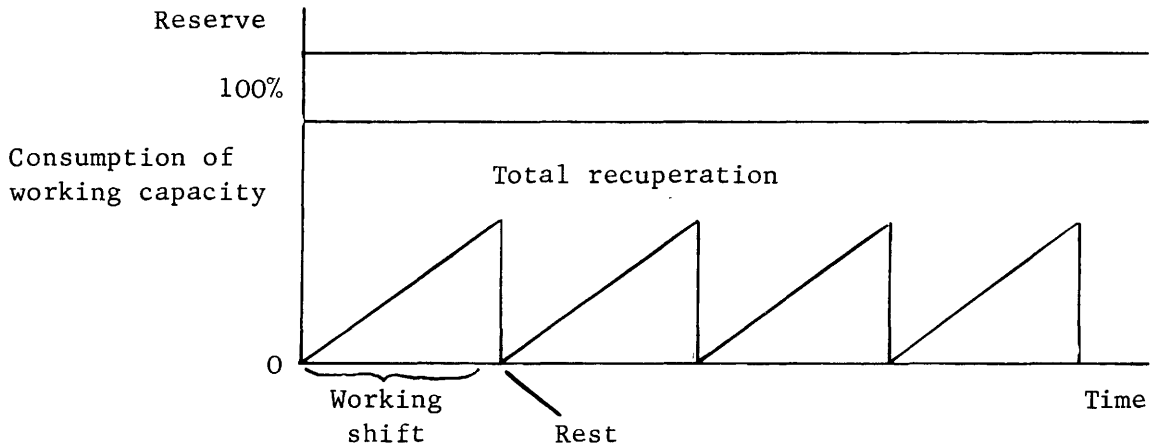
To these factors must be added sources of stress away from work (commuting, lack of social infrastructures etc.) which also condition, through varying degrees of deterioration, the response of the human organism to a particular working environment.

These factors do not generally act in isolation but are for the most part linked, with the result that they may cause damage to health even when, taken individually, their effect is not harmful.

Interaction between these factors also often has a cumulative effect making the total influence still worse.

The consequences of the aggression to which the worker is exposed in his industrial environment cannot always be cancelled out or compensated for during the periods spent away from the working environment.

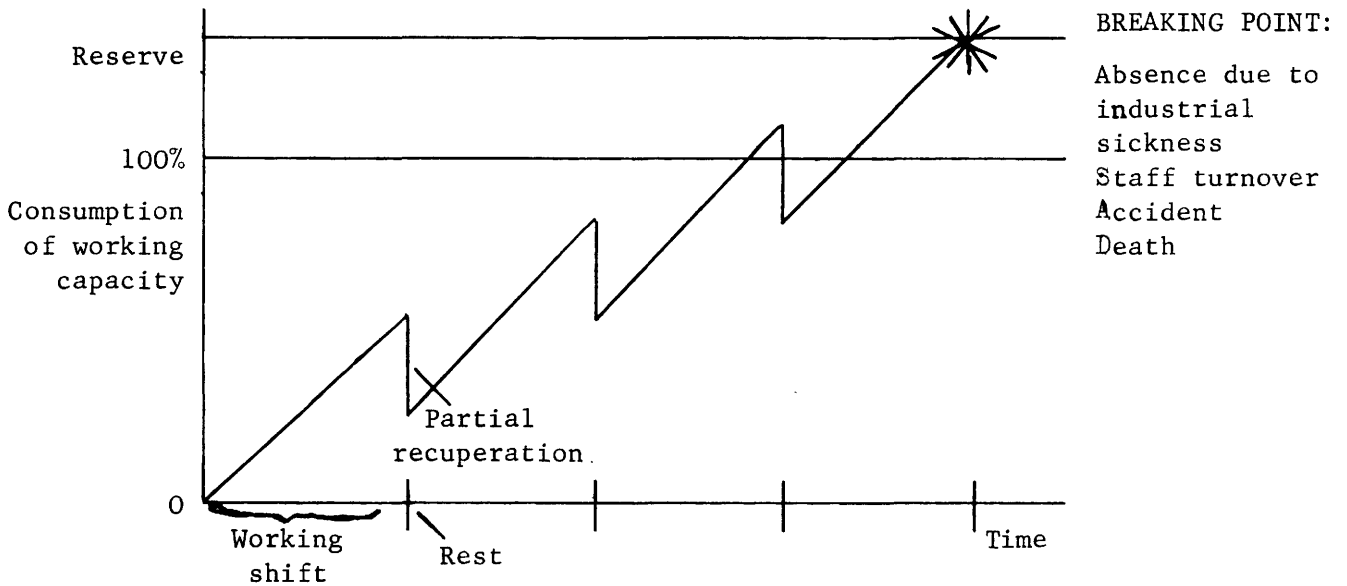
The process of compensation between periods at work and periods away from work, when there is total recuperation, may be outlined as follows:



The situation shown in the above graph is the most acceptable: the effects of stress are totally compensated for and the reserve is not encroached on.

This situation is becoming increasingly rare today: the stresses experienced during work and away from work are difficult to compensate for during periods of rest.

Man recuperates only partially and is often obliged to encroach on his reserve working capacity until a breaking point is reached.



For example, an industrial worker may be exposed during his working shift to the action of pollutants present in the environment in concentrations which, on the basis of our present knowledge, should not cause harm to the organism.

But the negative effects of the substances may be cumulative, in a manner which is not properly understood at present, with those of substances absorbed away from the working environment.

Similarly there is a cumulative effect of psychological stress at the workplace and away from work.

1.3 The working environment in Italy

Since 1967-1968, the working classes have become keenly aware of the need to break away from the principle of "risk payments" according to which

workers exposed to higher risks were paid more, the corresponding payment being classified as danger money.

With the slogan "Health cannot be bought" the workers' unions asserted in 1969 the absolute priority of man over production requirements. This involved a review of the relationship between science and work organization which showed the shortcomings and mistakes of the past and the compromises accepted up to then by almost all the engineers and official scientific bodies.

The criticism - certainly not neutral - of this attitude on the part of scientists, led the trade unions to formulate a number of principles:

- "No delegation", i.e. a refusal to make the industrialist or his representatives responsible for assessing and verifying the effects of work on man. "No delegation"* means not giving the employer and his representatives responsibility for ascertaining the harmful effects of work on man; no delegation means an uninterrupted process of acquiring knowledge of the environmental reality and verification of the effectiveness of the instruments which ensure maintenance of the highest level of health; no delegation means an uninterrupted process of acquisition of knowledge to control and regulate environmental conditions led by the groups of workers concerned in a particular production process with the cooperation of the Internal Committees, the Joint Committees on Toxic Influences, the Prevention Committees of the Safety Representatives and the Union Section in the enterprise; no delegation means that the group of workers involved in a production process must deal with the problem of controlling toxic influences in its own working environment as the chief protagonist in a continuous struggle in which no one can take its place if the aim is to produce a working environment geared totally to the human being, the only way of effectively guaranteeing the complete elimination of harmful influences".

* Oddone = Rassegna di medicina dei laboratori, No. 3 - 1969

- "Validation by general consensus", i.e. control by workers of their own working conditions.

A production system or technological change can only be accepted after subjective validation by the workers that their working conditions conform to human requirements.

- The formation of a "homogeneous group": the group of workers involved in a particular production process faces the problem of control of its own workplace and working environment as the protagonist in a permanent negotiation on the creation of a working environment and workplace which are acceptable from every point of view.

From the legislative angle, the Italian workers' statute (Law 300, 1970) states, in article 9, that "the workers, through their representatives, shall be entitled to validate the application of the norms for the prevention of accidents and occupational diseases and to promote research, development and implementation of all measures likely to safeguard their health and physical well-being".

The text of this law contains one element of key importance in that it confers on the workers themselves the task of "promoting research, development and implementation of all measures likely to safeguard their health and physical well-being".

All the preconditions therefore exist for resolute action to modify the workplace and working environment in order to adapt them properly to man.

The complexity, variety and interdependence of the problems relating to the environment and workplace and their links with life away from the place of work therefore make it impossible for individual experts to conduct analyses and seek solutions on their own.

The sole alternative is to use groups of workers from all the groups concerned.

Hence ergonomics or, better still, ergonomics design is able to make a contribution.

2. ERGONOMICS

In 1949, in the office of K.F. MURRELL at the British Admiralty, a meeting was held of experts from various sciences (doctors, engineers, physicists, psychologists, physiologists, biologists) who, during the last World War and in the immediate post-war years, had devoted their efforts as a group to the achievement of environmental conditions and workplaces adapted to the requirements of the human organism.

During this meeting it was decided to place their activities on a formal basis and set up a scientific society as an association for all those persons interested in the problem of adapting working conditions to man.

A new term was coined to define these inter-disciplinary activities: ergonomics, the explicit aim being not to accept the dominance of any of the traditional disciplines which might help to achieve the objectives of this new line of research.

The inter-disciplinary and above all conceptual nature of ergonomics is clearly reflected by McCORMICK in his definition "to design work, dwellings and organization in human terms".

At present the most representative national societies are the HFS (Human Factors Society) in America, the ERS (Ergonomics Research Society) in Britain and the SELF (Société d'Ergonomie de Langue Française) with representatives from France, Belgium, Luxembourg and parts of Switzerland.

The SIE (Società Italiana di Ergonomia) was founded in 1961. The IEA (International Ergonomics Association) was also set up in 1961 as an umbrella organization for all the national associations. In recent years

with the membership of ergonomics organizations from the peoples' republics in the East and with the entry of other countries such as Canada and Australia, the IEA has achieved an important status reflecting the interest which all countries show in the possibilities afforded by ergonomics.

The European Community has for some time been supporting ergonomics activities by financing, through the Directorate-General for Social Affairs, research into the improvement of working conditions in the iron and steel and mining sector.

However, in almost all situations, this geographical and quantitative development has not been accompanied by an effective commitment to improve working conditions.

This shows that the solution to the problems of the workplace and working environment is not a purely technical one but must involve important political and economic choices.

Moreover, in the evolution and development of ergonomics, little attention has been given to inter-disciplinary design and planning; on the contrary there has been sectional progress in the various disciplines concerned with the study of man. Finally, work has concentrated on stepping up productivity and on the provision of war materials.

Ergonomics was born as a valid, human scientific alternative to Taylorism and Fordism; it then became a more subtle and rational means of exploiting human resources and, in view of the needs of military and paramilitary bodies, was also used for the design and production of instruments of destruction, demonstrating once again that the concept of the neutrality of science has no basis.

The finest results of ergonomics have been achieved in space flights which reflect the realization of a satisfactory relationship between man and machine under altogether special conditions. These are peaceful applications (at least for the present) which, while on the one hand demonstrating

how much can be achieved through the use of science and technology, also demonstrate the enormous disparity between the efforts brought to bear to solve these quite special problems and the efforts used to modify the daily reality of the working environment.

While our knowledge is far from complete, there can be no doubt that a great many concepts established for some considerable time, in some cases through studies which have purposes other than ergonomics, are not yet being used to adapt production techniques to man and very often our factories not only lack the basic conditions of well-being but also the fundamental requirements for safety and health protection.

The ergonomics design of systems, environments and machines must be focused on man as a physical, psychological and social entity. There is thus a great difference from the ordinary designer who at best tends to consider man as a stereo-type, and in the great majority of cases forgets him altogether. These considerations clearly show the significance of ergonomics in relation to other disciplines such as industrial physiology and psychology.

While the latter study, or should study, the behaviour of the physiological and psychological parameters of the worker in the performance of his real tasks, ergonomics should, working on the basis of this data, introduce the human factor into design activities.

Productivity and utilization, which are the basic factors in the design problem, must be measured against human requirements.

By introducing a correlation between the requirements of man and those of production, our scale of priorities places first the requirements of the persons involved in or benefiting from the production process.

In other words, while it is meaningless to speak of an enterprise which perfectly meets all human requirements but is not able to produce competitively in its particular market, we must equally reject an environment or workplace which subject certain categories of persons or individual workers to unacceptable strains.

The very fact of belonging to the productive cycle necessarily reduces the area of freedom of workers, but this limitation must be situated within the optimal limits of the psycho-physiological and social adaptation of man.

An environment or workplace must not be judged solely in terms of protection against adverse conditions but should be considered valid to the extent that it allows the highest level of well-being and the best conditions for the worker to develop his personality.

At the same time the practice of selecting individuals able to withstand the aggression of a particular environment must cease. Selection may be used as a temporary expedient in emergency situations which must then be remedied.

The first experiments conducted in Italy have shown worker participation, an inter-disciplinary approach between the various techniques, and an overall definition of aims and targets, as the three basic and necessary characteristics of ergonomics methodology.

If design work is to be effectively adapted to man, we must be able to assess the latter both in his objective aspects and with regard to his feelings and subjective beliefs, but it is above all necessary to provide the people affected by design work with the practical means of validating the results and a real possibility of opposing mistakes due to wrong technological choices or specific speculative situations.

The technical aspect of worker participation is represented by experience based on objective and subjective knowledge of the workplace and working environment. Experience acquired during studies in the factory and through meetings with homogeneous groups has often led to the conclusion that there are two ways of looking at work and two ways of viewing the same productive process in a particular factory: the view of the factory management and the view put forward, with a great many highly relevant details, by the workers themselves (fig. 1).

The first view is almost always extraneous to work and simply illustrates the various phases of the process through which the product is advanced and completed.

It provides little information on the physiological and psychological behaviour of workers during their working activities as it centres on the technological aspects of the problem, which are of course necessary in ergonomics studies and applications.

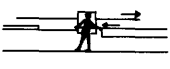

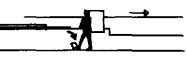
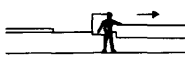

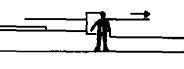
The second view on the contrary approaches work from the inside having regard to all the biological effects and with reference to all the different possibilities presented by the micro-climate, the working speeds, working positions, safety conditions etc.

Thus we have a comprehensive and global method of assessing and evaluating the compatibility of work.

Worker participation also enables us to consider the problem of the criteria used for assessing the physical comfort of the working environment.

In fact, the maximum levels of noise and environmental heat conditions which are dangerous to the human organism may be defined numerically, in a rough approximation, by setting limits above which physical damage occurs rapidly.

Fig. 1

						
DESCRIPTION OF ACTIVITY	<ul style="list-style-type: none"> - takes tube from table - introduces tube brush - introduces tube in gripper with tightened clamp - rests tube on pinch roll 	<ul style="list-style-type: none"> - starts pinch roll with pedal actuated by left foot 	<ul style="list-style-type: none"> - closes pinch roll by actuating pedal with left foot - removes tube brush - places tube on front bench 	<ul style="list-style-type: none"> - The tube is released from the carriage. - Checks fall of drawn tubes. 	<ul style="list-style-type: none"> - Opens and closes lever below tube brush chamber to actuate and stop 2nd pinch roll (1) - Actuates spot-welding pedal with left foot (2) - Actuates pedal to start fan and return carriage with left foot (3) - Actuates push-button to advance grippers (4) 	<ul style="list-style-type: none"> - The tube is introduced into the drawing unit (automatic) - Make sure that the carriage is actuated - Beginning of drawing operation
SUBJECTIVE ANALYSIS	<ul style="list-style-type: none"> - Raising the tube and placing it on the pinch roll involves an intense effort in a bent posture especially if the material arrives from the furnace for first passage. In this case the tubes are superimposed in a bundle and the frictional force does not allow normal spinning; the tubes must first be rotated on rubber lined supports and then drawn. 	<ul style="list-style-type: none"> - During the clamping operation the tube must be held by hand to ensure that it does not escape from the pinch roll rollers. - In the case of heat-treated tubes there is a risk that when a tube is tightened the frictional force will cause a second tube to drop down against the operator. - The lower roller of the pinch roll is bound with twine to increase friction and the speed of tightening as well as to absorb oil. This ensures that the tube is tightened before the carriage is released. 	<ul style="list-style-type: none"> - The pinch roll must stop instantaneously, otherwise the tube will be sent forward well ahead of the spot welder. In this case it must be brought back by the second pinch roll if it is operating, or pulled by hand. - If the tube is stopped by hand there is a risk of the hand being jammed in the pinch roll rollers. - Often, however, the operator cannot use gloves as they would reduce the sensitivity and mobility of his hands. 	<ul style="list-style-type: none"> - At the end of the drawing operation the tubes are held with the arm so that they are all lined up for the next pass and to make sure that they have been released from the carriage. - When working with large tubes, at the end of the drawing operation the tube will not fall onto the lower bench. It must then be knocked down. 	<ul style="list-style-type: none"> - During the operation tubes may strike the lower roller of the 2nd pinch roll and render it unserviceable; the tubes must then be introduced into the drawing units by hand. - When the end of the tube is being worked it must be held in the correct position, especially if this operation has to be repeated because the first was not a success. 	<ul style="list-style-type: none"> - During the drawing operation the tube may be released. If the carriage is close to the operator he will clamp it in position again with a compressed air torch. If on the other hand the carriage is near the middle of the bench a second person will have to be called; this may be the foreman or the operator of the next bench who takes care of the refining. In this case the compressed air torches mounted on each saw unit are used.
ERGONOMICS ANALYSIS	<ul style="list-style-type: none"> - The tubes are taken at a height varying between 80 and 150 cm above floor level for the upper line and a height of 45 to 75 cm in the case of the lower line. They are moved through 1.50 m and rested on the pinch roll at a height of 1.00 m. The lengths of the tubes during the different passes are 18/23/32 m and their weight is approx. 40/45 kg. On the first pass the worker raises about 1/3 of the length of the tube to place it on the pinch roll. 	<ul style="list-style-type: none"> - When the tube is tightened the operator has to check it by hand and is exposed to vibrations (at low frequency). 	<ul style="list-style-type: none"> - The pinch roll has no protection for hands. Some simply have a cap to prevent the oil on the tube from splashing onto the operator's face. - There is a risk of dermatitis caused by oil and aggravated by skin lesions when the skin is degreased with trilene. 	<ul style="list-style-type: none"> - Checking the fall of the tubes causes severe traction on the operator's arm. 	<ul style="list-style-type: none"> - If the tube did not fall from the bench during the carriage return travel, it will drop against the operator or anyone walking next to the bench. The carriage itself may also strike fans which are not completely open. 	<ul style="list-style-type: none"> - The carriage may release the tube because the head is not correctly worked, because the chain fixing hook is worn or because the drive motor stops when a relay is tripped.

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This figure shows part of the job analysis for a worker operating a copper tube drawing machine. At the top of the table an objective description is given of the sequence of operations, as shown by an analysis of the successive phases. The subjective evaluation of the work is also shown on the basis of data given by the workers themselves; together with the other objective data collected by the ergonomist, this provides the most important elements on which action to improve working conditions must be based. This results in an improved subjective assessment of the task, both because the workload is reduced and because genuine participation of the workers is obtained in the management and improvement of their own workplace.

If on the other hand the notion of well-being is to be quantified, the influence of these factors must be closely linked with the whole cultural, social, economic and political context in which the individual is situated.

The characteristic of inter-disciplinarity is derived naturally from the object of ergonomics design.

In fact, the difficulty of the problems present in the world of industrial work leads to increasingly advanced specialization, while the complexity of these problems shows the unsuitability of the conventional disciplines when they are used separately and without an overall view of all the factors at issue.

The ergonomist accepts this interdisciplinary approach to obtain a positive interaction of the various contributions; he rejects any separate consideration or simple summation of data. For example physical fatigue is a parameter which can be measured reliably and objectively, but it cannot have any precise significance without reference to other factors such as motivation.

In fact, an identical operation which is well-tolerated by a motor mechanic in a small garage may be quite intolerable to a worker on an assembly line.

If we were to consider separately the different aspects of a design problem we should run the risk of approaching that problem according to sectoral patterns of logic, assigning arbitrary importance in advance to one particular factor rather than others.

When designers have to assess man and his environment they do so with reference to sociological and biological theories, and often also make political choices.

Often these operations suffer from an amateur and superficial approach and even when specialists are called in there is a tendency not to go beyond

an individual point of view, thus contradicting the original contribution which they themselves asked for and forgetting the existence of a user.

In contrast to this approach, ergonomics design proposes an inter-disciplinary working group within which there are no forms of hegemony.

All the different specializations play an equal part and act within the ambit of their own spheres of reference without drawing a priori conclusions.

An inter-disciplinary group must base its own work on interest in the final result beyond the individual problems; on respect for the roles and terms of reference of each specialization and on ensuring that the individual contributions can be passed on using language which is comprehensible to everyone or techniques for the conversion of data which take account of the particular point of view of the recipient.

In group work, the only dominant tendencies must be those which emerge from time to time from the characteristics of the particular operations.

For example, in the initial phase of a design study, greater weight will attach to the expert in political and economic aspects because of the very nature of the situations confronted in this phase; at the implementation stage on the other hand more strictly technological aspects will take priority.

It should nevertheless be repeated that all the factors, even if their importance varies at different stages, must always be present throughout the design process.

The presence of all those interested in the design is therefore an important factor and one which is indispensable for group work; this means that individual requirements must take second place to a collective

evaluation of the various types of knowledge and capability. Within a design group those individual values which are normally suppressed by the hierarchical structure of the industrial world are expressed and implemented.

The third characteristic of ergonomics design resides in its comprehensive nature.

Basic questions rather than individual aspects of the problem should therefore be taken as the tasks for designers.

When the environmental problem in a factory consists of noise levels, it is wrong to approach this problem simply from the viewpoint of specialists in noise reduction.

In the great majority of cases, to solve problems of this kind which are technically difficult and involve high costs and long implementation times, measures must be taken not only to change the source of the noise but also to adapt the tasks of the workers concerned, to improve normal and exceptional maintenance operations and to adapt the environment and the training of everyone involved in the work in question.

In other words the problem must not be seen from the angle of a specific workplace and working environment but must be extended in time and to all the structures which determine or are influenced by the subject of the design task.

3. ERGONOMICS ACTION

3.1 The cost of not taking ergonomics action

This may be summarized as follows:

- Direct cost: absenteeism for health reasons due to the working activity and possibly associated with additional stress factors (commuting, inadequate public services etc.); increasing unwillingness of workers to perform particularly strenuous tasks; complex negotiation of working rates and shifts; overall cost of accidents (direct and indirect cost).
- Postponed social costs which have to be met by society: total and partial handicap.
- Human cost: dissatisfaction with work; impact of working conditions on social behaviour; impossibility of compensation between working life and life away from work.

3.2 Conceptual and corrective action

The cost of failing to take action is not taken into account in the typical quantitative evaluation of industrial programming and economics. The approach which encourages and justifies action when the cost of failing to act has become apparent (retrospective evaluation) must be replaced by an a priori assessment which takes account of the entire process under consideration, i.e. the human factors of technology must already be considered in the initial phase, and which encourages appropriate levels of investment.

This means a tendency towards conceptual intervention in which the human factors are already programmed at the design level. The cost of this action is distinctly lower than the cost of corrective measures.

The latter involve an interruption of the production cycle to adapt machines and equipment by measures which are not always effective although they are always complex and difficult to evaluate.

Nevertheless corrective action is still in very great demand from industry today.

3.3 The industrial reality must be treated as a dynamic entity

In every company there is a need for technological updating, for changes in production and there is also a change in the acceptance of working conditions.

This means that ergonomics action must be continuous and the company structures must acquire the resources, knowledge and mentality which allow the constant presence of ergonomists in the dynamic reality of the company.

3.4 Resistance

The resistance to the ergonomics approach which is generally encountered in the industrial context is as follows:

- Resistance on the part of employers:

This arises when the company climate is of the traditional authoritarian type which refuses real participation in any form.

This resistance becomes clearly apparent when the employer realizes that the ergonomics approach involves participation as a fundamental aspect and covers the entire undertaking.

If resistance does not arise at this level it may be replaced by technocratic resistance.

- Technocratic resistance:

This resistance comes from technicians who see in the ergonomics approach an excessively sudden change from their established habits.

Moreover the observation of deficiencies in the man/machine/environment system noted during the ergonomics action is seen as a more or less direct accusation of their own work.

The observations of principle made by ergonomics experts are accepted but not the changes which their implementation would imply.

This attitude may be attributed in large measure to the complete lack of biological and psychological tuition in the universities and institutes which train industrial engineers.

- Resistance by foremen:

This resistance is especially noticeable when cooperative participation is necessary. This generally stems from the stereotype behaviour of foremen who, having experienced the environment at the workplace over the past years, do not wish to recognize the importance of the factors involved. The foremen do not willingly accept action which involves a loss of authority from them to the workers.

- Resistance by workers:

This resistance occurs unless there is an appropriate awareness stimulated by the unions. This happens because many workers have become used through habit, and with differing degrees of facility, to unsatisfactory working positions and situations. Also, they are willing to accept environmental changes, but not changes in the man-machine system, because they think that wider change may require a further process of adaptation which they consider an additional source of fatigue.

Our direct experience suggests that the most difficult resistance

to overcome is that of the technologists and foremen.

On the other hand the employers and intermediate supervisors are one of the most important factors, in the methodological system outlined by us, if there is to be any real change in the workplace and working environment.

4. INSTRUMENTS OF ERGONOMICS ACTION

Our experience of conceptual ergonomics action is very limited and many of the difficulties involved are still in the initial study phase.

The following observations therefore relate essentially to corrective ergonomics action on the existing production unit where methodological and conceptual experimentation is now in a very advanced stage.

The proposed methods must, however, be carefully evaluated and related to the different industrial, social and political situations.

The essential factors in ergonomics action are as follows:

- knowledge of the conditions of the workplace and working environment (man/machine/environment system and man/machine) through preparatory analysis;
- preparation of technicians and workers for verification and critical assessment of the environment through ergonomics training courses;
- continuous acquisition of objective and subjective data on the working environment through the compilation of an environmental data register;
- control of health and determination of the subjective views of the individual workers by opening a health and risk register;
- verification of the pathological condition of the homogeneous group of workers through the Register of Biostatistical Data of the homogeneous group in question;
- formation of an interdisciplinary action group which will meet regularly to implement the ergonomics design or redesign;
- validation by consensus among the workers; this may determine later phases of the design or change the approach.

4.1 Preparatory analysis

Preparatory analysis is in general the first operation on which negotiation is necessary between the employer and workers. The agreement between the two social partners should clearly indicate the terms of the action and the characteristics of its management. There will be the following aspects:

- technical measures carried out at the point and times considered significant by the workers and in other areas or sectors considered necessary by the technicians for a complete knowledge of the real situation in the enterprise and its dynamic;
- recording of objective and subjective data relating to each homogeneous group;
- acquisition of factors characterizing the production cycle: layout - flowchart technology - organization of work.

The results of this analysis, set out in a document which must be distributed to all the interested parties, will be used for the study and negotiation of the priority choices and as the first input for the phase in which the modifications are planned.

In the case of a conceptual action, the preparatory analysis may be carried out by analogy with a reference unit, having due regard to the social and technical context in which the new production unit will be placed.

4.2 Ergonomics training course for engineers and workers

It is impossible to achieve a cooperative design (even for corrective purposes) unless conditions are created to enable the different staff of the company (engineers, workers, union representatives and ergonomics experts) to acquire a common language.

It will therefore be necessary to hold a training course for the persons belonging to the Ergonomics Action Group. This course will therefore be of interest to the departments responsible for management and training of staff, industrial hygiene and safety, technical control, design, production, organization and maintenance of plant in addition to workers' representatives.

The essentially formative nature of the course, and the fact that the group is heterogeneous in its interests and through the level of its training, makes it undesirable to attempt to draw up a programme covering all the disciplines involved in ergonomics.

The choice of the subject matter to be dealt with must centre on those subjects which are closest to the average level of awareness of the group undergoing training: i.e. the characteristics of the physical and chemical environment (microclimate, noise, vibration, lighting, pollution).

It will be the task of the teachers to find the points of reference which enable the programme to be inserted in a more overall context by bringing in other topics related to ergonomics (layout, working space, workload, psycho-social and organizational factors etc.).

A fundamental aspect of the course is discussion which enables not only the subjects dealt with to be clarified but also, and above all, favours the acquisition of a common language easily comprehensible to all the parties.

Too often in fact the difficulties of communication resulting from different levels of training and experience are an obstacle to the type of discussion between equals which is fundamental to the effectiveness of the Ergonomics Action Group.

An equally important objective for courses of this kind is to create the conditions necessary for an initial change in the traditional outlook of

the designers, managers and users, through the development of an awareness which enables the designer to view man as the principal factor affecting his design and the user to assess, in critical terms, his own working condition.

The ergonomics approach, in accordance with the basic assumption of a comprehensive view, must be progressively extended to all the sectors of a company.

The group participating in the course is the initial nucleus which enables the problems and concepts of ergonomics to be extended to all parts of the company.

One final objective of the course is to train a group of workers to validate their own working environment by instrumental recordings. Workers are enabled to do this through the introduction of a "Register of Environmental Data" which, together with the "Health and Risk Register" and the "Register of Biostatistical Data", is, in Italy, one of the most recent achievements of the unions for the direct control of health in factories.

4.3 Register of Environmental Data

The preparatory analysis is the representation of a reality which is limited in time.

The parameters influencing working conditions differ according to the season of the year, the rapid and continuous changes in technology and organization, the characteristics of the products produced and the state of maintenance of the machines and equipment. It is therefore necessary to keep a continuous recording of environmental characteristics and of the subjective views of workers together with all the phenomena which may influence them.

For this purpose the Register of Environmental Data is introduced which enables a recording to be kept, and a comparison made at the different seasons or at times considered otherwise significant, of the parameters of the environment at points defined as characteristic of the homogeneous group of workers.

The course of ergonomics training will provide the initial technical and practical knowledge required for keeping the Register of Environmental Data.

The data collected will be set out in graphs enabling comparisons to be drawn easily and clearly.

The influence exercised on the working environment by the plant under the different conditions of use and by the climate and measures taken can thus be assessed and the objective and subjective effectiveness of such measures validated.

During the regular meetings of the homogeneous group, the data recorded in the Register of Environmental Data will enable timely action to be taken and necessary adjustments made, while a broader study of this data, together with biostatistical information and the subjective use of the homogeneous groups, is sufficient to define and motivate priority choices at regular meetings.

4.4 Health and Risk Register

The purpose of the Health and Risk Register is to record the state of health of workers at intervals negotiated between the workers and employers as a function of the health and environmental characteristics of the workplace, or at the request of individual workers. In this way a clinical history of the individual is prepared which will enable the health service to make a more accurate diagnosis of pathological conditions while the worker himself will be familiarized with his own state of health and have documentation on it.

The clinical history of the homogeneous group will then enable the degree of harmfulness of the environment to be evaluated and the impact on health of changes in the working conditions to be determined objectively.

The Health Register has three basic parts:

- the record, which is periodically updated, of the conditions to which the individual is exposed at his workplace. These conditions are deduced from the Register of Environmental Data from which the significant elements are extracted;
- the observations made by the Industrial Health Service during the medical examination and the non-industrial illnesses reported by the worker himself or by his doctor;
- the subjective assessment made by the worker of the conditions at his own workplace.

Comparison of the objective environmental analysis (Register of Environmental Data), the objective health analysis (medical inspection) and the individual's own views (subjective) enables the service to analyse the existing relationship between health and working conditions.

All the documentation relating to the medical inspection and analyses will be personal to the worker and kept by him, while the results of the inspections and the statistics for the homogeneous groups will be forwarded to the groups themselves, to the company management and to the factory council.

4.5 Register of Biostatistical Data

The results of the medical inspections and laboratory and instrumental analyses, worked up statistically for homogeneous groups of workers, together with the statistics of absence for reasons of health or accident, constitute the Register of Biostatistical Data of the homogeneous group.

The former enable all types of change, including those which are still latent, affecting the organism to be shown, while the latter indicate known pathological conditions.

Study of the Register of Biostatistical Data provides a general view of the effects of aggression by the working environment on the homogeneous group.

It may be used for an immediate assessment of the harmfulness of a particular workplace, for analysis of the evolution of working conditions as a function of time or as an effective instrument of scientific research on the medium and long-term effects of work on man.

4.6 Regular meetings

For practical implementation of the ergonomics approach, regular meetings of the working group must be held. These meetings will provide an opportunity for fruitful exchanges of views and information on objective data.

The objective and subjective elements which contribute to our knowledge of the working environment are as follows:

- the preparatory analysis which enables the working environment to be defined at a particular point in time;
- the Register of Environmental Data which enables variations of environmental conditions as a function of time to be determined;
- the subjective views of the homogeneous groups of workers and their requests for changes;
- the statistical evaluation of the health data for homogeneous groups through the Register of Biostatistical Data.

The basic task - typically inter-disciplinary and cooperative - of the regular meetings of the working group is to correlate and interpret these factors.

The meetings should be held at regular intervals to check the achievement of the objectives and their effectiveness as a function of time.

The working group will thus realise how important it is to organize relationships within the factory in a new way.

4.7 Cooperative designing

Cooperative designing of environments, instruments and machines leads to the user's requirements being taken as one determining factor for the conceptual choices made, in addition to those determined by the knowledge and experience of engineers.

Because the user is able to become a protagonist in the design function bringing his stock of knowledge acquired through daily experience, it is necessary to find new relationships within the design group.

The traditional system consists of two parties, the engineer or engineering group and the employer's representatives.

A language of equals is established between them, reflected essentially in numerical data and graphs.

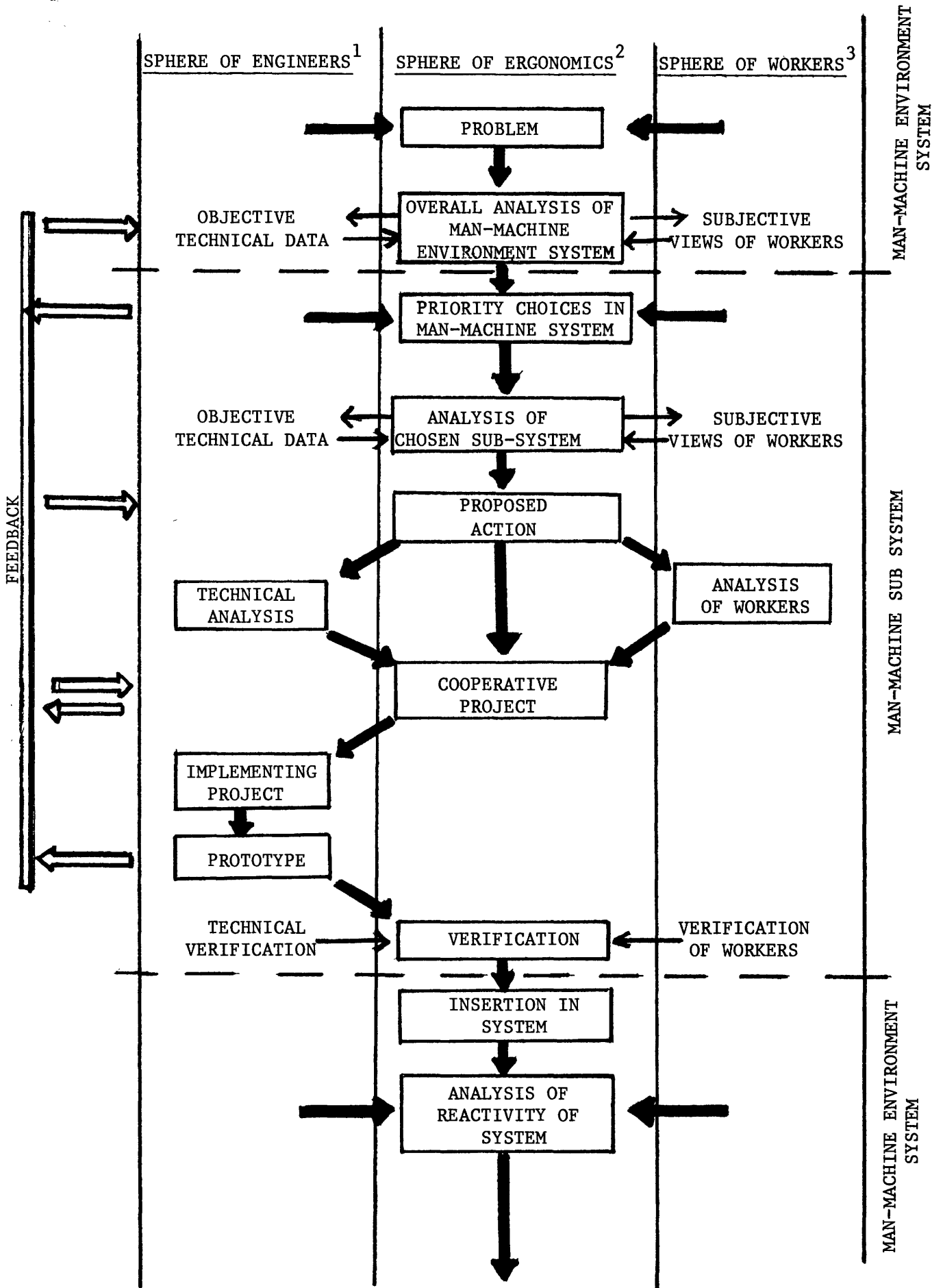
If this system is replaced by a tripartite scheme in which the user joins the engineer's and employer's representatives, normal techniques can no longer be used. The user speaks a different language, not only because of his cultural training but also because of his aim which is to achieve wellbeing in the factory rather than to concentrate on productivity.

The technical and human objectives must be placed on the same level because a system which, while respecting the productive aspect, fails to take account of the wellbeing of workers, must be considered inadequate.

Engineers who are generally only interested in the productivity angle must therefore abandon their "disciplinary patriotism" by participating in the implementation of priority choices in the joint group.

Figure 2 summarises in the form of a chart the procedure described up to now.

COOPERATIVE DESIGNING of
THE MAN-MACHINE SYSTEM



Notes on figure 2

- 1 - Sphere of engineers - "objective technical data" provided by experts in the design of machines, plants and environments; also data provided by production and management experts, staff responsible for relations with workers, safety and hygiene at work.
- 2 - Sphere of ergonomics - synthesis based on technical data and subjective views and in which the knowledge, techniques and procedures of the disciplines belonging to ergonomics are utilized.
- 3 - Sphere of workers - "subjective views" of workers expressing in overall terms their working conditions and needs.
- 4 - Objective and subjective analysis of the system to be designed or redesigned. The objective component will be inherent in the measurable system and characteristics: dimensional factors, technological cycle, production criteria, polluting factors, working rates, organization, maintenance, statistics on accidents of any kind.

The subjective section concerns the subjective views of workers, highlighting all the informal and individual factors which change the system in relation to its theoretical functional nature.
- 5 - Group synthesis of collated data enabling the salient aspects to be shown in respect of which action is necessary; these aspects are both of a technical and of a human nature;

- development of alternative design hypotheses. These must be translated into terms which are easy to communicate and understand and be accompanied by factors which will help to facilitate a solution.
- 6 - Group analysis of the design hypotheses. At this stage a common language and a single level of knowledge are reached; during the discussion the final hypothesis will emerge which tends to establish an equilibrium between the various requirements which are often contradictory.

5. CONCLUSIONS

The observations made so far show that to obtain an effective and far-reaching change in the working environment the acquisition of technical data is not sufficient; a profound evolution is required in the management of the company and in the design methods. We have also seen that the participation of workers in the control and management of the environment is a fundamental and necessary step in this new approach.

The internal or external bodies responsible for this design function must assume as the design data, side by side with the traditional considerations of production, all the objective elements likely to prevent negative effects on the worker; they must also obtain the subjective views of the workers themselves. This will enable models of the environmental working conditions to be established which will guide the design choices for new productive systems.

It must be recognized that there is a need for traditional assessment parameters to be reviewed. For example the aim of reducing space is not always an effective saving if expensive adaptations are subsequently necessary.

The logic of reducing distances covered often conflicts with the problem of housing, in the same complex, equipment which has varying polluting characteristics, with the result that enormous volumes have then to be dealt with.

As regards the management of the problem of health in the factory, the documents for the control of the working environment and health of workers are the instruments which enable negotiations between the two social partners concerned to be held on the subject of priority action.

The design phase will be managed by the inter-disciplinary action group in which the company's and workers' representatives will participate,

and it will have the task of studying and deciding on measures to improve the environment at the workplace and then verifying the effectiveness of the action taken.

Validation by consensus will be effected by the workers.

Finally we should stress that the image of ergonomics for most people is still one of "increasing production and productivity by improving working conditions".

This misconception must be removed once and for all, otherwise ergonomics will fall back into the position of a revised and corrected Taylorism.

The sole purpose of ergonomics is to adapt work to man and as such it is consistent with the needs of workers. It is the task of the employer and not of the ergonomics expert to establish a compromise between these requirements and production criteria.

The ergonomist or ergonomics action group must treat productivity as merely one aspect of the problem and not as its entire task.