COMMISSION OF THE EUROPEAN COMMUNITIES – ECSC

RESEARCH ON INDUSTRIAL
PHYSIOLOGY AND PSYCHOLOGY

Human Factors and Safety

(1st and 2nd programmes)

Ergonomics

(1st programme)

Research on Industrial Medicine, Health and Safety as at 1 January 1968

LUXEMBOURG, 1968

HUMAN FACTORS AND SAFETY – ERGONOMICS

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FOREWORD

When the High Authority was succeeded by the single merged Commission of the three European Communities, it was expressly stated that the new Executive intended to continue the activities begun under the ECSC Treaty. Accordingly, the various ECSC-aided research programmes under way have proceeded as originally arranged.

The present report concerns work in hand under the industrial physiology and psychology programmes shown in the annexed table as B, a) Human Factors and Safety, and B, b) Ergonomics. The table will give the reader an idea of the place assigned to these subjects in the Commission's overall research promotion work with respect to industrial medicine, health and safety.

The Commission's principles and methods in this connection remain those described in detail in the publication "Policy of the High Authority concerning Studies and Research on Industrial Health, Medicine and Safety."(1)

For the benefit of readers not in possession of this document, they may be summarized as follows :

a) Promotion of worker's health and safety by the acquisition and dissemination of knowledge relevant to :

   (i) prevention of occupational diseases and industrial accidents ;
   (ii) treatment of their manifestations and sequelae ;
   (iii) rehabilitation of workers affected by them.

   The interchange of views and experience and the undertaking of original research and study work are sponsored and aided with this end in view.

b) Part-financing, from the Community levy, of research projects and other necessary activities, under programmes extending over several years, each relating to a specific field of investigation.

c) Close co-operation with the employers' and workers' association and responsible Governement departments at all stages, preparation, implementation and follow-up.

F. VINCK
Director-General

(1) Publications Department of the European Communities, Luxembourg, 1966.

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INTRODUCTION

The previous progress report first gave a brief general outline of the Community's work in connection with industrial physiology and psychology, and then, for the sake of convenience, described in turn the research under each of the three programmes, two on Human Factors and Safety and the third on Ergonomics. The present report adheres to this separate presentation.

At the same time, it is well to bear in mind that the two aspects are basically very closely interlinked. In consideration of this, the two later programmes have all along been treated as the two halves of a drive for better and safer working conditions : the experience of the last couple of years has confirmed that they are indeed indissociable, and it is now likely that the two sets of research will be amalgamated under the title " Man at Work ", the great aim being to help improve what may be termed " social economics " by seeking ways of meeting the dissatisfaction and disquiet that are growing up in face of the march of technological change. Thus, as regards applications of industrial psychology in order to make the individual better adjusted to his job, the object is to assist personnel of all grades to fit into their working environment : technological advance can be achieved only if the human problems it involves are adequately dealt with, while at the same time the personnel can find their work genuinely satisfying only if it means they are sharing in the operation of the production system. As regards applications of industrial physiology and psychology in order to make the job better adjusted to the individual, the object is to provide the technical experts with accurate information as to human abilities and tolerances for the purpose of enabling the working conditions and the plant to be organized to best advantage from the point of view of reducing stresses and promoting efficiency.

Human Factors and Safety

1st Programme on " Human Factors and Safety "

A general account of the 1st programme on Human Factors and Safety, completed in 1966, was given in the previous progress report. (1)

Three publications were issued in 1967. The first, " Les Facteurs Humains et la Sécurité - Étude Documentaire, " reviews the state of knowledge on the subject prior to the 1st programme ; the second, " Les Facteurs Humains et la Sécurité dans les Mines et la Sidérurgie, " summarizes the findings of the individual projects carried out under the 1st umbrella programme, and the third contains reports from the different countries giving the results of the 11 projects making up the " common " (Community-level) research on safety.

In addition, two covering reports on the portions of the " common " research relating to the iron and steel industry and the portions relating to the coal and iron-ore mines, entitled respectively " Recherche Communautaire sur la Sécurité dans les Mines et la Sidérurgie - Étude No. 4 : synthèse des Recherches menées dans la Sidérurgie " and " Recherche Communautaire sur la Sécurité dans les Mines et la Sidérurgie - Étude No. 5 : Synthèse des Recherches menées dans les Charbonnages et les Mines de Fer, " were issued in a provisional edition to the industries and research establishments, and are now reprinting for wider circulation.

It is now for those concerned to draw the appropriate conclusions from these various documents and decide as to their practical application at enterprise level.

2nd Programme on " Human Factors and Safety "

A description of the programme and list of the projects concerned were given in last year's progress report. " (2) As was there indicated, the main aspects being investigated are selection, training, safety equipment, problems of perception and information, and work situations in relation to safety.

The whole subject of selection and training has been thrust very much into the foreground by the research effected under the previous programme. This brought out sharply the influence of proper occupational adjustement on safety, and con-

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(1) " Research on Industrial Physiology and Psychology – Human Factors and Safety – Ergonomics – Research on Industrial Medicine, Health and Safety as at 1 January 1967 " (ECSC, Luxembourg 1976) pp. 3-5 and Annex I.

(2) Ibid., pp. 14-18 and Annex II.

sequently the importance of ascertaining the individual's particular abilities and preparing him adequately for the job he is to do. In addition, it underscored the role played by personnel attitudes, not only to the job but to the enterprise, whence the need to influence the men's attitudes towards work situations and stresses and to promote " industrial education " in order to help them understand the industry they belong to and so do their share in making it all it should be.

Individual projects

The 13 projects begun in 1966 went ahead according to schedule, [3] and a further three were adopted. The following is a brief conspectus of the work now in hand. [4]

Selection

The research under this head is aimed at devising improved methods of pinpointing positive aptitudes for particular duties, these having been shown by the findings under the 1st programme to be an important factor in safety.

a) On the steel side, Dr. G. Bäumler in Germany is working on a series of recognized tests for the selection of supervisory personnel.

   For the first six months the work consisted mainly in establishing the method to be employed and effecting and evaluating preliminary try-outs. These preparatory studies included four audile alertness tests by means of wich the optimum operational conditions were ascertained, efforts to work out performance tests for assessing the different capacities, and the preparation of a 550-point personality questionnaire for recording certain personality factors relating mainly to work behaviour. In addition four visual alertness tests were worked out which will be used in the research proper.

   The object will be to study the correlation between eight alertness tests and the system of performance tests : the results should afford some idea as to whether there is an alertness factor as such to be taken into account.

b) Also on the steel side, Dr. Cantiant in France is studying specific aptitudes for crane drivers' and enginemen's duties.

   The starting-point here was testing with a pendulum mechanism constructed at the Laboratory of Applied Psychology in Metz and further developed in the Medical Department of the Société des Aciers de l'Est, Hagondange.

   The test is based on the assumption that efficient crane-driving aptitude depends on the ability to counteract pendular motion.

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[3] Fifteen projects in all were adopted in 1966, but two could not be undertaken (project No. 12/011, Kahn ; project No. 12/010, Molitor).

[4] Based on reports by Professor Cesa-Bianchi and Professor Koekebakker.

Three further tests have been devised, namely :

(i) The M-O reaction test, in which the aptitude tested is the ability to act at the exact moment a given movement can be performed whenever this can be done within the permissible safety limits.

(ii) The overload test, for studying behaviour in subjects under a work pressure approaching saturation.

(iii) The tracking or backtracking test, in which a pointer moves irregularly across a dial, and the subject is required either to bring it back to its previous position (backtracking) or to cause a second pointer to draw level with it (tracking).

Training

The research being carried out in this connection is concerned with ways and means of ensuring greater safety-mindedness and readier contact on the matter between those in position of responsability and the rank and file, the importance of which for safety was underlined by the earlier studies under the 1st programme.

a) Dr. Jongh in the Netherlands is investigating whether the safety training given to juveniles at the basic stage in technical education takes sufficient account of the problems they will actually encounter in this respect in industry.

The second- and third-year *theory training on safety* in the wood- and metal-working sectors is educationally and psycho-educationally sound in a number of respects ; on the other hand, there are often appreciable differences as between one instructor and another, even within the same college.

The classes observed showed a high proportion of knowledge transmission, the instructor expounding the subject and the students listening. The amount of actual knowledge imparted is probably considerable, but the approach is inadequate where, as with safety training, the aim is to inculcate attitudes and reactions. It would be of interest to find out to what extent this deficiency is offset by the practical safety instruction given.

Inquiries as to direct contact with the industries (on which the application of the safety training received in effect depends) showed that there is scarcely any organized contact at all. Not many instructors either take part in tours of enterprises, or undergo at-works training, or attend courses, though a great many think it would be a good thing for facilities of this kind to be arranged.

Instructors would also like to see more contact with enterprises' own training centres. It does indeed seem a good idea, likely to be of benefit not only as regards safety training, but all round.

Comparatively few instructors thought that their contacts with industry caused them to change what they taught about safety. Those who did think that there was a good deal of feedback in their teaching were the ones with the most contacts, which should surely be a reason for stepping these up ; at the same time

more definite efforts could be made to turn such contacts to account for the sake of the feedback.

A rather poor view of enterprises' safety arrangements is taken in the primary technical colleges. It has not as yet been possible to ascertain to what extent this opinion has affected the safety training given, nor was any relation observed between it and the amount of contact, on the instructors' side at any rate.

The instructors' teaching ability on the hand was found to vary in line with the amount of contact and feedback and with their view of enterprise safety. The individual instructor's motivation in his work may have something to do with this : the stronger his motives the higher his score for each of the variables taken into consideration.

There is little agreement between heads of colleges, teaching staff and students regarding the amount of contact with enterprises and opinion concerning them.

This would suggest that there is not much joint activity or discussion in this connection.

The general impression is that industry is not really a focus of interest to the primary technical colleges. It does come into the picture, but rather erratically ; indeed it often seems to be regarded as a background sphere to be found out about later on. Even though the college is of course only intended to serve as a a preparatory stage in vocational training, it seems fair to ask whether more attention sould not be paid to the radical changes in progress in industry nowadays.

As part of the research on safety training at the primary technical colleges, a survey was made of the *subject-matter taught concerning safety in the wood- and metalworking classes.*

Particulars were compiled of the subject-matter taught at 12 colleges chosen at random, and a comparative study was drawn up and submitted to two panels of 10 members each, drawn from the wood- and metalworking industries.

A third scheme, for recording the amount, variety and relevance of the safety tuition given by each instructor, proved impracticable owing to methodological defects.

However, an index was worked out of the importance attached by the woodworking instructors overall and the metalworking instructors overall to the matter taught by them. The woodworking instructors' index did not tally with the panel's assessment ; the metalworking instructors', to some extent, did.

On the strength of this, and of the finding that contact between the primary technical colleges and industry is deficient, the conclusion is clearly that such contact should be intensified. Only by consulting with one another can two sides properly judge as to the effective value of the subject-matter in question.

b) Prof. Bolle de Bal and Mr. Feldheim are conducting research in the Belgian coal industry on training, and especially the training of foreign workers, as it affects safety.

Initially, attention has been concentrated on the safety training given to supervisory personnel. While there have been no special developments lately as regards the training of the rank and file, quite a number of new departures have been adopted in training supervisors.

It was decided that the first step must be to build up a detailed picture of these new training methods by carrying out a comparative survey in a series of collieries. A questionnaire was accordlingly drawn up as a basis for eliciting information from the supervisory staff at the collieries concerned ; by this means particulars were obtained with respect to the selection, job content and training of supervisors, the safety angle being at the same time taken into account.

Next the researchers have gone on to examine precisely what difference has been made by a training course at one particular colliery. Their detailed case study on the effects of this comprehensive one-week course, based on thoroughly up-to-date teaching methods, does not go specifically into the safety aspect as such, but the examples described provide ample scope for commenting on points arising with regard to safety.

In assessing the effects of this type of course, it is necessary first to adopt accurate yardsticks, and then apply them as a means of establishing exactly what changes have been brought about. Part of the research therefore consists in securing objective criteria, such as accident statistics ; in addition, a number of objective reference values have to be fixed to bring out the effect of the training, in such matters as observance of the regulations in force and a better and broader grasp of people and situations.

As the whole point of training is lost if the effects wear off too quickly, the study needs to relate to the position as at several successive dates, fairly widely spaced. Partly in consideration of this, the project will also include a control group of supervisors from a different colliery.

c) Prof. Iacono, working in the steel industry in Italy, is trying to devise ways of improving communication between the supervisory grades and the rank and file.

From relevant literature and a series of snap interviews at the steel plant selected, a basic hypothesis has been constructed on which a number of working hypotheses are being built up. The basic hypothesis is that accident situations arise out of, inter alia, supervisors' inability to view job relations objectively, the variables governing this inability being :

(i) insufficient differentiation between " the self " and " the rest " ;

(ii) cognitive dispersion unaccompanied by objectivation of the situation ;

(iii) insufficient differentiation of the peripheral areas of the personality.

The constituent hypotheses serving to pinpoint the relation between these variables and the inability to view job relations objectively are argued from psychoanalytic, cognitive and educational premises.

The treatment of the variables is to be by :

(i) short group-therapy sessions (cf. Bion-Foulkes) ;

(ii) discussion methods to eliminate dispersions and discords ;

(iii) utilization of job to promote more functional work attitudes.

As soon as the necessary armoury has been prepared and the ground plan drawn up, the research proper can begin. It will be, so to speak, an on-the-spot experiment with the subjects receiving practical and theoretical tuition. By way of preparation the research centre held a seminar on " application of an experimental influence on attitudes, " attended among others by representatives of the test plant.

d) Also in the Italian steel industry, Prof. Spaltro is studying the psychological effects of supervisors' training.

Four criterion variables, viz. risk perception and risk-proneness, personal and social desirability, degree of socialization and perception of authority, are being measured by means of special tests.

This involves :

Surveying motivations in the supervisory personnel of the test plant.

In accordance with the survey findings, preparing appropriate audio-visual aids for the purpose of supervisor-level safety training.

Recording the four variables as found in approximately 100 supervisors and in a representative sample (approximately 200) of workmen before the aids are used.

Using the aids on the supervisors, successively or in combination.

Recording the four variables as found in the two samples at a suitable interval after the use of the aids.

Collating and evaluating the data so obtained.

Individual safety equipment

The object here is to help ensure that better use is made of protective equipment, whether by influencing attitudes in this regard, and in some cases in regard to safety generally, or by improvements in design making the equipment itself handier to employ.

a) Dr. de Cock is in charge of a project in the Belgian coal industry for elucidating how far the use of safety equipment is influenced respectively by the traditional directives on the matter and by the standards the individual gangs of miners evolve for themselves.

This research is part of a broader programme undertaken by the Centre d'études psycho-médico-social in Louvain on the processes of decision-taking. It covers independent and altero-dependent decisions, the influence of the two types of

decision, on behaviour, and the conscious, unconscious and preconscious elements underlying a decision.

The main aim is to establish whether the traditional influence by way of directives differs in its effect from the gangs own standards. A number of gangs are to be subjected in the course of a training period to traditional influence (" dependence "), a second set of gangs will be required to work out for themselves by group discussion what directives to apply (" interdependence "), while a third will act as control, i.e. will not be influenced at all.

In the initial stage of the research, intensive contact was established with the test colliery. The researchers familiarized themselves with their field of investigation, and analysed the accident statistics for the past few years.

One of the main types of accident, falls of ground, having been found to be often caused by inadequate trial borings, it was decided to take boring as the subject concerning which influences should be brought to bear. One advantage of this choice is that boring is a matter of practical importance in which there is plenty of room for improvement.

The project comprises the following variants :

(i) (dependence) the standards to be observed in boring are indicated to the gang in a talk by the charge hand ;

(ii) (interdependence) the gang themselves agree the standards to be observed, in a group discussion ;

(iii) (no influence) the behaviour of workmen engaged in boring is observed and surveyed, and subsequently restudied following subjection to influence (dependence or interdependence). A number of other variables (level of training, cohesiveness or otherwise of the gang, etc.) are also recorded and taken into account in evaluating the results.

Special attention was devoted in the stage now completed to choosing the most accurate method of rating behaviour in boring. Assessments by instructors and supervisors would appear a suitable means of doing this. In addition, a special, simply-worded *questionnaire* for the men themselves was drawn up, consisting of 37 questions each allowing of 3-5 possible answers.

It is hoped to study some 30 groups in all. In addition to computing the behaviour ratings immediately before and after subjection to influence, it is planned to make a further check six months after the research proper is over.

b) Dr. Girard is conducting research in the Italian steel industry on the extent to which the use or non-use of individual safety equipment is influenced by emotional elements in the men/management relation.

A number of hypotheses were worked out in the course of an earlier research project with regard to the interpretation of differences in off-sick rates. These are now being employed to investigate the relation between the men's attitudes and motivation on the one hand and their use of safety devices on the other, with the aim of obtaining data which may help in promoting greater reliance on this equipment. The research is to be practical in character.

Three stages have been completed :

(i) selection of subjects ;
(ii) observation of their work behaviour ;
(iii) interviews.

In selecting the field and subjects, a number of factors as the type of work, the risk of accident involved, and the opportunity afforded for observation of behaviour have been taken in account. After careful study of these data, a steelworks operating in three shifts, at which it would be possible to keep a particular set of 9-10 men under observation was chosen.

After ascertaining on the spot the details of the operations and work cycle concerned, the investigator next made a careful inventory of safety equipment prescribed for each type of work. From this it was concluded that as regards employment of the more functional items, such as gloves, all the subjects behaved much the same. In the case of items provided purely for protection and nothing else, there was more variation : junior ladlemen, most of whom were younger men, though more exposed to hazards were better trained and made more use of the equipment than did older hands.

In the interview stage, data were assembled on individual views and attitudes with respect to the equipment and the use made of it.

Now while some items are regarded as functional, as to others management tries to get the men to adjust rationally to the work situation and its various hazards. But a thorough sifting of the particulars recorded rather suggest that some of them, particularly the more experienced, tend to a pseudo-rational attitude based more on their own subjective feeling that all is well than on systematic use of their equipment.

c) Also in Italy and also in the steel sector, Prof. Cesa-Bianchi is in charge of another project relating to workers' behaviour in the matter of use of individual safety equipment, in which efforts are being made to devise a method of getting them to use the equipment more.

The researchers have supplied data to the research centres co-operating with the project and the test enterprise, and are now tackling the theory and methodology. Before they embark on the planned series of interviews, they have first to word the questionnaire so as to obtain really instructive information on points of theory, and not merely stale commonplaces and stereotypes.

Attitudes to safety equipment can be broken down into a cognitive element and an emotional element, plus in some though not in all cases, an " action " element. For the purpose of recording these attitudes, graduated scales are being worked out which will indicate as accurately as possible the individual's position vis-à-vis a series of " objects " (Coombs). Information obtained in this way has been tabulated as a basis for the preparation of a questionnaire.

The team have also been studying the theories of " latent structures, " in order to apply these in due course to the results of their observations. A model has been constructed and is being tried out ; in the study on " latent structure " use will be also made of discriminant analysis.

The paired-comparison method will also be tried.

Certain data have already been recorded over a period of two months at the test plant, and are now being methodically collated.

d) On the coal side, Mr. Rameau in France is investigating the use of micro-turbine dust masks from the psychological angle, and also working on ways in which these devices—in themselves very effective—can be made more convenient to wear and the men encouraged to wear them more regularly.

Some little time after masks were issued, it became clear that they were being used only intermittently and were not doing much good. Suggestions as to how this state of affairs should ne remedied varied widely, and the present research was therefore undertaken to ascertain the reasons for it.

In the course of discussions with experts a considerable variety of elements—technical, economic, sociological, physiological and psychological—were noted as being of possible relevance. It was decided to carry out observations and surveys in orders to find out more about the wearing of the masks in practice and the factors influencing this. Since so many different factors were involved, the study was confined to one type of working, power-cut faces, and the duties performed there. In eight such workings, differing in atmosphere, dust content and so on, four groups of miners were observed over a period of 150 hours.

How long the mask is worn depends largely on the wearer's job ; at the same time, even on a particular job, it is worn a great deal for some operations and hardly at all for others, and certain additional factors also come into play, such as the lenght and severity of exposure to the dust produced by the winning machinery, and the amount of open space round about. No differences between one worker and another on any given job were established, however, nor did there seem to be any difference to speak of between those who had their masks for some considerable time and those who had only recently been issued with them.

Job adaptation : environmental side

This section of the research and the next are devoted to the relation of man to job and job to man : even after everything has been done with regard to technical safety precautions, it is still necessary to adapt jobs, working methods, and even processes, to the physiological and psychological needs of the personnel, in such a way that working conditions will of themselves tend to make accidents more and more unlikely.

a) Dr. Plomp in the Netherlands is conducting research, partly in the laboratory and partly on the spot in the steel industry, on the extent to which the sound background and intrusive noises affect the men's ability to tell where an acoustic signal is coming from.

The point at issue is the perceptibility of warning signals, not only whether they are physically *audible*, but whether the hearer can recognize which *direction* they are coming from. The latter factor can be important as regards obtaining the correct response to the signal.

Generally speaking, perception of direction results from a time relation, namely the *timelag* between the catching of the signal first by the one ear and then by the other. Now background noise is likely to affect this relation and so interfere with the sense of direction. The following operations were carried out to quantify the degree of interference in a number of particularized situations.

The idea is to see how far it is possible to *distinguish* between two directions.

Two identical signals are sounded successively from different directions (source 1 and source 2) in random sequence, the listener never knowing which will come first : he is then required to say which, according to his impression, did come first. The experiment is repeated over and over, using a single fixed sound apparatus, and a *percentage* of correct resplies is recorded.

The degree of accuracy in direction perception depends on a great many variables. Some of these were taken as parameters in the tests (length of signal, strength of the background noise), while others were kept the same, viz. :

signal	—length	parameter (10, 30, 100, 300, 1000 msec),
	—nature	thermal noise, filtered by an octave filter with an average frequency of 500 c/s,
	—strength	50 db beyond the audibility threshold,
	—direction	the two directions symmetrically disposed in relation to an axis passing through the subject.
background noise	—length	continuous,
	—nature	thermal noise, filtered by an octave filter with an average frequency of 500 c/s,
	—strength	parameter, related to the strength of the signal (5 db, 0, —5, —10, —15, —20 db, no noise),
	—direction	45° to the right.

In the actual tests, the signal and background noise were conveyed to the subject via earphones, and not from sources located at a distance. A particular *incoming direction* was represented by a corresponding *timelag* between the signals to the two ears. This eliminates any effects due to " head's shadow " and enables the result to be interpreted purely on the basis of the timelag.

It was found that the *direction* of a very short (10 msec) and barely *audible* signal can be determined with 80 % accuracy ; for longer signals the results are slightly better still. As regards these particular signals and under these particular conditions, the direction perception seems adequate so far as the signal's warning function is concerned.

It should be noted that :

(i) the findings relate only to the ability to distinguish between sound sources to right and to left, not between sources moving away *from and towards the subject ;*

(ii) it would seem preferable from the point of view of *perceptibility* to use higher frequencies than was done here (approx. 500 c/s). The frequency chosen can appreciably affect the sense of direction ;

(iii) intermittent signals are easier to catch owing to their greater impact, and probably also assist direction perception.

b) Dr. Cazamian is making an investigation in the French coal industry into the influence of fatigue on ability to perceive danger signals. This involves studying auditive fatigue in miners and how it develops, its effects on safety, more especially as regards perception of acoustic danger signals, and appropriate human-engineering measures to tackle the problem.

The research is being conducted partly at the Centre d'études et de recherches ergonomiques and partly in the coalfields themselves.

At the Centre d'étude, a detailed and comprehensive corpus of reference material has been compiled, the members of the team have been working up a highly specialized knowledge of the field concerned, and manufacturers of noise analysis apparatus have been contacted with a view to securing a more sensitive filter, with a wider range, than that at present in the team's possession.

In the coalfields, an audiometric survey has been carried out on a sample of about 100 miners, a considerable series of ambient-noise levels have been recorded, and information has been collected to serve as a basis for the selection of suitable equipment.

Job adaptation : organizational side

This section of the research, like that just described, has been much influenced by the findings of the " common "-research on safety, in which emphasis was laid, in dealing with the ergonomic aspects of enterprise organization and structure, on the need for better communication and data absorption as between the working environment and the worker.

a) Prof. Rohmert in Germany is conducting laboratory research on the safety rating of various operations in a job at a press.

The idea is that occupational safety in the man/machine system should be indicated by a safety rating. Since accidents are as a rule, fortunately, few and far between, it was necessary for the purposes of the laboratory scale-model experiments to choose a high-speed system with a relatively high accident rate.

In addition, the simulated job has to approximate as closely as possible to the conditions actually obtaining in industry. Accordingly, the eccentric-press/man system was chosen.

The object is to study the influence of fatigue and of the faculty of concentration on safety by filming the operator with a television camera.

The initial results do not show any rise in the number of accidents even under difficult operating conditions.

This could be due do the increased risk being offset by man's built-in self-protection mechanism.

b) At another university laboratory, this time in the Netherlands, Dr. Winsemius is endeavouring to elucidate the effect of interruption on a movement's precision and accuracy.

The necessary observation work having been carried out, a mode of approach was devised based on the distinction netween " job streams " and " job phases ".

The " streams " may be visualized as continuous lines representing the operator's relations to the objects involved in his job, while the " phases " are successive periods during each of which a given combination of " streams " prevails, i.e. the objects concerned are not merely there but are actually being handled for a period of time.

The " phases " are marked off from one another by the transition to a different combination of " streams "

Detailed analysis of selected accidents suggests that the critical juncture as regards the safety of the movement is usually the transition from one phase to the next.

The transition phenomena most likely to contribute to risk-taking are " carried-over handling " (continued use of objects not in fact needed in the phase in question) and " solecism " (incorrect use of objects).

c) Mr. de Montmollin is making a study in French industry of the influence of the work load and the information content of signals and control panels in the control of automated processes.

In consequence of procedural hold ups, the project did not get administratively under way until 1 January 1967. The work will be conducted on the following lines.

Balanced job patterning nowadays, with so much intent watching and supervising work involved, is not really possible using just the normal work organization techniques, such as time and motion studies and the like. The work load is no longer merely the set of movements performed, but includes receiving and interpreting stimuli which practically always come in irregularly and at random. In studying the work load the aim must therefore be to establish which stimulus/response combinations represent an optimum for the operators, i.e. do not entail either.

(i) *overloading*, where too many stimuli come in almost simultaneously (or even quite simultaneously, which constitutes " jamming "). Overloading is probably one of the commonest causes of incidents and accidents ;

(ii) or *underloading*, where there are too few stimuli, with the result—demonstrated by altertness studies now accepted as conclusive—that perception is lowered, thus likewise creating the risk of incidents or accidents.

Underloading is a concomitant of the increasing fragmentation of jobs, which tends to make each particular job seem incomprehensible and meaningless.

This has been found a very real problem in various industries, which have realized that safety standards cannot be improved simply by appointing more supervisory staff.

Initial field studies made it clear that there was no easy way out, and that a special kind of work analysis would be required. Some possible ways of tackling the matter have been roughed out, but not in any detail, nor in a form suitable for transplanting from one enterprise to another.

The basic assumption is that it should be possible to devise a means of calculating simply and accurately in advance the work load resulting from a given set of random or non-random duties to be performed. The general method employed is to be analysis of the work in terms of data.

In studying the optimum work load, it is planned to evaluate the empirical observations and analysis in conjunction with a mathematical model of the " serve and wait processes " category, but going on the basis of " limited wait ", considering several usually interconnected displays simultaneously, and taking into account incidence of non-response.

d) Lastly, Prof. Merz is in charge of a project begun in Germany in 1967 on the performance of voluntary movements and the adjustment of these in accordance with the results of the action.

It is intended to assemble data which will help to establish, for purposes of machinery design, job adaptation and so on, what the human frame can reasonably be expected to stand and what it cannot. The guidelines so furnished, which will be of general application, will be offered with the aim of allowing economy of movement on the workers' part, combined with minimum risk of accident and maximum precision of operation.

As a rule, man and machine work together in production in such a way that the two systems, man and machine, form a single whole. Now the structural characteristics may or may not fully measure up. In the production processes of today, man's function is usually to control and decide. He receives information on how the system as a whole is working and what effects his own activity are having on it, and it is upon his ability to grasp and assimilate this information and modify his decisions in the light of the result that the successful operation of the overall man/machine system depends.

The research will concern certain aspects of the human side which are of some relevance in many occupational contexts. While the actual experimentation will be carried out in industry, the aim will be to study not particular working conditions, but fundamental human elements which come up in a wide range of jobs.

Research by a direct arrangement

Safety in relation to enterprise organization and structure

The joint scheme worked out among four research centres, by Professors Faverge, Leplat, Cesa-Bianchi and Brambilla, in Belgium, Italy and France,

was adopted by the High Authority in 1967, and work began in the three countries towards the end of that year.

Effectiveness of certain types of safety propaganda (posters)

Preparatory documentation has been assembled, but has not yet been examined by the research team. The matter is also one of those being tackled, from the angle of practical experience, by the Mines Safety Commission.

Ergonomics

1st Programme on Ergonomics

As was noted in the previous progress report, this programme comprises applied research in the field of practical ergonomics, aimed at securing optimum adaptation of mining and steelmaking jobs involving such stresses as high temperatures, noise, vibration, air pollution, and psychical or mental stresses, having regard to present-day advances in technology (mechanization, automation, new processes of various kinds) ; pure research on the relationship between the worker and his work, including such matters as the short- and long-term psychological and physiological demands and effects of the work, the relation of age to working capacity, possible ways of reducing stresses due do heat, to sound and to vibration, the amount and nature of the mental activity involved, and the possibility of adapting perceptional and sensory loads. The subjects specifically under investigation are physical effort, noise, vibration, working postures, mental fatigue, vision and mental activity. Attention has, however, been drawn by the researchers to certain further items of particular relevance.

One major problem is the reduction of physical stresses arising out of environmental conditions, including in particular heat, noise and vibration. This is becoming more and more important in consequence of mechanization and of the increasing noise and reverberation from transport and haulage, while in some industries the high temperatures involved in much of the work remain a big difficulty.

Another problem is the steadily increasing volume of transport operations both at the plant or mine and en route to and from it, which is giving rise to a number of complications with regard to safety, and calls for measures to lessen the strain on the men concerned. The subject is one which needs to be tackled overall, not purely from the angle of biomechanics. Research along these lines would be of the greatest value, as the findings could readily be applied throughout industry.

It is further pointed out that the question of mental activity and changes in mental capacity with advancing age is coming more and more to the fore. This aspect is gone into in part on a later page in the account of the research in progress.

Attention is also drawn to the need to treat ergonomics not only as a preparatory process affording presonnel better conditions in which to perform their jobs efficiently, but also as a chance for them to play their part in ensuring optimum job adaptation.

Lastly, the point is made that the overall function of ergonomics is to cause a mass of technical, physiological, psychological and organizational factors to operate in combination towards the smoothest possible running of industry, using the latest concepts and facilities provided by cybernetics.

Individual projects

The 26 research projects begun in 1966 proceeded on schedule,[1] and a further six were adopted. The position is now roughly as follows.[2]

Physical effort

This section of the research is concerned with working out accurate indices of fatigue and means of reducing physical and physiological effort levels. Whereas this section deals mainly with physical and physiological effort, mental effort is examined by three other groups referred to below.

a) Prof. Rohmert, in Germany, is studying stresses arising in materials haulage below ground at collieries. This has involved examining the conditions at present obtaining in this connection, and preparing two methods of analysing the degree of physical stress, by recording metabolic values and by establishing the effort required of the circulatory system in the course of the effort. In contrast to the conclusive experience described in published accounts of research on the subject, the team has had some trouble with the plastic containers used for carrying samples of exhaled air, which have proved insufficiently O_2 and CO_2 diffusion-resistant, and experiments have therefore had to be made with chromiumplated brass cylinders. Other preparatory work has included the incorporation of anti-firedamp devices in the existing equipment.

   Most of the work so far has consisted of methodological studies in preparation for research proper. The preliminaries for the recording of metabolic values have been completed by plotting the necessary calibration charts.

b) Also in Germany, but on the steel side, Dr. Schulte is conducting laboratory research on optimum individual degrees of effort in jabs forming part of mechanical processes. After first making a study of certain industrial operations effected at a given rate, he has developed an experimental apparatus – a machine for moving 1000-mm. discs to 12 positions – which can be fitted with various appliances. To vary the degree of effort involved, the movement of the discs can be made either steady or intermittent ; the speeds can be set between 0.2 and 60 secs. On the basis of initial tests, it was found necessary to develop an electronic recording device to compute the partial times.

c) In Belgium, in the coal sector, Prof. Lavenne is investigating the effects of the nature, hours, intensity, rate and conditions of work upon fatigue, by analysing

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(1) Twenty-seven projects in all were adopted, but one was subsequently dropped (project No. 22/044, Voelkner).

(2) Based on reports by Dr. Kalsbeek and Professors Leplat, Maugeri, Muller, Schmidtke and Wisner.

selected circulatory and metabolic parameters in physically-fit workers between the ages of 30 and 50. The following three parameters have been studied to date :

1) *Aerobic capacity* (maximum O_2 consumption) : 10 males were subjected at intervals of a few days to four tests, viz. :

   (i) work at the ergometer at 75 watts, 150 and 200 watts per minute, then with the wattage successively stepped up to 225, 250, 275 and so on ;

   (ii) work at the ergometer at 75 watts for five minutes, 120 for two minutes, 180 for two minutes, and successively 210, 240, 270 etc. for one minute each ;

   (iii) work at the ergometer at 75 watts for five minutes, 100 for one minute, and successively 150, 200, 250 etc. for one minute each ;

   (iv) work at the ergometer at 120 watts for six minutes, 180 for six minutes, 180 for six minutes, and successively 210, 240, 270 etc. for three minutes each.

   The circulatory and respiratory values during the tests were recorded. The most homogeneous were those for the fourth, namely maximum V_{O_2} 3 144 ml/min., maximum V_{O_2} per kg. 43,7 ml/min., and cardiac frequency 185 beats per min. From these results it is planned to develop an aptitude test for work at high temperatures.

2) *Level of lactic acid in the plasma :* although the Barker-Summerson colorimetric method is quite reliable, tests have been carried out with an alternative enzymatic method. It was found that the relation of absorbance (as recorded with the spectrophotometer at 366 u) to lactic-acid concentration remains linear up to levels of about 70 mg. lactic acid per 100 ml. plasma.

3) *Cardiac flow :* for the purpose of recording cardiac flow (in litres/min.), a method of diluting the colouring agents was devised on the basis of results recorded by previous researchers, and its usability established. 2-4 millilitres of cardiogreen are injected with automatic syringes for a period of less than one second ; samples of arterial blood are then taken and measured with a densitometer, and the dilution curve recorded on an X-Y recorder. At the same time, tests were made to see whether the Gilford 104 computer would calculate the surface integral underlying the dilution curve excluding recirculation phenomena. The results proving satisfactory, the method can now be applied in carrying out the research proper.

d) Dr. Tarriere, in charge of a project in the French steel industry concerning the physiological cost of shop-floor work, has been making preparations for recording certain physical data (amount of effort, amount of noise and atmospheric conditions) in forges, and analysing the degree of stress borne by workers there. This will involve recording cardiac frequencies (the rate during the work and any increases resulting from atmospheric factors), and noting points emerging therefrom as to cumulative fatigue.

   The specific stress for each job derives (bearing in mind atmospheric factors) from the relation between the behaviour of the circulatory system and the effort level.

In addition to analysing this aspect, the team have studied jobs planned in careful accordance with the principles of human engineering and designed to allow of alternation, for the sake of reducing the physical strain, between heavy duties (for instance rolling and forcing) and light ones (for instance cutting).

The research also includes comparing two methods of determining the biological effort required in a job, the indirect method, where the cost of the activity in calories is mathematically estimated, and the direct, where the relevant physiological data are recorded : the indirect method has been found less reliable, since it does not take sufficient account of the static load. Scattergrams are now being worked out.

Work is proceeding on the relation between the specific stress inherent in a particular jab and the morbidity and rate of ageing.

e) Prof. Margaria is conducting research in the Italian steel sector on the maximum aerobic and anaerobic working capacity of workers in heavy industry. Preliminary studies have been made on the maximum aerobic capacity (maximum O_2 consumption) of 50 subjects working in light industry, in whom energy expenditure was found in no case to exceed 25% of this capacity. The method adopted was to record the cardiac frequency, the basis being the linear relation between oxygen consumption and the steady-state heart rate. No significant variation in the capacity was observed in the subjects by the indirect method over an 8-10-hour shift : earlier research had, on the other hand, indicated that men worked to exhaustion showed a notable though temporary drop ($-13{,}8\%$) in maximum O_2 consumption.

A survey of 47 blastfurnacemen of no more than average functional physical capacity, each of whom put forth an experimental sub-maximum effort at the beginning and end of the shift, showed no significant variation in maximum O_2 consumption on completion of a stint of 8-10 hours, and it was therefore concluded that this particular work does not produce acute fatigue : such fatigue as was observed was ascribed to other factors of nervous or psychological origin. The results further suggested that the work rates and breaks allowed were reasonable.

In effect, the research demonstrated that some of the selection criteria currently applied might be inadequate in the case of men assigned to physically demanding jobs. It is suggested that maximum O_2 consumption be measured, by the indirect method, in recruiting new entrants, for men with an above-average functional capacity have a higher output reserve in relation to the strenuousness of the job, and so work more safely and confidently.

f) Prof. Margaria has in addition completed an appraisal, also in the Italian steel industry, of the amount of anaerobic work and its effects on the organism. The main finding are as follows :

(i) The diffusion of lactic acid through all the tissues of the body has a semi-reaction time of 2 min. 10 sec., superior to that of other monovalent anions. The distribution characteristics of lactic acid are those of an electronegatively charged substance, and the volume of distribution (37.7% $\pm$ 1.62 of the body weight as calculated by blood concentration, and 29.2% $\pm$ 1.55 of

the body weight as calculated by plasma concentration) corresponds to that of extra-cellular substance such as the chlorine ion or lithiocyanate. No comparable relation was established as to lactic-acid concentrations in urines.

(ii) Investigation of the xinetics of the metabolism of lactic acid showed that the rate of elimination of the acid does not continue indefinitely to rise in parallel with rising lacticaemia. The maximum value per minute is 0.122 mmoles (11-12 mg) per kilogram of body weight, representing the maximum capacity of the liver to resynthesize the lactic acid.

(iii) This slow elimination is not connected with oxidation, which proceeds faster. It has been found, on the other hand, that substances such as the barbituturates, which inhibit NADH reoxidation, considerably slow down elimination of lactic acid from the blood.

Biomechanics and postural stresses

Since every physical action brings into play muscles all over the body, the interaction of three variables of biomechanics (posture, type of motion and motility) is obviously highly relevant to the efficiency of sensorimotor activity. For practical purpose the principal categories are work movements, the study of which goes back some time ; walking and locomotion, wich poses the problem of slipperiness, and merits investigation in view of the number of falls on the flat ; impact and motion especially in connection with falls from a height ; passive biomechanics, which relates to the effects of vibration ; and performance of work movements amid disturbing influences (or " dynamic biomechanical effects combined with a passive biomechanical effect ").

The subject forms a single connected whole, and has to be treated as such in examining interference in a control system due to vibration and impact effect. The problem looks a traditional one enough, but in point of fact the approach to it has been radically altered by the latest advances in neurophysiology.

It is now becoming acute owing to the steady progress of mechanization, the increasing use of machinery giving rise to motion, impact and vibration, and the large volume of transport and haulage over uneven surfaces. Unless machinery and equipment are better designed, the difficulties already being experienced in recruitment are going to become really serious.

In the three projects now in hand on biomechanics and postural stresses, in Germany and Italy, three separate but complementary approaches have been adopted.

a) Dr. Schmidt's research in Germany on the characteristics of a tiring posture and the possibilities offered by job adaptation for devising an optimum posture is being conducted partly at laboratory and partly at enterprise level.

The arrangement was that cardiac frequency, as an index of physical effort, and the successive operating phases were to be recorded in parallel. Dr. Schmidt and his team have been able to put to very good use an apparatus they have developed which performs this simultaneous function. They report as an example

one of a highly successful series of recordings carried out in a big mechanical-engineering shop.

The same excellent equipment will be used to study other work situations, more especially those of scarfers, arc welders and foundrymen.

At the same time, as the heart rate is recorded in function of the different production cycles, the position of the body is photographed, and the team also notes dimensions of the job, the physical force to be exerted, and the characteristics of the workpieces.

Subsequently, similar work situations will be mounted in the laboratory, and deteriorations evaluated against the heart-rate yardstick.

b) Mr. Schnauber's research, also in Germany, is a purely laboratory project, aimed at elucidating the degree of fatigue resulting from performance of an activity above the operator's head.

On the basis of various preliminary studies, Mr. Schnauber has devised a hand ergometer (several ergometers for assessing the strength of the lower limbs are to be found in research establishments, and even in the trade, but assessing the strength of the upper limbs is a considerably more difficult matter and has received much less attention). The apparatus consists of scissors which can be set wider or less wide open according to the force to be exerted ; the handles can be placed at different heights in relation to the subject by a system of adjustable straps.

Some very instructive results have already been obtained. The same force cannot be exerted for nearly so long when the appliance is at head instead of at chest level, and conversely at chest level the maximum force exerted over an identical period is eight times as great as at head level. The heart rate goes up in line with the energy expenditure and added hydrostatic load, and behaves generally in a comparable manner. A degree of effort which sends up the heart rate only marginally when put forth at chest level produces a sharp upturn when the scissor handles are opposite the head. Fatigue, as reflected by shorter effort and a higher heart rate, is correspondingly greater, for the same amount of actual exertion, according as the dynamic workload and energy requirements are greater ; as the amount of exertion increases, fatigue sets in earlier and more and more severely, owing to the greater static load and reduced irrigation. In addition to these valuable findings, Mr. Schnauber details a number of further results obtained with respects to the break which can suitably be allowed in work of this kind. In the case of moderate effort under the worst conditions observed (work at head level), the rhythm should be two minutes on and four minutes off : on this basis, the operator can carry on for considerable periods with a regular and not unduly high heart rate.

The 1 : 2 ratio must not, however, be indiscriminately applied to shorter or longer periods : after four minutes' continuous work the operator will need more than an eight-minute break.

Mr. Schnauber is currently engaged in further research on the subject of work breaks.

c) Prof. Odescalchi in Italy is investigating the stresses occurring in a variety of jobs in the steel industry. This is a field study, conducted entirely at two major steel plants : it covers the work situations overall, postural factors being only one of the aspects dealt with.

Dustiness levels and prevailing temperatures in different departments of the plants (steelmaking proper, casting, transport, heat treatment) have been recorded in detail over a period of eight months.

At the same time, the jobs being studied were extensively photographed and the different workers' precise functions analysed.

Particular attention has been devoted to data transmission arrangements (coding and decoding).

The team have studied the jobs of filling-platform operators, travelling-crane drivers and men employed in the casting pits, comparing the conditions as between the different production stages.

As well as compiling full particulars of all these, they have made scientific job analysis.

In addition, they have continued a motivation survey which has been in progress in the plant concerned for some years.

Mental activity

Present-day advances in technology have very considerably altered the nature of work in industry, which is coming to involve more and more transmission of data, more particularly via monitoring and recording systems. Evaluation of the mental demands is necessary to make it as easy as possible for the personnel to receive the incoming " displays, " or combinations of stimuli, and to interpret their content and respond appropriately, while at the same time it must be remembered that only so will the enterprise be able to achieve really efficient operation of its expensive machinery, non- or under-utilization of which can entail serious financial loss. Generally speaking, the complexity of modern industrial processes and set-ups is making each individual activity more dependent on the system as a whole, and consequently proper patterning and proper communications are becoming more and more vital. Hence the growing importance of research into problems of display perception and mental work load in mechanized and automated processes, and of measures to ensure well-designed signalling and control installations and streamlined communication systems.

In this context three sets of projects have been undertaken, concerning respectively mental activity (dealt with in the pages immediately following), mental fatigue (in the next subsection) and mental effort (under the research by direct arrangement).

Only two projects relating to mental activity were carried out in 1967. Both are experimental studies, the first psychological and the second physiological. They are in the nature of analyses of the operator's duties in man/machine systems, the duties in question being perceptional and mental, of the kind involved in superintendence and inspection.

In view of the increasing number of different jobs in industry today, and of the importance of learning more about the origins and implications of mental fatigue, the research here described may well have very considerable repercussions in the practical field, in particular with regard to safety.

a) Mr. de Montmollin is conducting experiments in a number of French enterprises, including steel plants, in connection with monitoring under emergency condition. The object is to analyse the variables which can influence the operator's response to a given display, and on this basis try to simulate situations giving rise to incidents or accidents.

   Two preliminary stages have been embarked on, the assembling of reference material and the planning of the experiments. The test job consists in perceiving and correctly and promptly interpreting displays which the operator does not always know are coming at any given moment and which in many cases merely flash across his field of perception.

   (i) There are three *independent variables*, combined on a fully factorial basis :

      1) Complexity of the job, assessed in terms of data quantity from the relevant organization chart indicating the sequence of the occurrences (displays and responses). The system is actually a two-state one, in which the two states can be either simple stimuli or combinations of stimuli. There are six possible complexity ratings.

      2) Normal or quickened display.

      3) Stress : penalization of error (two possibilities).

   (ii) The *dependent variables* are the number of right, wrong and missed responses and the reaction time.

   (iii) The hypotheses are :

      1) the indicence of error and reaction time are proportionate to the entropy of the system at a given moment ;

      2) quickened display or heavier penalization causes a drop in the incidence of right responses ;

      3) behaviour deterioration following error is proportionate to the speed and complexity of the job ;

      4) the area of memory involved in the job should be assessed.

   (iv) The experiments are now in progress, with 10 subjects who are to be observed under each of the 24 test conditions.

b) Dr. Cazamian, also in France, is in charge of a project in the coal sector concerning the electrical activity of the brain, firstly, in mental activity and experimentally-induced mental fatigue, and secondly, in automated industrial operations.

   The work so far has consisted in getting the necessary equipment in readiness. The research proper will be in the form of experiments to ascertain any alter-

ations in the cerebral potentials produced in the course of a complex job entailing mental participation.

(i) The test job is that of watching a set of four galvanometers and acting on the readings in accordance with prior instruction. The frequency with which the pointers change position varies with the speed of the subject's response. The trst period is 2½ hours ; the responses can be recorded in the form of electroencephylograms. By this means it is possible to establish the qualitative and quantitative aspects of the changes that develop as time goes on, reflecting deterioration in performance.

(ii) The recording apparatus comprises a cathode-ray oscilloscope. A device connecting the oscillograph to the stroboscope shows with precision the periods of light stimulus, their duration and the stimulus rate. The analysing apparatus is made up of a number of items assembled according to the particular analysis in question : the morphology of the potentials produced is studied with an analogue (digital) computer connected to the tape recorder and to an electronic impulse counter. The latencies are studied by analysing the potential produced in order to work out the mean potential produced. The amplitude and certain correlations are also being investigated.

The potentials produced are to be analysed first in the case of the complex mental activity referred to above, and later in certain other industrial jobs requiring a high degree of mental participation.

c) Mention should also be made of the research just begun in the Italian steel industry by Prof. Misiti on individual ability to handle data in man/machine systems and learning under conditions of doubt as to the corrects response.

d) A German project adopted in 1967 has not yet become operational. This is the research to be undertaken by Dr. Schulze on objective criteria as to perception of light stimuli, including warning signals, taking into account environmental conditions and the sensory load.

Mental fatigue

This part of the research, like that just described, relates to the objective assessment of mental work loads.

a) Prof. Schmidtke in Germany is conducting laboratory research on psychical fatigue.

In many different types of enterprise it frequently happens that workmen already under considerable physical strain have to react to information, warning and danger signals, vital to their own safety, which often have to be perceived and interpreted amid a medley of background noises and other intrusive stimuli. Consequently, it is important to investigate psychical performance potential as affected by physical fatigue.

To do so the researcher has systematically and quantitatively to vary the levels of physical effort and/or fatigue. Since it is primarily the circulatory system

that comes under stress in physical effort, the criterion used is the heart rate. The effort is varied by means of a bicycle ergometer, the imposed work load being so scaled that the heart rate for each subject is 40% and 100% of that recorded under maximum physical load during a prior examination.

For the purpose of the experiments, the psychical performance potential is placed under quantitative stress as follows. During the same test series, the subject receives in turn visual and acoustic signals with which he has thoroughly familiarized himself beforehand. These have to be discerned amid interference from various other stimuli, the whole load being programmed on punched tape. The subject is required to react by pressing the appropriate button immediately on recognizing the signal : if his response is the right one, the next signal in the programme follows ; if not, the same signal is repeated until he does respond correctly. Each time the interval between the sending of the signal and the correct response is recorded.

This has to be gone through at three levels of physical effort, each maintained for 100 minutes : first nil effort, and then two effort situations sending up the heart rate to 40% and 100% respectively of that registered for a previous maximum effort described above.

A specially-designed electronic device is being constructed for programming the signals and recording the responses.

b) Prof. Salvini in Italy is engaged in laboratory research on the objective assessment of mental fatigue.

Attention is being focused on the galvanic skin reflexes (GSR) as influenced by mental fatigue. The method is to record, regularly at 6 p.m. on completion of a normal day of a day of sustained brain work, GSR induced by successions of auditory and vibratory stimuli in 15 healthy subjects aged between 18 and 22, and also their arterial digital pulse rate.

The brain work on the " mental effort " days consisted of tests requiring close attention to a monotonous activity, translations with a set deadline, and studying for university examinations. At the end of each day, the testee was asked to describe his subjective fatigue sensations.

The acoustic stimuli administered were of strengths of 60 and 80 db, and the vibrations of a frequency of 150. The GSR values obtained after 10 minutes' exposure were compared with those after 10 minutes' undisturbed rest in a recumbent position. Recordings were taken on two successive days of no special mental effort followed by two successive days of mental effort.

The testees were found to fall into two almost equal groups, of which one reacted markedly to the stimuli after a non-effort day and hardly at all after an effort day, while the other showed precisely the opposite effects.

c) A third project, to be conducted in the Belgian coal industry by Prof. Verhaegen, was adopted, but by reason of an administrative hold-up will not begin until 1968. It is an investigation of possible impairment of psychical activity in work at high temperatures ; the team will also try to establish tolerance limits, and to devise a fitness test for such work.

a) Dr. H.G. Wenzel is doing laboratory research in Germany on the influence of airflow rates on the physiological reactions of men working at high temperatures. The following test series carried out in an environmental control chamber have been provisionally completed :

   (i) easy physical work with an airflow of 0.3 m/sec., an ambient temperature of 24-48 °C, and 12-98% humidity ;

   (ii) medium-hard physical work with an airflow of 0.3 m/sec., an ambient temperature of 21-45 °C, and 13-80% humidity ;

   (iii) all-out work with an airflow of 0.3 m/sec., an ambient temperature of 18-42 °C, and 15-98% humidity ;

   (iv) all-out work with an airflow of 1.3 m/sec ; an ambient temperature of 24-45 °C, and 14-86% humidity.

   In preparation for further tests, preliminary trials have been made with airflows of 0.1 and 0.3-1.3 m/sec.

   Evaluation of the results to date has shown that a scale or index of heat stress based on the degree of sudation cannot be treated as for practical purposes interchangeable with one based on body temperature (of the rectum, ear or skin) and pulse rate.

   It is therefore all-important in any assessment of heat stress to decide whether sudation or the other physiological values constitute the better criterion. Now, if we were to take atmospheric conditions inducing the same sweat-rate (e.g. the same P4SR) as roughly equivalent, this would mean treating as identical, within the critical climatic range, conditions under which the human body retains an even heat balance and can accordingly carry on for hours, if necessary withstanding thermal stases. The sweat-rate cannot therefore be considered a thoroughly reliable criterion of heat stress. This most important conclusion marks a considerable advance in the assessment of working environments.

b) Prof. Lavenne in Belgium is experimenting in the coal sector in an endeavour to develop a simple fitness test for work at high temperatures, based on the recording of maximum aerobic capacity in normal surroundings.

   The following experiments have been carried out to verify the hypothesis that maximum aerobic capacity corresponds to maximum performance potential for high-temperature work.

   The team have studied how far the maximum oxygen consumption values established for a normal atmosphere are reproducible at different limit pulse rates as resulting from variously-graduated amounts of effort either with a bicycle ergometer or with a moving carpet. It was found, on the 5% confidence level, that the differences were statistically insignificant.

   Applied to 45 miners trained in rescue work, the effort test, scaled in a number of ways and giving a number of different and maximum pulse rates, showed

that for the subject to be passed as really fit for heavy work at high temperatures the maximum oxygen consumption must be at least :

35 ml/kg weight for 170 beats per minute ;
32 ml/kg weight for 160 beats per minute ;
30 ml/kg weight for 150 beats per minute.

The average for the best subjects was 44.2 ml/kg, and for the less good 37.9.

The maximum oxygen absorption/body weight ratio is the best yardstick for the purpose. Spirometric examinations yielded no correlation. The test can be effected in a normal atmosphere and will nevertheless accurately indicate the behaviour at high temperatures. Its only disadvantage is that it takes rather a long time, 17,5 minutes ; however, five modified test series of shorter duration showed that the maximum oxygen consumption can be established in only five minutes if the load is stepped up by 50 watts each minute.

c) Dr. Cazamian is carrying out an on-the-spot physiological study in the French coal industry on overstrain due to heat in certain types of working.

Tests in hot workings (dry temperature 31-32 °C, wet temperature 28-31 °C, ventilation 0-5 meter per second) gave the following results :

The energy-expenditure and pulse-rate values were the same whether recorded at rest in the laboratory or at work on the job. The only difference was in respiration. Individual variations in energy expenditure for a standard effort of 100 watts at the bicycle ergometer ranged from 5.2 to 7.3 kcal per min., and in recovery times following such effort from 5 to 10 minutes.

The following averages were recorded for energy expenditure, cardiac frequency and recovery time with respect to operations in a hot underground working :

Activity	Energy expenditure in kcal/min.	Cardiac frequency	Recovery time in min.
Materials handlings	4.6	96	8.6
Drilling	4.0	89	8.6
Operating Eimco 21 power shovel	6.0	96.5	11.0
Manual shovelling	6.0	90	8.1
Roof testing by pick	6.7	96.5	6.1
Propsetting	4.6	88.5	7.2

The " Eimco 21 " power shovel presented some difficulties ; its operation, and roof testing, involve substantial muscular static stresses. The individual workman's total energy output over an eight-hour shift in a stone-drift of normal temperature is approximately 2000 kcal, of which 25% is accounted for by manual propsetting. The charge hand's energy expenditure is about the same as the others'.

d) Prof. Margaria in Italy is making a laboratory study of the effects of work at high temperatures on respiratory resistances.

An apparatus has been developed for sinusoidally varying the volume of the respiratory system with a generator causing the volume to move in line with the system's resonance frequency. To calculate the system's total resistance, the air pressure/airflow ratio in the mouth was recorded during sinusoidal pressure variations of 5 c/s. The pressure on respiration is made up of the pressures needed to maintain elasticity, to overcome viscosity and to overcome inertia : as the first and third cancel one another out, only that serving to counter viscosity requires to be recorded.

The recordings were taken at rest and after 20 minutes' medium-hard work at the bicycle ergometer. The tests were first carried out at a comfortable temperature (20-24 °C), and then repeated at temperatures between 34 and 36 °C, the relative humidity being kept below 65%. The average heart rate of the subjects was 133 at 22 °C and 155 at 35 °C. The conditions thus experimentally created in the heat chamber correspond to the maximum stress to which blastfurnacemen are intermittently briefly exposed.

The respiratory-resistance values recorded at 22 °C were much the same as those at rest and during effort at 33 °C. Resistance is therefore not affected by effort or by heat. A cross-check carried out on 59 blastfurnacemen during their normal work showed no difference to speak of between respiratory resistances at the beginning and end of the shift.

e) Dr. Zannini is conducting research in the Italian steel industry on fitness and fitness criteria for work at high temperatures.

The atmospheric conditions in 13 hot jobs have been studied, and the results, entered on punched cards, are now being evaluated, together with a mass of clinical, sociological and psychological data on 250 workmen at Taranto and 250 at Genoa : by the end of 1967, the processing was almost finished at Taranto and 70% completed at Genoa. It is not possible at this stage to establish final conclusions.

f) Dr. Foehr, in collaboration with Prof. Metz, is studying work at high temperatures in the Luxembourg steel industry.

Pilot investigations with respect to blast-furnace melters showed that while as regards temperature there was no difference between the morning and afternoon shifts, the psysical stress as indicated by the heart rate appeared to be higher on the morning shift, the first melter being the most affected and the third melter the least.

In order to measure thermal stress and physiological reactions, a van has been fitted up as a mobile laboratory, enabling the men at work to be studied from close and automatic recordings made of the time taken for each activity and the corresponding cardiac behaviour. An environmental control chamber has also been installed in which the conditions can be varied as follows :

dry air temperature	22-40 °C
relative humidity	30-90%
air speed	0.2-1.0 metres par second

wall temperature . . . . . depending on the air temperature

Seven recording operations were carried out at blast-furnaces in the second half of 1967. More recently, studies have also been made of four steel-furnace jobs, observed during two shifts, and two converter operators of a converter and ferro-manganese furnace crew, also observed during two shifts. The data obtained have not yet been evaluated.

g) Owing to administrative complications, work has not yet started on a project to be undertaken by Prof. Lavenne in the Belgian coal industry on heat tolerances as indicated by the metabolic and endocrine effects of work at high temperatures.

Work amid noise

Community-sponsored research has been going on for some time on the physiological ill-effects of noise and vibration and possible improvements in protection against them. The studies currently in progress concern extra-auditory effects of noise on the organism, possibilities of early diagnosis, instruments for detecting damage, and ear protective devices. This breadth of scope makes the research particularly valuable now that noise abatement is becoming a major issue not only in industry but from the point of view of public health.

a) Prof. K. Schubert is in charge of a German project aimed at excluding all subjective factors liable to distort the results of audiometric tests.

The method employed to achieve this strict objectivity consists in recording by electro-encephalogram appropriately insulated and filtered cortical electrical potentials induced by a special noise through stimulation of the auditory system.

b) Prof. Maugeri in Italy is trying to establish which centres of the nervous system are acted upon by noise and vibration, how and at what stage these influences come into play in the development of psychical and mental fatigue, and how the neurovegetative and psychical effects can be reduced or eliminated.

Earlier experiments showed that noise brings about a change in vascular and cardiac behaviour, an alteration in breathing and deterioration in gastric secretion. When the matter was further gone into in conjunction with the question of mental fatigue, explored under another section of the research programme, it was found that noise also affects reaction times and lowers performance. It seems certain that these various changes stem from a neuro-vegetative reaction.

To find out more about how noise actually works, the team concentrated in particular on the behaviour of peripheral vascular reactivity and the electrical potentials of the skin.

In subjects who had undergone surgical excision of sympathetic ganglia in one limb, it was observed that in that limb neither vasoconstriction nor any real cutaneous potentials were produced even by a noise of 90 decibels SPL, whereas in the sound limb the normal electrical skin reaction occurred, together with vasoconstriction. From this it is clear that, for noise to produce a vasomotor effect, the post-ganglionic pathways for sympathetic impulse must be unobstructed.

In order to investigate the working of noise more fully, the research was extended to include the behaviour of the diencephalic centres when inhibited with mebutamate or stimulated with centrophenoxin.

In all the subjects who, prior to medication, reacted to noise by marked vasoconstriction, administration of mebutamate resulted in complete absence of angio-spasmodic reaction. With centrophenoxin, which increases the alertness and reactivity of the diencephalon, the angio-spasmodic reaction to noise was, in contrast, greater and more prolonged, similar to electrical skin reaction.

This would appear to indicate that noise acts specifically on the diencephalic centres, which receive, process and transmit the stimulus both to the cortex and to the vegetative centres.

Next, other substances acting specifically on the diencephalon were used : it was found that those reducing the sensitivity of the reticular matter made for less marked vascular reaction to noise, while those increasing it made for more marked and longer-lasting ones.

The diencephalon being the seat of all kinds of vital functions, research was further instituted into the fertility of persons exposed to noise. A survey of metal-workers showed very low fertility in couples one or both of whom worked under exceptionally noisy conditions (90 db and over).

Further investigations on this point, and also a series of in vitro experiments, are in progress.

c) Dr. van Laar in the Netherlands is working on the detection of occupational deafness by a simplified audiometric process, analogous with the one- and two-tone screening recommended for the octave audiometer.

In Dutch industry, occupational deafness is usually traced by means of an individual audiometer (the Peekel, models D2 and D4), which detects even incipient hearing loss confined to narrow frequency ranges and outside the ranges of the conventional octave audiometers in current use.

In the course of the audiometric research to date, Dr. van Laar has prepared a detailed anamnesis of occupational ear, nose and throat conditions. To establish appropriate selection criteria, use was made of audiograms of workers in whom any hearing loss was due exclusively to the effects of noise, the subjects being classified by degrees of noise exposure.

Of the 1,241 workers tested, 18% had a positive history and were still suffering from active morbid phenomena. Ear damage was hardly ever on one side only : in 97.4% of cases it was on both.

The results of a 15 db test within a fairly limited frequency range but in the third octave, around 4000 c/s, have also been published. A study is now being made of the performance that can be obtained with the noise at greater strength but in a limited range of frequencies.

d) Another project under Dr. Flora van Laar and Dr. Lindemann is concerned with aptitude by means of simplified speech audiometry.

Industrial medical officers do not usually possess the necessary equipment for making speech audiograms, and so have often to decide empirically whether the hypacousia recorded is a handicap to the worker in coping with his environment.

A simple apparatus has now been devised which will quickly establish whether the subject is able to catch the spoken word properly even under adverse conditions. This speech audiometry enables the works doctor to ascertain the exact state of the worker's hearing as regards conversation : any reduction in discernment can be expressed by a single figure.

The team have also studied the relation between the sound audiogram and the speech audiogram, and have worked out correlation coefficients between the two methods.

The results are considered most encouraging, and it is urged that every audiological unit should obtain an industrial speech audiometer.

The team are now engaged in checking as to the margin of error, if any, in the data relating tot speech audiometry as conducted in industry.

e) Prof. Wisner in France is also investigating the subject of work amid noise : a short account of his research will be found under " Applied Ergonomics. "

Vibration

A number of projects are in hand on ways of improving working conditions and performance on jobs involving potentially injurious levels of vibration. The subject is, as we have seen, closely bound up with that of biomechanics and postural stresses.

a) Dr. Ing. Coermann in Germany is conducting research on the construction of an " active " shock-absorber for the seats of certain industrial vehicles, the usual types of seat being very uncomfortable in this respect owing to the sharp accelerations at the lowest frequencies.

It is considered that the answer might be to have the seat positioned at 180° to the vehicle's acceleration. The idea is to use an electrohydraulically-driven piston to be controlled by an accelerometer built into the vehicle, and the mean position of the seat in relation to the vehicle kept constant by a regulating device.

The necessary calculations have already been made and the mechanism designed.

It is planned to apply the system to a tractor seat.

When it is ready, various other direct tests will be carried out, by which time the electronic regulator will also have been developed.

b) Dr. Ing. Coermann is also in charge of a second set of studies, on the effects of sinusoidal vibrations on the hand and arm, more especially in function of their frequencies.

Possible physiological criteria for assessing vibration tolerances are variations in the skin temperature of the hand subjected to vibration, the pulse rate in the fingers of the other hand, and any alterations in the periosteal reflex.

From a study of these it is hoped to formulate international guidelines as to the permissible vibratory stresses on workers' upper limbs.

c) Prof. Wisner in France is working on a criterion of tolerance to low-frequency vibrations by which to judge the value of planned improvements in the suspension and seating of industrial vehicles.

A survey has been carried out at a number of coal and iron-ore mines, where it was found that the anti-vibration equipment was defective in certain respects, the main trouble in these cases being 2 c/s oscillations, with the vertical component preponderant.

Meantime, in the laboratory, the team have been studying the behaviour of the skeletal muscular tissue when the body is subjected to low-frequency vibrations. By electromyography it has been shown that a rhythmic activity, in time with the vibrations when these are at frequencies of around 2-3 c/s, replaces the normal at-rest tonic activity.

Another experiment in which the subjects were exposed to vibration from a special oscillating table revealed considerable deviations from normal in the oxygen-consumption and ventilation values.

Applied ergonomics

The work in this connection consists partly of individual projects of the kind dealt with in the foregoing sections, and partly of " common " research as described further on. The individual projects are mainly concerned with improving auditory and visual perception.

a) Dr. Burkardt's project in the German steel sector, aimed at the improvement of visual conditions on quality-control jobs, includes both laboratory and field research. From a survey comprising on-the-spot tours and talks to specialists, it was found that jobs where lighting was especially important were those of sheet-mill sorter, roll grinder and travelling-crane driver in the annealing shop, the main points to be borne in mind being :

(i) relative luminosity threshold (detecting spot-type surface defects) ;

(ii) visual acuity (detecting punctiform defects and hairline cracks) ;

(iii) depth perception (relative distance between the craneload and the deposit area).

On the basis of these field data, the team selected a number of visual tests, including tests charts, small differences in brightness and tests of stereoscopic vision. 64 apprentices were subjected to these before and after prolonged activity involving visual exertion, in the form of 30 minutes spent gauging angles on steel block with a universal goniometer ; the lighting conditions were varied, as to type of lamp, candle-power and source brightness.

The main results were as follows :

1) The sodium-vapour lamp is greatly superior to other types of lighting from the point of view of visual acuity ; the incandescent lamp is the least satisfactory.

2) There appears to be no difference among the types of lamp as regards the relative threshold for differences in brightness.

3) As expected, the brighter the objects the better the vision ; the optimum level is reached sooner with the sodium-vapour than with other lamps (approx. 150-270 asb).

4) Stereoscopic vision could not be shown to be affected by the lighting conditions.

5) Accuracy of operation (in the angle gauging) could not be proved to be influenced by the lighting, individual differences being too great. Only the actual amount done, which can be regarded as indicative of attitudinal set, was noticeably larger at higher brightness levels.

6) Though the subjects' likes and dislikes with regard to the different types of lamp could not be statistically computed, the sodium-vapour lamp was definitely unpopular, as it has also been found to be in other sectors.

From these experimental findings, Dr. Burkardt goes on to make a number of recommendations concerning workplace illumination. His conclusions are in substance as follows :

1) For the jobs of sheet sorter and roller adjuster, sodium-vapour lightings is best ; brightnesses of 200-300 asb. should be aimed at. Account should, however, be taken of the men's dislike for it, though this is probably no more than prejudice, as neither in published material on the subject nor in Dr. Burkardt's own experiments has any evidence been found that sodium-vapour lighting is more tiring or otherwise adversely affects the vegetative functions.

2) In the matter of stereopsis, which is of importance for crane drivers, further research will be necessary.

3) The point brought out by the tests that the stimulant (performance-enhancing) effect of light may result not from the actual intensity of the illumination, but from spectral composition in the field of vision, should also be gone into further.

b) Prof. Wisner is conducting research in French industry on individual anti-noise equipment (helmets and ear plugs) and how it works in practice. The project is in three parts :

(i) investigation of speech intelligibility amid noise ;

(ii) physical assessment of the filtering effect by means of a sonograph ;

(iii) field checks as to the effectiveness of certain items of protective equipment.

The protection afforded by such devices has in the last twenty years or so usually been worked out by making first a tone audiogram for a subject wearing one, followed by a second audiogram for the same subject with ears uncovered, the difference between the two giving the degree of protection.

In point of fact, however, the devices are used amid a tremendous din, and it is necessary to ascertain what can and cannot be heard through them against this background of noise.

The team established that the muting effect observed at the threshold level was still in evidence at a noise level as high as 95 db, but that perception of tone and voice stimuli was much better amid intense noise than the threshold recording would have suggested.

Thus in making an audiogram amid silence with the subject wearing a protective helmet the speech level has to be raised by an average 22 db, whereas amid considerable noise it can actually be lowered by 8 db.

Anti-noise equipment used to be objected to on the ground that speech and various acoustic signals could not be heard. It now seems clear, however, that helmets and ear plugs simultaneously shield the wearer against background noise and assist perception of superimposed stimuli.

The sonograph recording, obtained by placing microphones inside the helmets and at the same distance from the ears of unhelmeted subjects, indicates that the audiometric results just described are probably of physical and not of physiological origin : the characteristic patterns of speech stand out more clearly from the sound background with the helmeted than with the unhelmeted subjects, while the reverse is found when the recordings are made amid silence.

Preparations have been made at iron-ore mines and collieries for the forthcoming field studies there.

Research by direct arrangement

Four areas of research were chosen in 1966 and the preparatory work begun : mental effort (with special reference to monitoring in automated processes), work at high temperatures (with special reference to protective clothing), round-the-clock operation in the steel industry, and ageing (with special reference to technological advances and redeployment of personnel).

Mental effort

The project undertaken by Dr. Kalsbeek, Prof. Leplat and Prof. Schmidtke is proceeding normally. The approach is the same as that adopted in the individual projects on mental activity (see above) ; the studies are being conducted in the automated sectors of the Dutch, French and German steel industries.

Several methods for assessing the mental work load involved by man/machine systems have been worked out and tested. The particular aspect selected for investigation is mental effort in remote control work, an activity considered certain to grow in importance with the march of automation : it is planned to make a thorough analysis of the duties of a circulation controller and a controller of a highly-automated process, such as blast-furnace operation.

Each team has its own methods and special lines of study. The French team under Prof. Leplat have specialized in job analysis, work organization, communication

and training, and the German team under Prof. Schmidtke in psychological and physiological assessments of fatigue and evaluation of subjective experience ; the Dutch team are doing checklist analyses, double-task studies and laboratory simulations of fatigue effects. While it is of course the idea that the projects as a whole should have the benefit of these different specializations, there will, however, be a single standard procedure for the on-the-spot job analysis and physiological and psychical recording of the research proper.

The plan of action is as follows. First, each team will make a detailed analysis of the job in accordance with its own special methodology. Next, the three teams will compare notes on their findings, on the basis of which they will make a comparative study of the present position in the different countries with regard to job adaptation in the sphere of monitoring, and will work out a standard method of analysis incorporating all elements that have been found useful in seeking to assess the mental effort involved in remote control duties. This standard method will then be applied in all three countries, researchers being switched among the three teams if necessary. In addition, physiological recordings will be effected by agreed standard methods. Methods of psychological assessment during and after effort, such as subjective evaluations and double-job tests, will also be studied, German and Dutch researchers meeting to discuss and agree standard procedures. As the French team have not the necessary equipment, physiological recordings in France will be carried out by their Dutch colleagues. Next, laboratory simulations will be mounted of the job elements found to be more especially responsible for the mental effort required, in order to study these in more detail. Since mental strain can be caused either by too many or by too few stimuli, it is hoped that these studies will suggest some possibilities for helping to ensure a balanced mental work load in control jobs. The simulations will be conducted by the German and Dutch teams. The French team will concentrate on drawing relevant conclusions as to the better organization and adaptation of the job from the thorough analyses made, and will also study the training and selection aspects.

The full findings of all three teams will be embodied in a joint final report.

The liaison and secretarial side of the work will be attended to by Dr. Kalsbeek's Applied Research (TNO) Ergonomic Psychology Laboratory in Amsterdam.

As a start, Prof. Leplat and Prof. Schmidtke have assembled a corpus of bibliographical reference material in order to obtain details of the relevant information and methods and of research already carried out in this connection. The French team's part of the documentation centred on remote control, Prof. Schmidtke's on all objective methods of fatigue assessment. The teams also contacted steel companies in their respective countries, and test jobs were chosen according as the companies were able to offer observation facilities.

Prof. Leplat has in addition made a study of the past development of remote-control technology from its inception, and Prof. Schmidtke of the various methods of machine-processing of physiological data recorded at work.

Dr. Kalsbeek has been doing comparative research on methods of assessing sinus arrythmia (the regular waxing and waning of the pulse rate) under the influence of mental stress, with a view to computer programming. His work on objective assess-

ment of mental fatigue, though part of the joint project, is somewhat aside from the main stream of the research.

He is studying the breakdown of complex activities by a method he has named " experimental distraction. " By progressively occupying the capacity of the single central channel on a binary-choice job, the amount of attention left over for devoting to a second job can be systematically varied. Tests have been conducted with 50 subjects who were given as their second job the writing of a text on a theme of their own choice : in this way it is established which elements of thought and psychomotor activity disappear first and which stand up better to stress, the texts produced being subjected to quantitative analysis. In a second stage, it is planned to induce real states of increasing fatigue, instead of experimental distraction, in the same subjects : where the effects prove identical, it will be possible to express a state of fatigue as a given number of experimental-distraction binary choices. The basis hypothesis is that the effects of central fatigue are due mainly to reduction in the capacity of the single central channel.

Work at high temperatures (protective clothing)

This project, though approved some time ago by the High Authority, has been held up by a variety of administrative and technical complications, including in particular the setting-up of Prof. Metz's new bioclimatic laboratory. The researchers are to meet at an early date.

Round-the-clock operation in the steel industry ; repetitive activities

The working party of experts from the industry who were to have settled the aims of the projects on round-the-clock operation, which a selection of specialized centres were then to be commissioned to carry out, was not able to meet in 1967. Meantime, however, attention has been drawn to another, allied problem, namely the study of jobs involving repetitive or serial activities, which is coming up in new forms in connection with current developments in the manufacturing industries, more especially in the electrical-engineering and electronics sectors.

Ageing

Here again it has not yet been possible to make a definite start. The experts emphasize the notable change in working capacities with age, particularly given the steadily-increasing mental work load involved in so many present-day jobs, and the importance of appropriate job adaptation in order to obviate the need for premature redeployment of the workers.

The change with age is not the same for physical and for mental activities : men on jobs with a high mental content begin to have difficulty in coping even between 35 and 40, and indeed sometimes earlier still. Yet in consequence of technological advance, jobs with a constantly higher mental content are coming into being. Every time there is a big technological break-through, which is roughly every five to ten years, in any one industry, the result is, unless proper steps have been taken in the matter of job adaptation, that the industry concerned loses the services of a large section of its personnel aged between 35 and 40 who cannot be retrained (inability to follow symbols, to keep up with the work, etc.).

It is important, therefore, that new jobs should be planned with an eye to workers' changing mental capacities.

"Common" ergonomic research

As was noted in last years's progress report, the aim here is to work out, on the basis of existing knowledge, pratical proposals for the adaptation of certain typical jobs in the mining and steel industries to produce work situations at once satisfactory to the men and calculated to make for top efficiency economically. The financing arrangements were approved by the High Authority in 1967

The three research teams set up have been carrying out necessary groundwork, in co-operation with the appointed scientific advisers, Prof. Rohmert and Prof. Wisner, and with the Luxembourg "Société des sciences médicales."

On two studies prepared by the French coal team, the first concerns the use of mental props (including transport and handling), stresses involved, possible improvements as regards job adaptation and organization, and problems arising out of the employment of elderly men for this work ; the second is to be a contribution to the planning in human-engineering respects of a new thermal power-station.

The Dutch coal team have prepared five studies, all having to do with underground railway systems. The subjects covered are radio communication with engine-drivers, traffic signalling, an analysis of the duties of the head transport switchboard man, automation of one of his subsidiary duties, and telecommunication at the face—all matters having ergonomics as well as organizational and technical aspects.

The Dutch steel team have prepared seven studies, on seven carefully circumscribed points, namely the work load of converter bricklayers, the effectiveness of protective clothing against heat stress and its wearability in practice, the improvement of warning and information signals from locomotives, the work load in furnace repair work, scope for improvement in jobs relating to the quality control of the surface of rolled steels, the work load of billet trimmers, and the work load of cooling-bed testers.

Representatives of the German coal and steel employers' federations, the Steinkohlenbergbauverein and the Wirtschaftsvereinigung Eisen- und Stahl-Industrie, and Prof. Metz on behalf of the French steel industry, are holding a watching brief on developments.

A report drawn up by Prof. Rohmert and Dr. Schaich following the preparatory investigations, describing the ergonomic research establishements in German industry, has been issued in a provisional edition.

ANNEXES

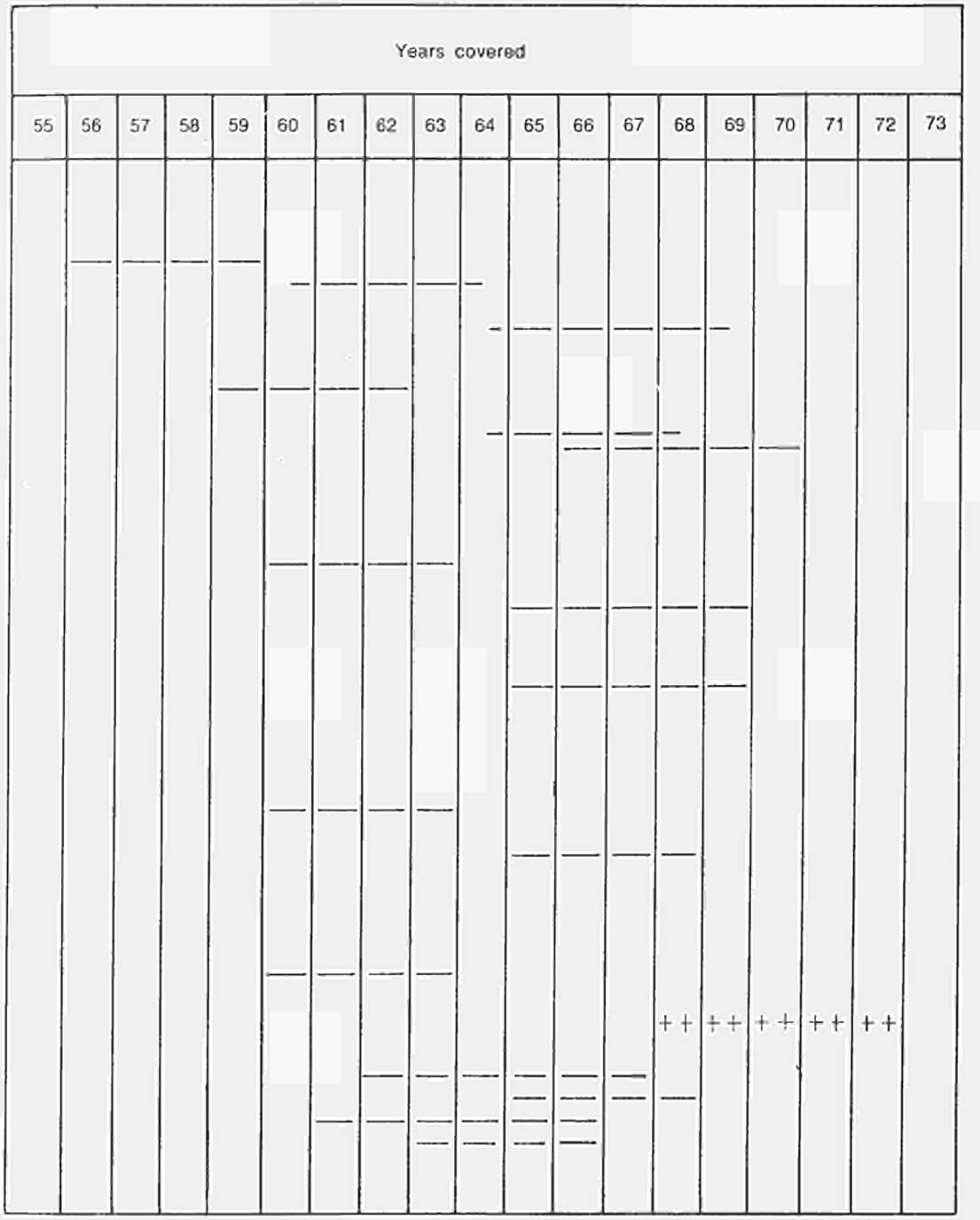
I—Recapitulatory table of research programmes on industrial

Area and title of programme	Approved on	Financial assistance (dollar units of account, roundes figures)	
		Total allocated	Amount committed
A. *Industrial health and medicine*			
a) Physiopathology and clinical medicine			
1st programme (Industrial medicine)	5 October 1955	1,200,000	1,200,000
2nd programme (Industrial medicine)	7 April 1960	2,800,000	2,700,000
3rd programme (Physiopathology and clinical medicine)	28 April 1964	3,000,000	2,300,000
b) Traumatology and rehabilitation			
1st programme (Rehabilitation)(1)	5 December 1957	500,000	500,000
2nd programme (Traumatology and rehabilitation)	19 June 1964	1,800,000	1,100,000
3rd programme (Burns)	18 May 1966	1,500,000	6,000
B. *Industrial physiology and psychology*			
a) Human factors and safety			
1st programme (Human factors and safety(1)	5 December 1957	1,000,000	1,000,000
2nd programme (Human factors and safety)(2)	4 November 1964	1,200,000	600,000
b) Ergonomics			
1st programme (Industrial physiology, psychology and job adaptation)(2)	4 November 1964	2,000,000	800,000
C. *Industrial health*			
a) Dust prevention and suppression in mines			
1st programme (Dust prevention and suppression in mines(1)	5 December 1957	900,000	900,000
2nd programme (Dust prevention and suppression in mines)	21 December 1964	6,000,000	4,300,000
b) Dust prevention and suppression in the iron and steel industry			
1st programme (Dust prevention and suppression in the iron and steel industry)(1)	5 December 1957	600,000	600,000
2nd programme (Dust prevention and suppression in the iron and steel industry)	14 June 1967	4,000,000	1,000
c) Sundry research projects			
Converter gases (brown smoke)	18 July 1961	1,000,000	800,000
Converter gases (brown smoke)	19 June 1964	1,825,000	1,000,000
Atmospheric conditions in mines	16 March 1966	116,000	116,000
Defluorization of gases	16 March 1966	66,000	66,000
Total		29,507,000	17,989,000

(1) Part of a single financial-aid programme under the general heading of "Safety", comprising four smaller programmes.

(2) Part of a single financial-aid programme under the general heading of "Human Factors and Ergonomics", comprising two smaller programmes.

medicine, health and safety : position as at 1 January 1968



Legend :
——— Programmes completed or in progress
+ + + Programmes in preparation

II – Research Programme on Industrial Physiology and Psychology

a) Human Factors and Safety

A – *General studies*

A – 1. Assessment of safety ratings and individual and group safety achievement criteria
A – 2. Studies on causes and circumstances of accidents

B – *Personnel selection and guidance as affecting safety*

B – 1. Physiopathological aspects of selection and guidance (including in particular subclinical states)
B – 2. Guidance and redeployment of physically and psychically-handicapped workers
B – 3. Guidance and redeployment of eldery workers
B – 4. Migrant workers
B – 5. Inventory of selection and guidance methods used in the mining and steel industries

C – *Training as affecting safety*

(including in particular the study and assessment of group safety training)

D – *Individual safety equipment*

D – 1. Psychological aspects of the use of individual safety equipment. Possible ways of promoting more extensive use
D – 2. Possible improvements in design, to make models more capable of meeting physiological demands and other requirements of miners' and steelworkers' jobs

E – *Work load and work/break rhythms as affecting safety*

E – 1. Influence of the work load on safety (tempo, stress, monotony, alertness)
E – 2. Influence of the work/break rhythm on safety (within time-off allowed during the shift, in the division of the working day, over an extended cycle of shifts)
E – 3. Influence of continuous operation on safety (selection and training of suitable personnel for such work, influence of age on ability to adjust thereto, sociological elements involved in such adjustement)

F – *Relations between the worker and the work situation as affecting safety*

F – 1. Perception of stimuli (especially danger signals) as affected by environmental sensory loads (noise, vibration, lighting, etc.)
F – 2. Compatibility of operational processes or directions with perceptional and psychomotor faculties (especially reflexes)
F – 3. General structure and organization of the work and working environment (planning of jobs, design of installations, layout of premises, etc.)
F – 4. Psycho-sociological problems with respect to the make-up, stability and cohesiveness of gangs, crews, etc. (in particular size of the gang, alternation of gangs on continuous operation, ethnic origin and language of the men)
F – 5. Managerial attitudes to safety

b) Ergonomics (industrial physiology and psychology, job adaptation)

1. *Physiological and psychological demands and effects of work*

11. General studies

111. Short-term effects of work (given the nature, duration and intensity of the work)
Effects of job rotation
Effects of particular stresses in particular jobs

112. Fatigue in industry
Effects on the nature, duration, intensity, tempo and conditions of the work ; detection, prevention and treatment of fatigue
Psychical manifestations of physical fatigue
Objective pinpointing of mental fatigue

113. Long-term effects of work
Effects in certain strenuous jobs
Effects as regards ageing, disability and life expectancy (statistical, biological and psychological research)

12. Specific studies

121. Work at high temperatures
Aptitude, including aptitude criteria, for work at high temperatures
Simple test to establish aptitude for work at high temperatures
Tolerance limits in workers at high temperatures, given the environmental conditions (radiation, convection, temperature, humidity, air speed) and work load
Protective measures with respect to work at high temperatures
a) environmental, viz. walls, screens, air conditioning
b) individual, viz. protective clothing (type of fabric, how washed or cleaned, skin tolerance thereto)

122. Work amid noise
Simple audiometric method and apparatus to enable the ordinary industrial practitioner to make quick and objective assessments
Noise abatement
a) at source
b) by environmental measures
c) by individual anti-noise equipment

123. Vibration
Vibration transmitted to the upper limbs by the various types of pneumatic pick ; ways of reducing this
Criteria for establishing tolerance to vibration transmitted via the hands
Suspension and seating of material-handling vehicles

124. Working postures
Unaccostumed postures (crouching, kneeling, semi-recumbent)
Static effort, especially in the use of heavy implement, such as pneumatic picks

125. Objective symptoms of interference with the regulating mechanism, affording pointers as to fitness for duty in steelworkers

126. Demands and effects of mental activity in watching and control jobs
Data reception and handling
Possible adaptations

127. Demands and the question of age
Demands imposed by certains jobs in which age is of special relevance ; possible adaptations whereby the men concerned could be kept on at these jobs

2. *Adaptation of certain jobs, bearing in mind the physiological and psychological demands, and employing, inter alia, multidisciplinary and ergonomics methods*

NOTE : A number of jobs have been listed by the mining and steel industries as calling for adaptation in view fo the various stresses they involve, and which should where possible be reduced, viz. effort, postures, noise, vibration, heat, fumes, atmospheric conditions, lighting, high mental work load, psychological tension, irregular working tempos with intermittent overstrain, etc.

III — Projects in hand under the programme on industrial physiology and psychology

a) 2nd programme on human factors and safety (as at 1 January 1968)

Individual projects (16 projects)

Personnel selection

Dipl.-Psych. G. BÄUMLER
Psychologisches Institut der Universität Würzburg

Preparation and validation of a series of tests for selecting workers for supervisory and control jobs in industry (Project No. 12/015)

Dr. M. CANTIANT
Laboratoire de psychologie appliquée, Metz

Detection of specific aptitudes for crane driving (Project No. 12/014)

Training

Prof. M. BOLLE DE BAL and M.P. FELDHEIM
Institut de Sociologie de l'Université libre de Bruxelles

Occupational training as it affects safety (Project No. 12/009)

Prof. G. IACONO
Istituto di Psicologia dell'Università di Napoli

Validation of psychological advanced training for supervisory personnel with respect to accident prevention (Project No. 12/018)

Prof. G. SPALTRO
Istituto di Psicologia dell'Università Cattolica di Milano, Milano

Effects of advanced safety training for supervisory personnel (Project No. 12/030)

Dr. J. JONGH
Stichting voor toegepast sociaal-agolegisch en sociaal-psychologisch onderzoek, Amsterdam

Safety training in elementary technical education (Project No. 12/029)

Individual safety equipment

Dr. G. DE COCK
Psycho-medico-sociaal Studiecentrum, Leuven

Use of individual safety equipment by workers acting independently and interdependently (Project No. 12/028)

Ing. R. RAMEAU
Cerchar et Houillères du bassin du Nord-et-Pas-de-Calais, Mazingarbe
Ergonomic study of a portable anti-coniosis fan (Project No. 12/034)

Prof. M. CESA-BIANCHI
Istituto di Psicologia della Facoltà Medica, Università degli Studi, Milano
Behaviour regarding use of individual safety equipment ; development of a method of promoting such use (Project No. 12/004)

Dr. G. GIRARD
Torino
Emotional elements in workers/management relations with regard to use or non-use of individual safety equipment (Project No. 12/001)

Job adaptation, environmental side

Dr. P. CAZAMIAN
Cerchar (Cerem) et Houillères du Bassin de Lorraine, Merlebach
Detection of auditory fatigue in workers at a colliery, effects on safety, possible ergonomic remedies (Project No. 12/035)

Ir. R. PLOMP
Instituut voor Zintuigfysiologie R.V.O.-T.N.O., Soesterberg
Influence of intrusive noises on sense of direction (Project No. 12/020)

Job adaptation, organizational side

Prof. W. ROHMERT
Institut für Arbeitswissenschaft, Technische Hochschule, Darmstadt
Influence of work load on safety (Project No. 12/039)

M. de MONTMOLLIN
Société d'Études de Mathématiques appliquées, Paris
Methods for computing the work load in primarily watching jobs (Project No. 12/008)

Dr. W. WINSEMIUS
Nederlands Instituut voor Preventieve Geneeskunde, Leiden
Experimental research on job structures in given work situations and operations as they affect safety (Project No. 12/021)

Prof. F. MERZ
Institut für Psychologie der Philipps Universität, Marburg/Lahn
Performance of voluntary movements and adjustment of these in accordance with results of movement (Project No. 12/038)

Direct-arrangement projects

Organization and safety (3 projects ; 1 project planner)

Prof. M. CESA-BIANCHI
Istituto di Psicologia della Facoltà medica dell'Università studi di Milano, Milano

Prof. J.M. FAVERGE
Laboratoire de psychologie de l'Université libre de Bruxelles, Bruxelles

Prof. J. LEPLAT
Laboratoire de Psychologie appliquée de l'École des Hautes Études, Paris

Safety in relation to enterprise structure and organization (Projects Nos. 11/001, 11/002, 11/003 and 11/004)

b) 1st programme on ergonomics (as at 1 January 1968)

Individual projects (32 projects)

Physical effort

Prof. W. ROHMERT
Institut für Arbeitswissenschaft - Technische Hochschule, Darmstadt
Effects of stresses arising in given jobs (Project No. 22/007)

Prof. B. SCHULTE
Institut für Arbeitswissenschaft - Technische Universität, Berlin
Optimum individual work intensity in jobs forming part of mechanical processes (Project No. 22/004)

Dr. F. LAVENNE
Institut d'Hygiène des Mines, Hasselt
Effects of nature, hours, intensity, rate and conditions of work upon fatigue (Project No. 22/056)

Dr. TARRIERE
Laboratoire de Physiologie et de Biomécanique de la ENUR, Rueil-Malmaison
Contribution to study under actual conditions of physiological cost of shop-floor work (Project No. 22/053)

Prof. R. MARGARIA
Istituto di Fisiologia Umana dell'Università di Milano
Maximum working capacity in aerobiosis and anaerobiosis of workers in heavy industry (Project No. 22/017)

Prof. R. MARGARIA
Istituto di Fisiologia Umana dell'Università di Milano
Assessment of amount of anaerobe work and its effects on the organism (Project No. 22/040)

Biomechanics and postural stresses

Dr. H.G. SCHMIDT
Institut für Arbeitswissenschaft, Technische Universität, Berlin
Characteristics of a tiring posture ; introduction to job adaptation for optimum posture (Project No. 22/005)

Dipl.-Ing. H. SCHNAUBER
Max-Planck-Institut für Arbeitsphysiologie, Dortmund
Fatigue causes by activity having to be performed above worker's head (Project No. 22/047)

Prof. C.P. ODESCALCHI
Istituto di Medicina del Lavoro dell'Università di Pavia
Unaccostumed working postures (Project No. 22/009)

Mental activity

Mr. de MONTMOLLIN
Société d'Études de Mathématiques appliquées, Paris
Data handling in monitoring under emergency conditions (Project No. 22/030)

Dr. P. CAZAMIAN
Cerchar (Centre d'Études et de Recherches ergonomiques minières), Mazingarbe
Electrical brain activity under simulated conditions of mental activity and mental fatigue, and as found in automated industrial operations (Project No. 22/051)

Prof. R. MISITI
Istituto Nazionale di Psicologia del Consiglio Nazionale delle Ricerche, Roma
Learning under uncertainty as to correct response (Project No. 22/035a)

Dr. SCHULZE
Max-Planck Institut für Arbeitsphysiologie, Dortmund
Objective criteria for assessing perception of light stimuli, taking into account the sensory load (Project No. 22/039)

Mental fatigue

Prof. H. SCHMIDTKE
Institut für Arbeitspsychologie und Arbeitspädagogik der Technischen Hochschule, München
Psychical manifestations of physical fatigue (Project No. 22/049)

Prof. M. SALVINI
Istituto di Medicina Preventiva dei Lavoratori e Psicotecnica dell'Università di Pavia
Objective determination of mental fatigue from a psychophysiological angle (Project No. 22/032)

Prof. P. VERHAEGEN
Possible impairment of psychical activity in work at high temperatures ; tolerance limits ; an aptitude test (Project No. 22/033)

Work at high temperatures

Dr. H.G. WENZEL
Max-Planck Institut für Arbeitsphysiologie, Dortmund
Influence of air speeds on physiological reactions of men working at high temperatures (Project No. 22/046)

Dr. F. LAVENNE
Institut d'Hygiène des Mines, Hasselt
Simple test to determine fitness for work at high temperatures (Project No. 22/055)

Dr. F. LAVENNE
Institut d'Hygiène des Mines, Hasselt
Tolerance limits with respect to work at high temperatures, as indicated by metabolic and endocrine reactions to such work (Project No. 22/054)

Dr. P. CAZAMIAN
Cerchar (Cerem), Houillères du Bassin de Blanzy, Montceau-les-Mines
Physiological aspects of overstrain due to high temperatures in certain colliery workings (Project No. 22/050)

Prof. R. MARGARIA
Istituto di Fisiologia dell'Università di Milano
Effects of high temperatures on respiratory resistances (Project No. 22/006)

Prof. D. ZANNINI
Istituto di Medicina del Lavoro dell'Università di Genova
Fitness and fitness criteria for work at high temperatures (Project No. 22/021)

Dr. R. FOEHR
Service de Médecine du Travail, ARBED, Dudelange
Work at high temperatures (Project No. 22/003)

Work amid noise

Prof. K. SCHUBERT
Universitäts-HNO-Klinik, Bonn
Objective audiometry (Project No. 22/031)

Prof. S. MAUGERI
Istituto di Medicina del Lavoro dell'Università di Pavia
Mechanism of action of noise and vibration on mental fatigue, and tolerances to these influences (Project No. 22/010)

Dr. F. VAN LAAR
Nederlande Instituut voor Preventieve Geneeskunde, Leiden
Detection of occupational deafness by a simplified audiometric process (Project No. 22/027)

Dr. F. VAN LAAR
Nederlands Instituut voor Preventieve Geneeskunde, Leiden
Simplified speech audiometry, to determine communication capacity (Project No. 22/028)

Vibration

Dr. Ing. R. COERMANN
Max-Planck-Institut für Arbeitsphysiologie, Dortmund
Possible improvements to shock-absorption capacity of vehicle seats (Project No. 22/026)

Dr. Ing. R. COERMANN
Max-Planck-Institut für Arbeitsphysiologie, Dortmund
Effects of sinusoidal vibration on the upper limbs, taking the frequencies into account (Project No. 22/019)

Prof. A. WISNER
Laboratoire de Physiologie du Travail du CNRS, Paris
Development and validation of a criterion of tolerance to low-frequency vibrations (Project No. 22/025)

Applied ergonomics

Dr. F. BURKARDT
Hauptabteilung Arbeitsschutz der Salzgitter Hüttenwerk AG., Salzgitter
Reduction of strain in various jobs in the steel industry by new types of lighting (Project No. 22/041)

Prof. A. WISNER
Laboratoire de Physiologie du Travail du CNRS, Paris
Filtering properties of individual anti-noise equipment ; audibility of speech ; longterm tolerance of the devices (Project No. 22/024)

Direct-arrangement research

Mental effort (3 projects ; 1 project planner)

Dr. J.W.H. KALSBEEK
Laboratorium voor Ergonomische Psychologie TNO, Amsterdam

Prof. J. LEPLAT
Laboratoire de Psychologie appliquée de l'École pratique des Hautes Études, Paris

Prof. Dr. SCHMIDTKE
Institut für Arbeitsphysiologie und Arbeitspädagogik der Technischen Hochschule, München
Mental work load in jobs connected with control of automated processes in the iron and steel industry (Projects Nos. 21/01, 21/02, 21/03 and 21/04)

"Common" ergonomic research (11 projects ; 2 advisers)

Prof. F.H. BONJER
Afdeling Arbeidsgeneeskunde, Nederlands Instituut voor Preventieve Geneeskunde, Leiden
Work load of converter bricklayers (Project No. 6242/23/05, Study No. 1)
Effectiveness of protective clothing against heat stress, and wearability in practice (Project No. 6242/23/05, Study No. 2)

Improvement of warning and information signals from locomotives (Project No. 6242/23/05, Study No. 3)

Ergonomic study of work load of billet trimmers (Project No. 6242/23/05, Study No. 4)

Possible improvements in jobs concerned with quality control of surface of rolled steels (Project No. 6242/23/05, Study No. 5)

Dr. P. CAZAMIAN
Centre d'études et recherches des charbonnages de France, Centre d'études et recherches ergonomiques minières, Paris

Problems arising out of use of metal props in mines (including transport and handling), stresses involved, possible improvements as regards job adaptation and organization, problems arising out of the employment of elderly men for this work (Project No. 6242/23/03, Study No. 2)

Dr. G.B.L.M. KOENE
Sector Psychologie en Personeelsresearch, NV Nederlandse Staatsmijnen, DSM, Heerlen

Radio communication with engine-drivers below ground (Project No. 6242/23/04, Study No. 1a)

Signalling of rail traffic below ground (Project No. 6242/23/04, Study No. 1b)

Automation of a subsidiary task of the head transport switchboard man (Project No. 6242/23/04, Study No. 1c)

Telecommunication at the face (Project No. 6242/23/04, Study No. 2)

Prof. W. ROHMERT
Lehrstuhl und Institut für Arbeitswissenschaft der Technischen Hochschule, Darmstadt

Prof. A. WISNER
Chaire de Physiologie du Travail et d'Ergonomie, Conservatoire National des Arts et Métiers, Paris

Assistance to the European Commission with the co-ordination of the "common" ergonomic research (Project No. 6242/23/01)

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