EUROPEAN COAL AND STEEL COMMUNITY

Community Ergonomic Research

DOC. Nº 1396/72 e RCE

Original : French

Translations : Dutch, German
Distribution : Enterprises

Summary of
technical report nº 8

DESIGN CONCEPT OF A THERMAL POWER STATION : ERGONOMICS CONTRIBUTION

(S U M M A R Y)

Source : Ergonomic team of the French coal mining industry
Project nº 2

Author : Dr. P. CAZAMIAN

Reference period : 1.1.1968 - 31.12.1970

65.015

EUROPEAN COAL AND STEEL COMMUNITY

Community Ergonomic Research

DOC. N° 1396/72 e RCE

Original : French

Translations : Dutch, German
Distribution : Enterprises

Summary of
technical report n° 8

DESIGN CONCEPT OF A THERMAL POWER STATION : ERGONOMICS CONTRIBUTION

(S U M M A R Y)

Source : Ergonomic team of the French coal mining industry
Project n° 2

Author : Dr. P. CAZAMIAN

Reference period : 1.1.1968 - 31.12.1970

Financial assistance was provided for this study by the European Coal and Steel Community

1.2.1

CECA: 787

DESIGN CONCEPT OF A THERMAL POWER STATION :

ERGONOMICS CONTRIBUTION

(S U M M A R Y)

N O T E

As part of the Community Ergonomics Research Programme sponsored by the Commission of the European Communities, the Ergonomics Study and Research Centre of the French Coal Board (Charbonnages de France) cooperated in the design of a new thermal power station at a coal-field in central France.

The relevant studies have been described in a 200 page report by Mr. Y. CHICH and Mr. G. FAURE. I was asked to summarize the main results in this short document. The following aspects will be considered in succession: the methods used in the study (section I), the two operating modes (automatic and manual) for a power station (II) and analysis of the control room supervisor's duties (III); subsequent sections describe ergonomics recommendations for the recruitment and training of control room supervisors (IV), the design of the control room (V), the communications system (VI) and noise control (VII).

17 March 1972

Dr. P. CAZAMIAN

Research Director

Photo-copy of the report disposable in French at the Secretariat of the "Recherche communautaire ergonomique, 29, rue Aldringen, Luxembourg" (tel.: 292.41 - extension : 552 - 553)

I - NOTES ON METHOD

A distinction is conventionally made between design ergonomics and correction ergonomics but this distinction is no longer justified in the case of large automated plants :

- on the one hand, the rigidity and complexity of the installations and the complicated interactions between sub-systems prevent subsequent correction of initial errors; correction ergonomics are therefore ruled out;

- on the other hand, the same factors prevent the ergonomist working on the design of a new establishment from forecasting optimal solutions based on his theoretical knowledge; ergonomics confined to the design office would therefore be ineffectual.

The best method - which we used - is therefore to conduct a survey of similar existing istallations, adopting the critical approach of correction ergonomics (job analysis, conversations with staff, record of incidents etc.) but with the aim of implementing in the future establishment improvements and corrections suggested by operation of the existing plant.

This procedure was facilitated in the present instance by the fact that we were concerned with the project for a 250 MW thermal power station (LUCY Station) for which a prototype (GARDANNE Station) was already operational in a coal-field in the South of France.

However, to lend greater weight to our conclusions, we also studied older and less powerful stations situated in the Nord/Pas-de-Calais mining basin (COURRIERES, HORNAING and VIOLAINES power stations), making due allowance for the difference in the age and size of these establishments.

II - AUTOMATIC AND MANUAL CONTROL SYSTEMS IN A MODERN THERMAL POWER STATION

It has been possible to increase the size and output of power stations by installing automatic regulating systems which allow centralized control of the entire plant. But there is a big difference between automatic regulating systems ans full automation. In the present state of knowledge computers still cannot function without human operators.

The problem of the division of functions between the two can best be illustrated by a simple example, that of a servo-system in the form of a regulating loop; in such a loop arrangement, a measured parameter is systematically compared with its reference value and any significant disparity is followed by action on the interfering factors with a view to eliminating the observed disparity. A system of this kind has three basic functions to perform :

- a function of comparison between two parameters of a given type;
- a function of correction to eliminate any disparity between these two parameters;
- a function of anticipation which, allowing for the time factor, enables an incipient disparity to be foreseen and prevents the fault from actually occurring.

In all these areas the strategy of the computer clearly differs from that of the human operator :

Certain parameters which are transient of continuously variable must be integrated into a regulating chain (the very rapid variation in superheating temperatures results for example in the choice of acceleration as a significant index). Here the computer is superior to man. On the other hand the human operator is able to use qualitative, informal signals which he obtains either directly or from staff elsewhere in the power station; these signals are not accessible to the computer (e.g. flame colour).

In addition, both within a given regulating chain and at the level of the general interrelation between different systems, automatic control is only possible during stable operation. When disturbances occur or seem likely to develop, the operator must by-pass the computer and switch over to manual control as soon as the degree of uncertainty exceeds the factor allowed for in designing the chain or interchain regulations.

He then adopts a "heuristic" strategy which differs from the algorithmic strategy of the computer and remains unexplained in many of its aspects. The aim of this manual, intra- or inter-segmental regulation is then to progressively restore equilibrium, making it possible to return to stable operation and automatic regulation.

Is this "competition" - or complementarity - between the computer and operator inevitable ?

Some experts have thought that even without explaining the internal logic of operational heuristics, it might be possible to copy the procedures used to restore balance and break them down into an algorithmic sequence of microregulations which could be fed into the computer.

We believe, however, that the two strategies are incompatible : automatic control uses specific processes expressing a fixed and stringent causal order; progress can only result from better scientific knowledge and a more complete mastery of the entire technical process. Meanwhile there are still gaps in our knowledge and inadequacies in the methods of measuring and transmitting the relevant data : the operator - in this instance the control room supervisor - is responsible for filling these gaps empirically; on the basis of the general operating plan and the ultimate aim to be achieved, he must determine his position at each instant like a navigator using a sextant, locating and avoiding the pitfalls. His heuristic approach lacks the rigour of an algorithmic sequence; the path he chooses may not be the best one but there is no alternative in the present state of technical knowledge.

III - DUTIES OF THE CONTROL ROOM SUPERVISOR

The control room supervisor has a fixed workplace consisting of the entire control room with its data transmission devices and control console. Theoretically he works on his own; in fact, he is only alone during the night shift.

The supervisor's apparent activities are very unevenly distributed :

1° During normal operation under computer control, no incidents occur and the supervisor's task appears very simple; this is the case for long periods. In reality, however, he is still responsible for two-level supervision of the panels in the control room :

- He selects five or six items of information which his experience has taught him to be particularly important and monitors them constantly or at least at very frequent intervals; if an abnormal variation occurs in this selected data, the supervisor will examine all the information relating to the divergent parameter in order to determine the reasons for the variation and take remedial action.
- In addition, he will periodically review all the more secondary data displayed on panels (several hundred) to detect incidents or trends which may subsequently interfere with the main parameters; the quality of this "anticipatory supervision" will have a direct bearing on the number of unforeseen incidents or defects. The supervisor is assisted by luminous and acoustic warning signals which draw his attention to any departure from the specified values. However, our study led us to believe that supervision is not primarily based on these alarm systems; the operator does not acquire a pattern of reflex behaviour, of the stimulus-reaction type, in which a given alarm signal automatically triggers off a given action. In fact he makes full use, in checking and elucidating the symbolic

indications given by the panels, of information obtained from staff responsible for direct supervision of the equipment situated outside the control room in various parts of the station.

2° If incidents occur, the supervisor must take rapid decisions which may have major implications both for output and for the security of items of equipment. He does have some criteria to guide him which are particularly imperative in matters of safety. But more often there are no guidelines or none which are applicable in the particular instance. The supervisor must then reach his own decision; generally, he will try to solve the problem by a compromise but since his choice always involves a number of uncertain factors, it cannot be altogether reliable.

IV - RECOMMENDATIONS FOR THE RECRUITMENT AND TRAINING OF CONTROL ROOM SUPERVISORS

1° Recruitment

Once the management decided that supervisors would be recruited from volunteers already employed in the mines, the following criteria became relevant :

- Experience acquired in existing power stations as a boiler operator or turbine or panel supervisor (this is the most important criterion).
- Age : preferably between 30 and 35; candidates should be as young as possible so that they have the minimum professional experience (this will make it easier for them to acquire the essential additional knowledge).

- State of health : ability to work 3 x 8 shifts is particularly important.
- Variables relating to character and sociability : these factors are important in view of the need for frequent communication and mutual assistance within the working teams.

2° Training

- Effective participation at the stage of construction of the power station (this presupposes sufficiently early recruitment of staff). This is the essential phase of training which enables staff to be present while the various units are being installed, to inspect them one by one and understand their workings, to become acquainted with the various circuits, carry out trial operations and make the necessary checks etc. Participation must be active : each staff member will be given a precise task connected with supervision of the progress of work; he will report once a day to the engineer responsible for building the power station from whom he will obtain all necessary clarifications. In addition he will frequently exchange information on his experience and take part in group discussions with other trainees. Active, personalized and above all practical training of this kind is not only suitably adapted to the requirements of adult training, it is also essential to enable staff to begin to memorize the workings of the plant; this information will subsequently be of great assistance to them in developing their operational strategies.
- Training period lasting for a few months in a 250 MW power station with a technical course given by a power station engineer.

- In-service training.

Training does not end when the new power station is brought into service. The running-in period provides an excellent opportunity for additional training during which the "personality" of the new plant becomes apparent; even if the design of two power stations is identical they always have special operating features of their own (which in our case are mainly due to differences between the fuels used). At a later stage, it will also be necessary to provide permanent training on two different levels : that of the acquisition of further theoretical knowledge necessitated by the development of control and regulating techniques and that of better understanding and mastery of operating incidents; it would even be desirable for engineers to make a special analysis of incidents and accidents and encourage the exchange of experience between control room supervisors.

V - RECOMMENDATIONS ON CONTROL ROOM DESIGN

1° General design

The present trend is to provide large glass windows in the control room opening onto the surrounding area and machine room (to allow communication by signs with other supervisory staff). All or part of the remaining walls will be used to display data on panels opposite which the control console is situated.

The position of the console in relation to the panels must be carefully chosen (with the aid of plans and mock-ups) :

From his console, the operator must :

- have a good general view of the panels;
- be sufficiently close to read the indications given on them;
- but at a sufficient distance for the top of the console back not to hide the bottom of the panels.

The console should be designed for work in a standing position.

While the station is working normally, the supervisor can sit at an adjacent desk with telephone and intercom sets.

2° Environmental conditions

- Lighting : natural and artificial (indirect).
- Air conditioning : with individual adjustment facility (allowing for inter-individual variations in temperature preferences, especially during night shifts).
- Noise and vibrations : normal insulation against noise and vibrations.

3° Presentation of data

- The structure of the data must be suitable for two stage interpretation by the supervisor; as indicated earlier, he normally chooses a small number of parameters which are constantly checked and only monitors the others occasionally. It will therefore be desirable to group basic data on a clearly visible panel area, possibly with a repeat facility on the rear console panel (e.g. steam pressure, superheat and re-superheat temperature readings, water flow and boiler level indications as well as temperature trend records).

In addition the structure of the data system must be compatible with that of the control system; the position of the control knob for each parameter and dial indicating the value of the parameter adjusted by this knob must be coordinated to facilitate regulation.

- The alarms will take the form of small rectangles with their technical significance clearly marked; the visual warning will be accompanied by an acoustic signal (klaxon or bell). These alarms are extremely numerous (700) and arranged all round the top of the panels as well as on the console back.

There is no way of avoiding this physical dispersion of the alarms and the supervisor must therefore move round the control room to interpret peripheral alarms.

However, to facilitate correct interpretation of the alarms and enable the order of response to be determined if several alarms are activated simultaneously, it is desirable to establish an ergonomic differentiation between the signals (based on position or colour) as a function of a distinction between e.g. alarms which require direct action by the supervisor or simply the transmission of messages; alarms which indicate the development of a process or actuation of a given unit; alarms which necessitate urgent action or an operation which may be postponed. In addition the conventional system for clearing alarms (the operator depresses a button which clears the acoustic and visual warnings simultaneously) could usefully be duplicated, i.e. one operation to clear the sound and another for the light; it would then be possible to retain a provisional record of the alarm. This may be particularly useful if more than one alarm is activated at the same time.

A more far-reaching innovation would consist in concentrating the whole alarm system on a small console near the operator, a print-out machine being used to list the alarm signals either in clear language or in code; an equipment state recorder of this kind has already been successfully used in the Loir-sur-Rhône power station.

4° Controls

There are two conflicting trends at present in the design of control consoles. One is to miniaturize the controls so that they can all be installed on a short console arranged in an arc round the operator. The other is to increase the size of the controls and use a longer console (five metres) which is usually straight. Both solutions have their advantages and drawbacks : the first facilitates complex regulation operations involving a large number of controls. The second makes it difficult for a single operator to control the system on start-up or during incidents, but the larger size of the control knobs ensures faster and more accurate adjustments.

Whichever solution is chosen, a second problem arises, namely the uniformity of the adjustment scales. Different scales should not be used for controls associated with physically identical reference points; however, variations of this kind are commonly encountered.

VI - RECOMMENDATIONS CONCERNING THE COMMUNICATION SYSTEM

In this area an ergonomics problem arises only in regard to communications between the control room supervisor and staff in the power station (especially other supervisory personnel). The difficulty is to ensure good reception by personnel in the power station of messages from the control room supervisor; this problem is created by the high noise level (90 to 100 decibels in existing power stations) at the place of reception.

The control room supervisor has a network of loudspeakers to transmit messages throughout the station; but these messages are generally incomprehensible to the persons who are supposed to receive them (a spoken message is unintelligible unless its intensity is at least 10 decibels higher than that of the background noise).

Quite apart from the acoustic engineering measures to reduce background noise which will be discussed in the next section, it would be useful to improve the comprehensibility of messages by modifying the loudspeaker system : the traditional amplifiers could be modified by the peak-clipping technique (chopping the voltage peaks of the input signal before re-amplifying).

If this method fails, spoken messages would have to be replaced by coded calls (noise generator) notifying supervisors in the power station that they must report to an intercom or telephone station (distributed at many points throughout the plant) to contact the control room supervisor; however, if the environment is extremely noisy, even calls of this kind may go unheard; in such cases it will be necessary to duplicate the acoustic call by a light signal or better still to provide each supervisor in the power station with a small portable receiver whose sole function would be to notify him of calls from the control room.

VII - NOISE CONTROL MEASURES

In the LUCY power station, measures of this kind have three main functions :

- to relieve staff in the plant of discomfort and even the risk of occupational deafness caused by noise (this is a problem of ergonomics and industrial hygiene);

- to improve communications, as outlined above (organizational problems);
- to prevent the propagation of noise outside the plant since the power station is situated in the vicinity of an urban area (to avoid legal action).

  The wide-ranging acoustic studies conducted with this end in view (described in pages 110 to 190 of the report) are too technical to be considered here; readers should consult the basic document for further information.

  In should simply be noted that efforts centred on the three following aspects :

  - determining noise standards to be incorporated in the specifications which are binding on equipment manufacturers and checking observance of these standards on acceptance of equipment;
  - improving the installation of units which generate the most noise;
  - sound-proofing noisy units (blowers, pumps, transformers, etc).