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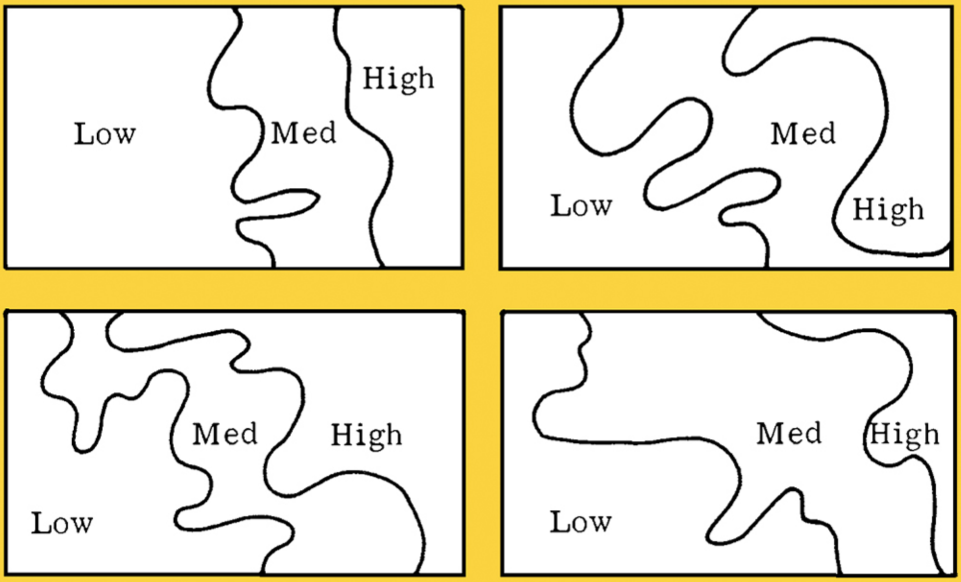

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Ergonomics Problems in Process Operations

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PREFACE

The engineering world cannot afford to ignore ergonomics – no longer limited to academic research but directly applicable to process operations and design. As the pace of technology steps up, especially in computer applications, so attention to the human factor becomes imperative.

The objectives of the symposium are: To enable engineers from process, power, and offshore industries to exchange information and experience with ergonomics specialists; To discuss ergonomics problems in process operations and methods of recognising and controlling these problems; To explore effective ways of applying ergonomics research to solving process operations problems.

The symposium is intended to appeal to: Operations and maintenance managers: Equipment designers and project engineers: Designers and managers of pilot scale R & D plants: Ergonomists.

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3. Job Design, Organisation and Training

ELEMENTS OF PROCESS CONTROL OPERATOR'S REASONING : ACTIVITY PLANNING AND SYSTEM AND PROCESS RESPONSE-TIMES.

Maud Boël (*), François Daniellou (**)

Abstract

Process industries are particularly characterized by dynamic aspects of process evolution.

The operator's activity in the control room of a computer-controlled process has to take into account different time-characteristics : some of these are specific to an automatized process (response-time of analyzers, "age" of informations); others are not (such as process delays, response-time of field informations).

Some characteristics of the operator's reasoning, issued from research carried out over one year in the control room of an oil-refinery are presented :
- on the one hand, how the operator plans his activity when facing one incident, and manages the different response times,
- on the other and, how the operator faces several simultaneous incidents.

The elements presented in this paper issue from research carried out in the control room of a refinery, the process of which had been computerized a few years ago.

The control room operators control the process on the basis of :

. information displayed on visual display units (V.D.U.)
. information collected from the plant by field operators.

Based on the example of one incident, some characteristics of the operator's reasonings when he is facing incidents will be presented, with special reference to how he takes into account the different response-times induced by the system, and the way he deals with simultaneous incidents.

I - THE METHODS USED

It is obviously very difficult to analyse the operators' mental process in a real control-room situation as there is no question of interrupting them in

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the course of the resolution of an incident.

. The method chosen was to continuously record (*) the control operators' behaviour, that is :

- the consulted displays and the actions taken,
- the professional conversations and the radio communications and to submit some of these records later to the operators during interviews in which they were asked to explain the reasons for the different actions carried out from the board.

The confrontation of :

- the actions recorded,
- the verbalizations made during the activity (radio communications, conversations in the control room or comments to the researchers)
- operators' subsequent comments
  allows restoration within some limits, of elements of the reasonings supporting the action at one moment.

It is obvious that the methods used do not make it possible to infer the structure of the operator's long-term knowledge of the process control.

The operators concerned are 39 to 47 years old. They have been in the post from 2 to 5 years.
All of them had been field operators for some years in the past.
When appointed to the control-room, they were trained in dual post for four to eight months.

2 - AN EXAMPLE OF AN INCIDENT

To introduce some elements of the operator's thought processes when facing an incident, an example will first be presented : owing to the number and diversity of indications consulted, emphasis is not laid on a quantitative approach, but rather on the organization of the observed VDU and field consultations.

The word "incident" refers to any disturbance or adjustement requiring the team's intervention.

To understand the example, it is necessary to know that the operator has to type the number of the desired displays to set the items of information he is looking for. The appearance of a new display erases the previous one.

. The example :

Two refining columns, C1 and C2 are linked together in two ways :

. on the one hand, the top products of C1 feed C2;
. on the other hand, a reflux of C1 is used to heat C2.

(*) The records were made during a total period of 105 hours, in 39 different shifts, by means of a V.T.R., tape-recorder or note taking.

During one of the recorded incidents, the C1 reflux circulating pump broke down. Such an incident can lead to :

- a general disturbance in C1 as it is no longer cooled enough, which means that out-of-tolerance products are sent to C2;

- a lack of heating in C2, and the risk of feeding downstream units with faulty products.

It has been observed that, in the first moment, the operator seeks to restore normal temperatures in C1. He acts on from one to eight regulation-loops relating to C1, while only keeping watch on the temperature in C2. From the evolution of this indicator and from field information about the permutation of the pump, he is led to switch over to a new set of groups (i.e., displays of the automatic regulators) which is made up of the connections between C1 AND C2. He then acts on the loops which regulate these connections, only keeping an eye on the developments in C1 through a small number of indicators. At the same time, he watches for possible consequences dowstream through only one source of information, the level of the C2 top tank. If this level changes, this means that the disturbance is about to reach downstream units, and the operator will then consider a new set of groups which includes C2 and the next unit.

In this example,the following can be observed :

. the operator works on sets of groups, synopses and graphs, relating to :

. first, column C1,
. then, columns C1 & C2,
. then these columns plus another unit,

. the sets of groups change in the course of the incident.

. While working on one set, the operator consults certain other indicators (e.g., the temperature of C2 while working on C1).

. switching from one set of values to another seems to be the result either of a change in the disturbance (change in the tank-level) or of the arrival of information from the field, which involves delays (waiting for a pump to be exchanged requires 3 minutes while other actions only stretch over 48 seconds).

. Through the verbalizations made, it is learned that the operator determines a temporary objective : not to lose the reflux flow.

The incident presented above is only one illustration of the activity observed during incidents.

Despite the variability of incidents and of operators controlling them, an interpretative model presented below seems to be applicable to the analysis of most incidents observed, as far as the overall organization of information processing is concerned.

3. ELEMENTS OF A MODEL

At one time, the operator has to deal at one time with more or less numerous incidents which progress simultaneously. These incidents may affect different parts of the refinery, and possibly interfere with each other.

To solve an incident, the operator determines intermediate objectives to be achieved. Theses objectives are fixed on the basis of a representation of the incident issued both from immediately available information and from knowledge gained through experience.

To reach such an objective, the operator focuses on specific parts of the refinery, which are either directly affected by the incident or functionally linked to the sections concerned. The action taken to reach an objective concerns what will be called a Set of Functionally Linked Elements (S F L E), defined in detail below.

The following paragraphs deal with :

. Some features of the operator's reasoning within one given SFLE,
. his changing from one SFLE to another in the course of one incident,
. **his facing several incidents at** one time.

3.1. Reasoning Within One SFLE

Owing to the process design, disturbances in one place are likely to have many consequences in several different areas of the refinery. The parameters that may be affected are thus extremely numerous.

Consequently, the question to be investigated is : how does the operator organize the way he keeps watch on this number of parameters ?

It can be noticed that he partly foresees the likely developments of the incident, based on his knowledge of the process and of similar incidents which had occurred in the past. He is more or less in a position to anticipate :

- the nature of oncoming disturbances,
- their occurrence order.

He can then determine intermediate objectives, which aim to limit the foreseeable sequence of repercussions of the initial disturbance.

Thus partitioning the resolution of the incident, he can focus his current action on a subset much smaller than the set of all parameters likely to be affected. This subset, which will be referred to here as a "Set of Functionally Linked Elements", includes the details of all parameters involved in reaching the intermediate objective. It is the framework within which the operator keeps watch on parameters, acts on the process (especially valves), either straight from the keyboard or through field operators.

It has to be noted that this subset is functional, meaning that it can include parameters relating to different refining columns or other devices linked by the process.

Since the operator's reasoning is orientated by the consequences of the incident (at least the ones he knows), the SFLE is constructed on the basis of the units likely to be reached by the incident.

Therefore, the SFLE is not mainly specific to the causes of the incident, but rather to the foreseeable consequences which the incident may have on the other parts of the refinery.

3.2. Switching From One SFLE To Another.

As indicated above, the development of an incident is only partly foreseeable. The operator, while focusing on an intermediate objective, may be led to modify his plans by the occurrence of a new event or by the abnormal development of a parameter. He then determines a new intermediate objective, which causes him to work within the frame of a new SFLE. The question is then to understand how, while working within SFLE 1, he decides to leave SFLE 1 and devote himself to a new SFLE, say SFLE 2.

As already mentioned, the operator can anticipate that the incident is likely to affect not only SFLE 1, but also other parts of the plant. It can be noted that, while closely following the development of the situation in SFLE 1, he keeps watch on the evolution of these other parts. But the monitoring maintained on these parts is not of the same nature as that for SFLE 1.

Whereas within the current SFLE the operator follows all parameters in a nearly continuous manner, he keeps an eye on the development of other parts only through the intermediary of a restricted number of parameters, that will be referred to as "CUES". These cues give information in a synthetic way on the overall state of a unit. If one of them becomes abnormal, the operator leaves SFLE 1 to focus on the detail of the new problem arising, within a new SFLE, SFLE 2. He will in turn keep an eye on the next developments in SFLE 1 through a limited number of cues.

. Cues and memorization

It seems that watching neighbouring units through a limited number of cues permits the operator to reduce the number of continuously followed parameters, which may perhaps lead to a reduced memorization.

But on the other hand, cues are not sufficient for precisely identifying components of a malfunction and, when necessary, they have to give way to the detailed examination of the relevant SFLE.

3.3. Several Incidents

In the reality of work, the operator often has to face several incidents developing at the same time.

It can be observed that, as above, the operator will focus on one SFLE relating to one incident and keep an eye on its other components AND on other incidents through cues.

Managing incidents requires an up-dating of the representations at every occurrence of a new event. It implies memorizing developing incidents while dealing with one of them.

3.4. Responses Times

It has been indicated before that switching from one SFLE to another was a result of a parameter developing abnormally. Another factor has to be taken into account, namely the operator's knowledge of the response-times of the process and the system.

The main features of response times are described below and their consequences for the operator's action discussed.

. Response-time of field interventions

As described in another paper (see : DANIELLOU, F., BOEL, M. in this Symposium) all items of information required by control room operators are not available from VDUS. Some have to be collected in the field by field operators. Other indications have to be confirmed by field checking. In the same way, all actions on the units cannot be taken from the keyboard. Some require an intervention on the spot, e.g., starting or stopping a pump.

In all cases, asking for information or intervention from the field implies a certain response-time, due to the operator's displacements or actions. Thus some devices fans are situated on top of a refining columns, some valves are difficult to operate and so on. The time required for operating a device is thus specifically dependent on its implantation.

It can be observed that control room operators are able to estimate the time required by the outer operators to satisfy their demands. This is probably possible mainly because they have learnt to know the units when they were operators in the field.

. Response-times of analysers

Automatic analysers display the composition of products. However, according to the type of analysis, the response time range from a few seconds to ten minutes or more.

In some cases, the operator who changes an adjustment will know its result only after waiting for the measure to be completed.

. Process delays

The flows of products between the units take time, sometimes an hour or more. The operator knows this and he can evaluate how long a disturbance will take to reach the next unit.

. Consequences of response-times on operators' thought process

The knowledge of these different kinds of response times is a major element of the operator's management of one or several incidents. Once he has given rise to an action, either from the keyboard or through a field operator, he is often observed to provisionally leave the SFLE with which he had been busy, for as long as the response-time mentioned is not over. From the operators' verbalization, it has been learned that he switches back to it when he has the feeling that the requested actions have had time to take effect. In such a case, the change in SFLE is not necessarily brought about by the evolution of a cue, but rather by the awareness of elapsed time.