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ELECTRONICS DEPARTMENT

ON THE COMMUNICATION BETWEEN OPERATORS AND INSTRUMENTATION IN AUTOMATIC PROCESS PLANTS

by
Jens Rasmussen

April 1968

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Abstract

Copies to

Summary

The tasks of the operators at automatized process plants during normal operation and under fault conditions are discussed, and it is attemped to make a simple classification as a bäsis for the formulation of demands on the information display function of the instrumentation. The possibilities of utilizing a digital computer to increase the efficiency of the man machine communication is also discussed.

Abstract to

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Introduction

Industrial process plants are normally supervised by a complicated instrumentation system which, in co-operation with one or more human operators, controls the process under general routine conditions, such as normal operation and start-stop operations,, and monitors the operation in such a way as to allow abnormal conditions to be detected and counteracted by suitable, i.e. safe. and economical measures. The allocation of tasks to operators and instrumentation depends upon the degree of automatization, and the requirement of narrow operation tolerances and operation close to the tolerable limits for plant components has to a great extent led to automatization of the normal operation, while abnormal operation and fault conditions still require highly qualified actions by the operators.

The situation is then that several tasks connected with the normal operation are taken out of the hands of the operator.,, who thus loses touch with the plant, at the same time as the steadily increasing complexity of the plants during abnormal conditions places on the operators the demand of still more knowledge of the functions and reactions of the plants.

Even in plants having a very high degree of automatization of normal and abnormal operation, situations will occur in which the human operator has to control the operations, for example the initial operation following the installation of new, major parts or major repairs,, and the longer the periods are between such demands on the operator, the more efficient the means 6f communication between the plant and the operator have to be.

The digital computer is now finding its way into the control system of automatic plants. Up to now it has been used especially for information processing in connection with automatic control and monitoring of plants., but not to any great extent for improvement of the communication between plant and operators.

In the present report the tasks of An operator at an automatized plant are discussed With a view to formulation the ba8is for an appraisal of the possibilities of using the digital computer to improve this communication.

Co-operation between Operator and Instrumentation

The tasks in which the operator and the instrumentation system co-operate may be classified into several different functions. The measuring function, which is the conversion of representative variables in the process into signals suitable for further data processing, is at present carried out almost entirely by transducers in the instrumentation system, although in certain types of plants the capability of operators of detecting small changes in the operation by otherwise undefined changes in the odour or noise conditions is still utilized.

The control action,, which conversely transforms the signals from the instruments into changes in the parameters of the process by means of actuators, can to a great extent be mechanized., but the function is often carried out by operators in cases where the frequency of control actions is so low that mechanization is uneconomical. Besides, manual control may be an important stand-by for normally automatic actions. The data processing ties measuring and control together and is the function, requiring the most complicated co-operation between operators and instrumentation. In complex process plants this co-operation places great demands on the information display function, which by means of sound and light signals, meter indications and graphic recordings converts the information present in the signals of the instruments into a form that can be further processed by the operators.

It is a condition for the development of automatization that the necessary data processing can to an increasing degree be carried out in the instrumentation system without any action on the part of the operator; this in turn means that the equipment required for advanced data processing must be accurate, economical and reliable.

An electronic system, to be economical and reliable, miist be based on units., produced in numbers, and the development of the practical possibilities of automatizing process plants has been characterized by the mass-produced electronic process controller, which is so flexible that the same type of unit can be adjusted to a wide variety of processes.

During recent years the development has been highly influenced by the digital computer, which is a mass-produced, end thus reliable and economical, unit that can be fitted by programming to meet highly advanced and specialized needs for information processing in process automatization.

This feature, together with the high operating speed of the computer, which makes it possible to share its time among many functions and thus perform these with a reasonable amount of equipment, makes it attractive to utilize the digital computer in process instrumentation even though its highly centralized structure is not very attractive for instrumentation purposes from a reliability point of view.

The high degree of interconnection between the different functions of the digital computer may lead to serious consequences of

faults In the instrumentation, besides it makes it more difficult for the operating personnel to maintain a general understanding of the functioning of the system.

The rapid development of the prices of integrated circuits and subsystems and thus of digital computing elements will presumably in the future contribute towards a continuation of the decentralized structure that characterizes conventional instrumentation systems, since it will be attractive from a reliability (decentralization) as well as an economic (simpler programming) point of view to use control-systems comprising several computing elements.

The introduction of the digital computer in process instrumentation should thus not be -looked upon as a revolution, but as an evolution of the technological and economic possibilities of further utilization o-f automatic data processing, in the instrumentation,, and it is still important to base the layout of instrumentation systems and their adaptation to the process and the operator on the vast experience gathered from the operation of conventional systems.

Especially in its relation to the operators in industrial processes the digital computer has been encumbered with the tradition established by its users in the administrative and scientific fields; communication facilities -,uch as typewriter and@tine printers have been transferred directly from these fiels to the industrial scene, where in most cases they will be inexpedient.

In order to formulate the demands on a suitable form of communication between operator and plant it is necessary to define the functions of the operator in more detail. In the following discussion his tasks are classified in a simple way into groups covering: tasks during normal operation, during changes in operating conditions such as start-stop procedures, and during monitoring, e.g. detection and identification of failures.

The Operator's Task during Normal Operation

During normal operation periods the operator and the instrumentation in co-operation are to ensure that the process plant as a whole is in an economically optimal condition.

Regardless of the level of automatization, the operator for this task needs accurate information of the main data of the pln-nt., presented in a way that allows him to compare directly with the primary operation specification given to him.

These principal plant data are normally presented to the operator by big, clear Indicators located In a central position which allows them to be read by the operator even if he is carrying out other tasks. In conventional systems meters of great size or indicators/recorders are often used. The main data should be compared with the primary specification to a good accuracy; they are not to be compared mutually, end therefore presentation in digital form with indication of measuring units should be preferable to analogue presentation.

In plants with a moderate level of automatization the control of the normal operating conditions is often carried out by a number of rather simple feedback controllers, which control the individual plant parameters in correspondence with secondary references adjusted by the operator to satisfy the primary specifications.

For this function the operator needs more secondary information about the conditions in the different feedback loops to be able to supervise the result of his adjustments. In this respect there are not special demands on the layout of the display equipment. The operator will be able, without hurry, to act on the basis of his daily experience, and his task will normally be well defined and limited. This intervention in the operation of the plant, based on his evaluation of the operating conditions and specifications, will be of an experimental nature, he can use P. trial and error technique in a reversible way and correct his actions if they prove wrong. In this situation the operator's working conditions are favourable provided that the interdependence between the primary operational specifications and the secondary control reference values is not too complicated.

To make the operator responsible for the adjustment of the control loon references - set points - may be advantageous to his other tasks. Different operators may have different ideas of the optimal operating conditions and therefore may have a tendency to check the adjustment of the set points at shift take-over and during operation to make sure that conditions are optimal. This frequent experimentation with the process will contribute to the operator's understanding of the behaviour of the plant and thus increase his ability to perform a monitoring function. This may be of importance for plants without frequent manual start-stop operations.

At higher levels of automatization the different set points in the control loops will be calculated by the control system itself and automatically brought into correspondence with the primary operation specifications, and the role of the operator during normal operation will be purely supervisory.

The Supervisory Task

This task, to which both the operator and the instrument system contribute., may be divided into three parts: failure detection, i.e. the discovery of a departure from the normal, specified operating conditions, identification, i.e. the determination of the nature, location and cause of the abno7-mal condition., and finally the corrective action upon the process, ,ihich is based on an evaluation of the consequences for the plant of -the different possible modes of continued operation and a. decision regarding the optimal action.

Detection of failures is usually not possible solely on the basis of the information utilized by the operator during normal operation optimalization, since a large group of abnormal situations and failures will not appear in this information or will be recognizable here at too late a stage. The operator should therefore have at his disposal detailed information on the state of operation in the different subsystems of the plant.

A great deal of this information is not needed by the operator for his optimalization of the normal operation; he only has to check that the data remain within the range of normal operation. Most of these secondary data have no immediate correspondence with the primary specifications for the plant operation, and it is therefore important to lay out the display function in such a way as to increase his awareness and his memory of the normal ranges.

Normally this is done so that the instrument system compares fixed limits with measured data representative of abnormal situations demanding immediate action by the operator, and gives a warning signal when the limits are exceeded, while failures that have only minor consequences for the operation of the plant are covered merely by the measuring dat,,- being presented to the operator.

This presentation has to be such that the operator only has to run an eye over the instrument panel to ascertain whether the operation is normal. The layout of the control console can facilitate this task to a high degree even in conventional systems: related measuring data are grouped together, normal operating conditions are indicated clearly, for example by edge wise meters arranged so that the hands are normally in line., or meters that can be rotated so that the hands normally point in the same direction. Meters have to be grouped so as to clearly indicate the different subsystems.

The essential thing in this connection is to obtain an overall view of the process by inter-comparison of data rather than a high accuracy reading of individuE.1 data.

The great data handling capacity of the digital computer can be utilized to relieve the operator of the failure detection task in a very efficient way. The monitoring of the measuring data can be highly effective, a great number of data can be included in an automatic alarm scanning, and the alarm limits may be made dependent on the operating conditions of the plant; for instance they can be changed during start-up. Furthermore the digital computer is able to monitor the relation between data by making simple comparisons or more complicated calculations such as heat or mass balances, and in this way the instrumentation can be made more efficient and alert than the humqn operator. It may be considered R drawback that one takes from the operator a task that keeps him in touch with the process, which is essential for his correct action in failure situations. For the operator to be effective it is therefore necessary that he has the possibility of obtaining and maintaining a general view of the conditions of the plant.

When an abnormal state of the plant has been detected., the failure has to be identified with good certainty and its cause and the consequences upon the continued operation must be evaluated. To the operator this is quite a different task from the normal optimalization of the operation. In case of more serious failures the allowable response time may be short; the task will not be to solve a well-defined problem, but rather to formulate the problem corresponding to the pattern of data presented. The situation will be characterized by a set of abnormal data, each of which may occur rather frequently during the daily work (e. g., instrument failures), but which in just the combination in question may have been caused by a serious or dangerous failure that would have been considered very improbable in advance. This means that the operator is not allowed to trust his daily operating experience but has to base his decisions on detailed knowledge of the functioning of the plant and its response to the different types of failures. He should be imaginative enough to Postulate a covering set of npossible causes of the failure situation on thc-, basis of the immediately available information and then., after processing of more detailed information, to make Fi, well-founded decision.

The great difficulty is usually to ensure - by training, layout of control console and plant, etc. - that the correct and in many cases very improbable cause of a failure is among the possibilities that occur to the operator. Experience shows that an incident is not seldom allowed to expand, not because the instrumentation fails at the critical instant, but because the explanation of the abnormal situation that first comes to the operator's mind by virtue of his experience corresponds to more trivial routine failures, whereas less probable failures have much more serious consequences for the plant and should therefore have absolute priority in his mind.

If one chooses to define the cause of such an incident as a human failure, it is very reasonable to discuss whether the blame should go to the operator or to the designer, who chose the information environment of the operator. In quite a few cases such failures may be classified as "technical failures" since the development of the incident may be due to a rather high frequency of unimportant failures that have contributed to the experience of the operator and thus influence his reaction in the case in question.

In his task of identifying the failure and evaluating its possible consequence for the plant, the operator must therefore be supported by the designer of the system. The information directly available in the form of measuring data and alarm data has to be displayed-in a suitable way, and the operator's need for knowledge of the reactions of the plant to failure conditions must be supported as much as possible by incorporating the designer's knowledge into the instrumentation in the form of automatic evaluation procedures that analyse the alarm and measuring data patterns.

In modern plants the task of the operator in an abnormal situation is initiated in the way that an alarm system detects that one or more measuring data have exceeded the range of normal operation. In small plants it is possible for the operator to get a sufficient overall view of the situation on the basis of a simple indication of the individual alarms, but an alarm system does not have to be of very great size to necessitate special means of supporting the operator. In conventional systems this is done by indication of the latest alarms in a way that separates them from earlier ones by a different character of light, by special indication of the first alarm in a sequence, etc.

Where it is chosen to use an extensive alarm system in a larger plant - e.g. by installation of data loggers or digital computers - so that a great number of variables are monitored, perhaps even with alarm limits depending upon the operating conditions of

the plant, the operator will lose his general view if the output information is presented to him unsorted. The more detailed monitoring will result in long sequences of secondary alarms, and it may be of important assistance to the operator that the designer incorporates in the instrumentation as an automatic sorting Procedure the result of an evaluation of tire reactions of the plant in such a way that the operator is presented with information on the primary and essential alarms only to an extent sufficient for the preliminary identification of the failure. It is not appropriate to record the alarm information in tabular form with typewriters or line printers. A clearer Presentation is obtained with plain text incorporating parameter identification and data in conventional alarm status displays or computer-controlled picture displays (CRT), which might also be utilized for the presentation of results from the more comprehensive analyses mentioned below.

The information from the alarm system will normally only be able to serve as a rather course guide in the identification of a failure and to locate the failure to one of the subsystems of the plant. The operator must supplement this information with a survey of the conditions in the plant as a whole end in the subsystem in question.

Such a survey comprise:3 sets of related data characterizing the actual operation conditions. Experience shows us that a human operator is able to accept a large amount of information directly when it Is presented to him in analogue form as a situation or a picture, while information in alphabetic or digital form requires conscious acquisition by detailed reading, a slow and very selective procedure.

Analogue presentation of measured data by means of meters and recorders, as normally used in conventional systems, can give the operator a good overall view of the operation if nrcperly laid out since he need not go into detail in reading the meters, but can perceive the meter deflections as a rattern. In his preliminary failure identification he has no need for accurately measured individual data., but only for comparison and classification of data in sets.

In case a digital computer is used in the instrumentation there are further possibilities of supporting the operator in his survey of the operating conditions. Related measured data can be coded by the designer into series of graphic pictures representative of the plant as a whole and of subsystems, which may supply the operator with a very efficient means of comparing data.

By thus elaborating a number of graphs giving surveys of the conditions in representative systems, functions and situations,, the designer may ensure that the operator is presented with all relevant data in close relation as a supplement to the alarm information.

Already at the formulation of his first hypothesis about the cause of the failure the operator will thus have all relevant information available in a clear forms This will increase his possibility of finding a correct explanation as the first one, and he may avoid the hesitation and fidget in which he may find himself if he has to change his working hypothesis several times because important new information turns up when he evaluates the detailed data to confirm his findings..

An efficient coding of the information in sets as graphic patterns will also counteract-, the tendency of a human operator to limit his attention to very 1'ew parameters in a critical situation and to let the hypothesis he has already made influence his interpretation of the supplementary information he is seeking.

The most important feature of these graphic Patterns or pictures is that they give the operator that overall view which in conventional systems he can get by running an eye over the instruments in the control console. He should, however, have Possibility of supplementing with accurate, detailed data as easily as he can read the meters and recorders in conventional systems.

This detailed information should be easily obtainable in preferably digital form with a c--ear indication of the name of the parameter and the engineering unit, or as graphic curves showing the evolution of the parameter in time; for instance the operator may call the information from his graphic patterns by means of a "light Dent'. If the system is arranged so that it is only possible for the operator to call detailed information from a survey pattern., it can be avoided that he uses d(@tailed information without considering its relation to the general conditions in the system,

Examples of a possible 3-ayout of such displays are shown at the end of the report. This type of dismay is today used especially in aviation systems; its application in computer-aided design is developing rapidly, and the same tendency is to be expected as to its use in process control systems.

The advantage of these Displays is not so much that they can be used to give "mimic" diagrams, as known in conventional plants, but rather the possibility of coding the information effectively in a symbolic form which the operator can perceive as Patterns or pictures.

In the discussion given above the possibilities of the designer of analy8ing in advance the reactions of the complete plant to the different types of failures and the corresponding data- and alarm patterns is only utilized to provide a basis for selection of the parameters of the plant that are to be monitored by the alarm system, for the design of a simple alarm reduction function and for the classification of data into appropriate sets for the graphic displays.

The capacity of the computers makes it attractive to support the operator further with the results of the designers' previous analyses of the plant. This can be done by Incorporating in automatic procedure in the instrumentation, which, initiated by an alarm, analyses the alarm and data patterns and directly localizes the primary fault. It may be extremely difficult, if not impossible., for the designer of a large plant to carry through an analysis that takes into account not only all failures in the plant itself and the instrumentation, but also the combination of failures, which may cause serious disturbances.

How far it pays to go J-n this direction in an actual plant depends upon which situation is the more dangerous: that the operator in a given situation doeE-1 not have sufficient knowledge about the nature and functioning of the plant, or that the designer has not foreseen the situation during, the design phase and has therefore not included it in the automatic analysis one has to realize that direct automatic identification of the primary fault based on a not completely covering analysis which assumes that an operator critically evaluates the result of the analysis, involves a great risk of further decreasing -the probability that the operator takes into consideration very improbable, but hazardous failures not dealt with in the simplified analysis of ttie designer and thus of the instrumentation.

If one utilizes a simplified analysis of failure conditions in this way,, one may therefore be in the paradoxical situation that it as risky for the operator to trust the analysis -too much when it indicates a probable causes of the failure as to Incline towards distrusting the analysis when it indicates an a Driori improbable cause,

A better result will presumably be attained if the automatic analysis is allowed to follow principles that the operator will immediately accept. The analysis should then, as the operator will be inclined to do., deal first with the simple and most probable causes and currently keep the operator informed of the result.

In the case of more frequent and routine failures one then obtains an automatic identification of the failures, while in the case of more complicated and rare failures the analysis will rapidly exclude the simple and trivial causes. This will save the operator's time so that he may concentrate on the more rare and serious situations on the basis of a limitation of the possibilities; thus it can be avoided that the operator forms a sequence of preliminary hypotheses which he may not be willing to reject.

In this way the operator may acquire more faith in the analysis, and it will suffice, when a new plant is put into operation., to incorporate a simple automatic analysis since it can be gradually expanded according to the operational experience gained: further the display function may be based immediately on the conventional tradition.

When a failure has been identified in this way, <u>a decision</u> must <u>be taken</u> concerning the appropriate corrective action. This decision has to be based upon detailed knowledge about, the trend of the operational conditions resulting from the failure and the influence of the possible corrective actions on the abnormal plant. Knowledge of this category will not be kept up by the operator to great extent during normal operation, and besides he has to make his decision under mental pressure; thus a decision based upon common knowledge and understanding of the principles underlying the plant Ray not be reliable.

Like the automatic failure identification, an automatic decision function must be based upon a thoroughly covering a priori analysis of the plant under abnormal. conditions, and in many failure situations the decision will therefore rest with the operator. Automatic safety action will be necessary against failure situations that are too dangerous for the plant and demands very rapid counteraction.

Automatic safety actions have to be based on simple criterion that can be automatized with highly reliable equipment and may be proved covering in all circumstances by an analysis. Therefore they must be simple but drastic actions, capable in all circumstances of bringing the plant into a safe state, for instance by emergency shut-down. The operator will furnish a back-up for this safety system and moreover will prevent less important failures from developing to such an extent as to initiate the safety system action and thus interfere drastically with the operation.

The decisions of the operator in situations foreseen and evaluated by the designer can be supported by instructions learned by the operator, but in order to be reflex-like and reliable such knowledge must be kept up by exercises. It may be appropriate to incorporate in the instrumentation such information as may support the operator's memory, for instance by making it possible for him,, after the identification of the failure, to call comments in clear text in em alphanumerical display. In more definite situations the operator may be supported by a computational function that gives him, on a fast time scale, the result of a simulation of the trend of the operational state of the plant and the effect of his 4Lntended corrective actions. This may be required for his evaluation of necessary corrections in case of Xenon poisoning in i nuclear reactor or "cold plugs" in a once through boiler.

Changes of the Operational State of the Plant

The problems of the operator in case of corrective intervention in the operation of a failing plant are in some ways the same as those connected with normal start-stop Procedures, which may also be very infrequent in automatic plants. In both cases the operator has to choose the correct Procedure and to carry it through without mistakes. The task of' the instrumentation is in both cases to assist him in memorizing the procedure, avoid mistakes in his manipulations and give him the possibility of judging their influence on the plant.

Changes of the operational state, e.g. start-un, are in large plants characterized by a complicated sequence of operations following a fixed procedure; the sequence and the duration of the individual operations may further depend upon the state of the plant. The operator thus has to carry through a complicated and often lengthy procedure, in some pants even at rather long time intervals.

The operator should only carry out the individual manipulations after checking that the necessary plant conditions are fulfilled and he should have sufficient means for a check of the effect of the manipulations upon the plant. The choice of the sequence of manipulations and the check of the necessary conditions may be based on a learned or written procedure, which may be present in the form of more or less detailed instructions. The operator's memory may be supported if the procedure is partly incorporated in the control system as an interlock system. This is to some extent the case in conventional systems, and the great data handling capacity offered by digital commuters makes it attractive to increase this automatic interlock or let the instrumentation directly control the sequence of operations.

The interlock function is today often preferred to the automatic control of the sequence because it may be impossible or very difficult to carry through an analysis sufficiently detailed in all circumstances of the sequence and the necessary conditions for each step and the operator's evaluation of the different situations may therefore be needed as a supplement to the function of the instrumentation. In both cases the operator has a monitoring task., and he therefore needs information that gives him a survey of the conditions in the plant and its subsystems by means of displays with the same characteristics as those mentioned in the discussion of his identification of a failure, supplemented by information describing the state of the interlock system., for instance textual information presented by means of a light tableau or cathode ray tubes.

If the operator is responsible for the control action, the display system must give him a feedback of information about the effect of the control actions upon the plant. To make sure that an operator having correct intentions chooses the proper control knob, one attempts in conventional systems to give the knobs and the corresponding meter indications characteristic forms and to group them clearly according to their functions in such a way thal, the operator sees the control console clearly divided into sub-systems and functions and may thus immediately pick the right knob.

In large, modern plants like power stations, the control console is often very extensive. The designer tries to avcld this by centralizing the function:3 to some degree in such a way that manipulations and monitoring of their effect are carried out by a smaller number of devices whose functions are selected by the, operator with switches. This is not in accordance with the need for a clear layout of the console, and it may be necessary to enable the operator to check whether the instrumentation has accepted his order correctly before he asks the system to carry it out.

This centralized layout is natural in particular if the presentation of information to I;he operator is concentrated by the use of a digital computer; it will be an obvious solution to use the varied display possibilities of the digital computer to provide an effective control of the choice of orders. A survey display of the conditions in different parts and subsystems of the plant may for instance serve to indicate what control actions and orders the operator can use in the situation concerned. He may choose the appropriate order by means of e.g. a light pen, and the dismay may indicate how the order has been accepted by the system before he executes the order by means of a general "go" knob.

In complicated plants, rapid and closely controlled start and stop Procedures may be decisive for the economy and safety pf the plant, and the procedures may be so complicated that manual operation is too risky. The trend is therefore towards a more extended use of automatic start, and stop operations and the present development of the different types of digital data processors seems to indicate that they will be used in future because of their low price compared with that of tailored hardware systems. The task of the operator will therefore develop towards effective action in abnormal situations, and maintenance,, but the demands on the instrumentation with respect to furnishing the operator with information in an effective form will not decrease even in highly automatized plants.

The thorough analysis of the function of the plant necessary for the automatization of start-up and shut-down procedures. will contribute to the basis for the evaluation that is a condition for the automatization of the choice of proper corrective action in case of failures in the plant. An effective automatic control system, able to control the operation within a wide range of conditions, is also a necessary condition for the application of automatic intervention in case of failures and for a differentiation of these actions beyond the choice between normal operation and complete shut-down.

Operation of the Control System

The highly concentrated layout of the control system and the dismay and operational devices natural for computer-based systems require an expedient layout of the operation of the control system itself. I t is Important that the operator is able to call a survey dismay with the same ease iiith which in conventional systems he surveys the console, and it must be as simple for him to get accurate data as to read a meter.

The electric typewriter, normally used with digital computers, is not an appropriate tool for the operator in the tasks at regular intervals, e.g. every hour, a complete recording of all measured data should be made on punched or magnetic tape; in abnormal situations all alarm information together with measured data for a suitable time period before the fault should be recorded; likewise it may be convenient to record all the operations of the staff with indication of time. The operator may from time to time have comments to make on the operation and plant condition, for instance at shift take-over, and these comments should be included in the recorded material.

All this operational information may be sorted and processed off line.

Conclusion

A discussion of the tasks of the operator at automatic process plants seems to indicate that his need for information characterizing the operational state of the plant may expediently be classified into three groups. In the task of optimalizing the normal operation he needs an accurate and clear presentation of rather few primary operational data which may be easily compared with the main specifications of the operation. For normal monitoring of the operation and for evaluation of the conditions of the plant in case of failures it is essential for him to have a large amount of data presented in a way that makes it easy and convenient for him to compare data representative of the operational conditions in different systems, functions and situations, and thus to establish an efficient survey. Finally he must have convenient access to accurate measured data 'and their trends in support of more detailed evaluations of failure states.

Furthermore there will normally be a need to support the operator in his identification and decision function under abnormal operational conditions. This may be done by supporting his general knowledge of the plant and its reaction by incorporating automatic analyses in the instrumentation, based upon the analyses made by the system designer.

The data handling capacity of a control system utilizing a process computer may be used with advantage both to code and reduce the information presented to the operator and to carry out efficient analyses of abnormal operational conditions.

It is very difficult to judge beforehand the importance of the different aspects discussed here and their influence on the reliability of the human operator. The main reason for this is the adaptability of the operator, which enables him to compensate to a very large extent for less appropriate layout of the instrumentation. Difficulties will only appear in process plants or in situations in which the mental load on the operator is very heavy.

Explicitly formulated knowledge of the qualities of the human operator as a part of a system is very limited; especially it does not cover all his functions. The utilization of a new technology in the communication between operator and plant should therefore be based on the experience from conventional systems and the traditions of the operator of such systems, supplemented by information from realistic experiments with the new technology.

As en example of a possible layout of a display system utilizing a-digital computer are shown in the following pages a series of display formats which are parts of an experiment at the Ris8 reactor DR2. Here. especially communication end traffic problems between operator and plant will be studied, together with reliability problems and their dependence upon structure of the system, e.g. upon different degrees of centralized structure.

Acknowledgement

This discussion is based upon impressions from incidents and accidents in automatic plants, traffic systems, etc., reported in the literature, supplemented by discussions with the operational staffs at Danish power stations and the reactors at Risø.

I want to thank the members of these staffs and Mr. P. Timmermann of the Electronics Department of Risø for illuminating discussions, and Mr. F. Steenbuch for his review of the translation of the report.

References

N. Jordan: Allocation of Functions between Plan and Machines in Automated Systems. Journ.'Appl. Psych. Vol. 47. No. 3., June 1963.

D. Russel Davis: Human Errors and Transport Accidents. Ergonomics, 2., 1958.

Peter R. Williams et al.: An Evaluation of an Integrated V/STM Display Concept. I.E.E.E. Transaction on Human Factors in Electronics Vol. H.F.E.-8., No. 2. June 1967.

Jens Rasmussen: On the Reliability of Process Plants and Instrumentation Systems. R-7-68 (Risø-M-706)

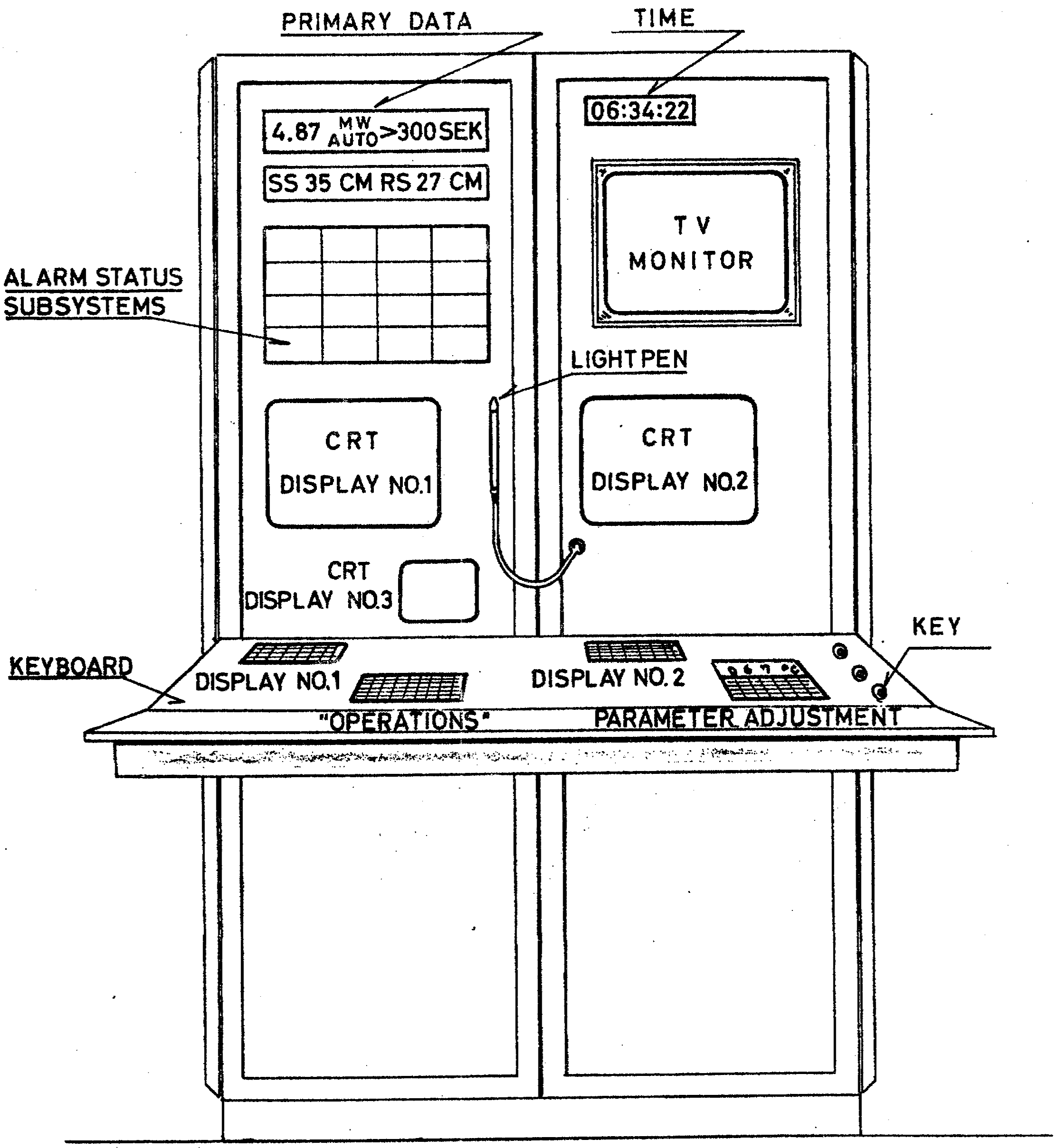

Fig. 1

Preliminary layout of experimental control console of the DR2 reactor, a 5-MW pool type research reactor.

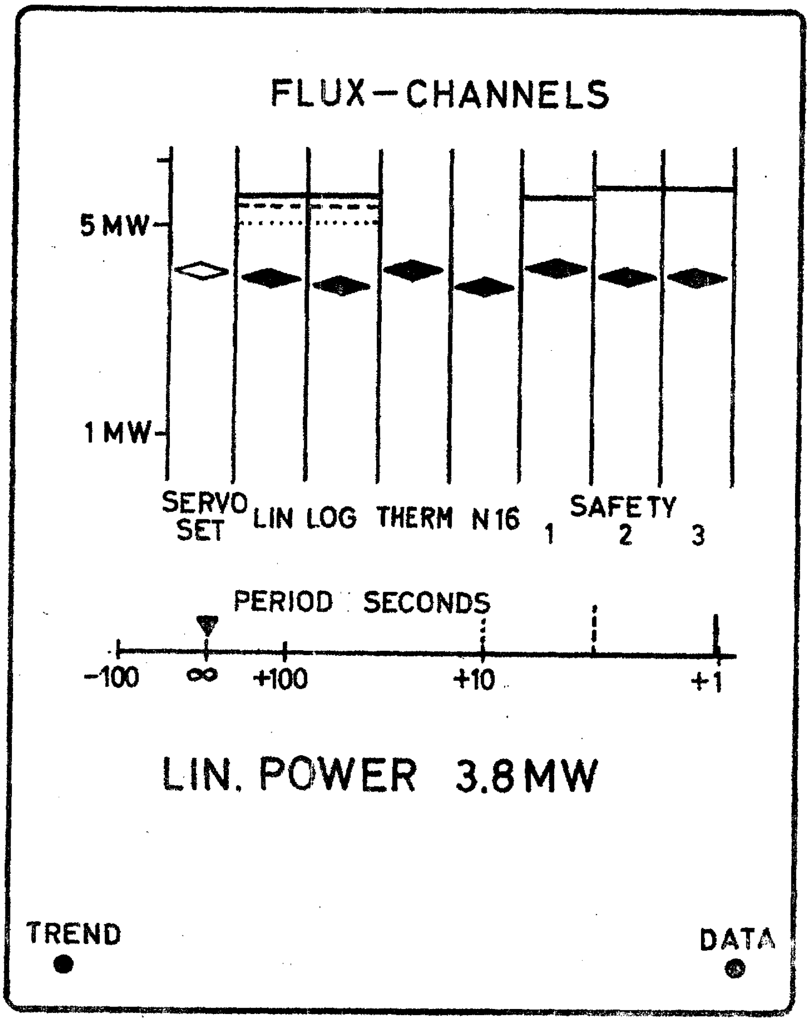

Fig. 2

Survey display. This display may be called by the operator for monitoring of the power measuring equipment. The thermal power is computed from measurements of coolant flow and temperature difference.

▬▬ indicates the automatic shut-down limit,

- - - - the automatic power set-back and

••••• the alarm limit.

Below are shown the orders, to be chosen by light pen, for indication of accurate digital data or trend. The measured value from the linear flux channel has been chosen here.

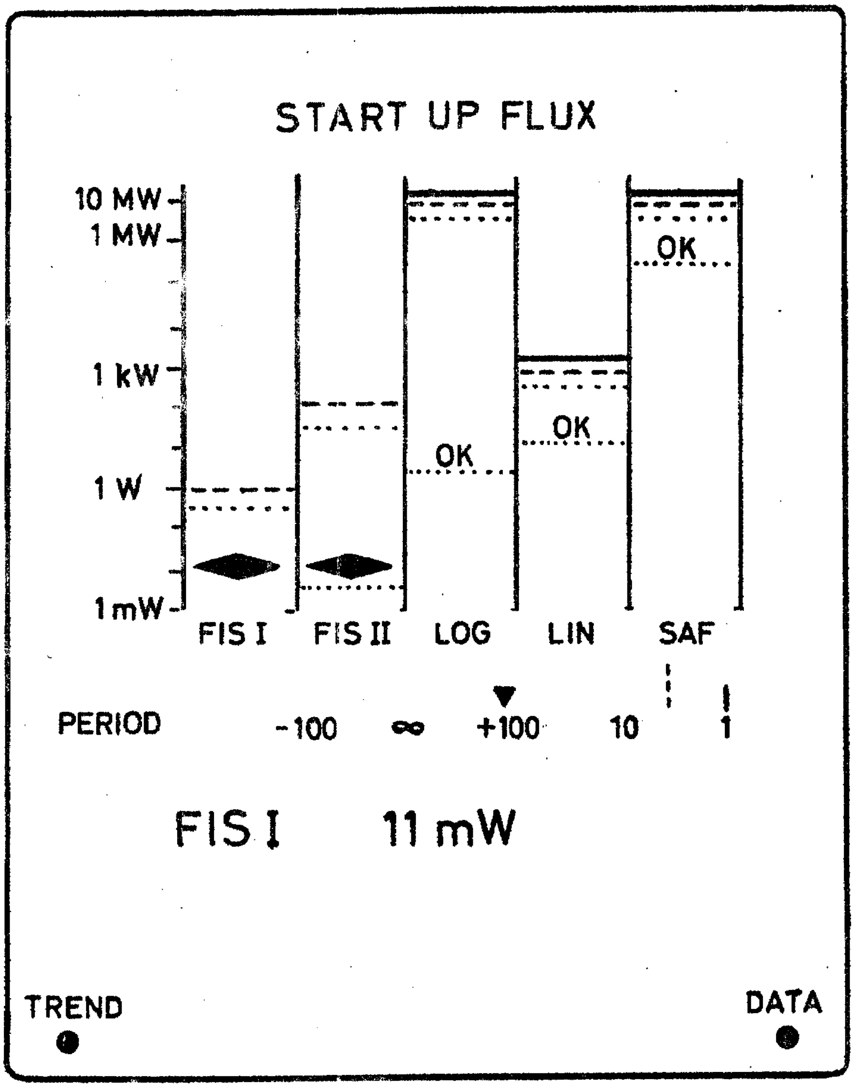

Fig. 3

Survey display allowing the operator to compare measurements of neutron flux in all start-up channels. Interlock and alarm limits are indicated by ····· , power set-back by ---- and automatic shut-down by —— . Channels that are "alive", but have too high a measuring range, show "OK"; this signature is replaced by ◆ when the flux reaches the measuring range. In the data field the data from fission chamber channel 1 have been chosen by the light pen.

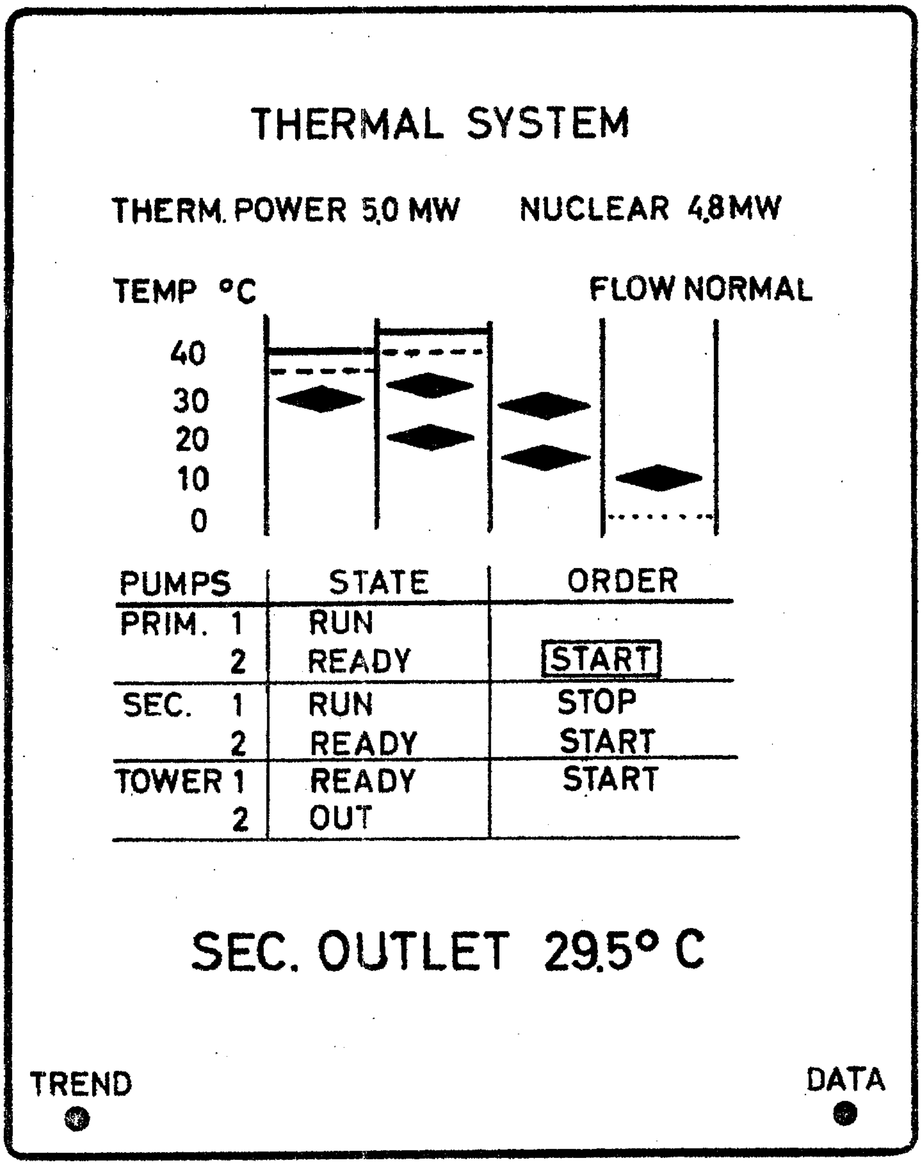

Fig. 4

Layout of survey display for the thermal system. Inlet and outlet temperatures of the primary and secondary cooling systems are shown together with pool and cooling-tower temperatures.

For the cooling pumps and tower fans are shown the operational conditions together with the orders allowed by the interlock system. Orders not allowed are not shown; e.g. stop orders are only shown for the primary pump when both pumps are running. Orders are selected by means of a light pen, and acceptance is indicated by computer. Here is shown acceptance of start order for Prim. 2 pump. The order is carried out by the operator by means of a general action key.

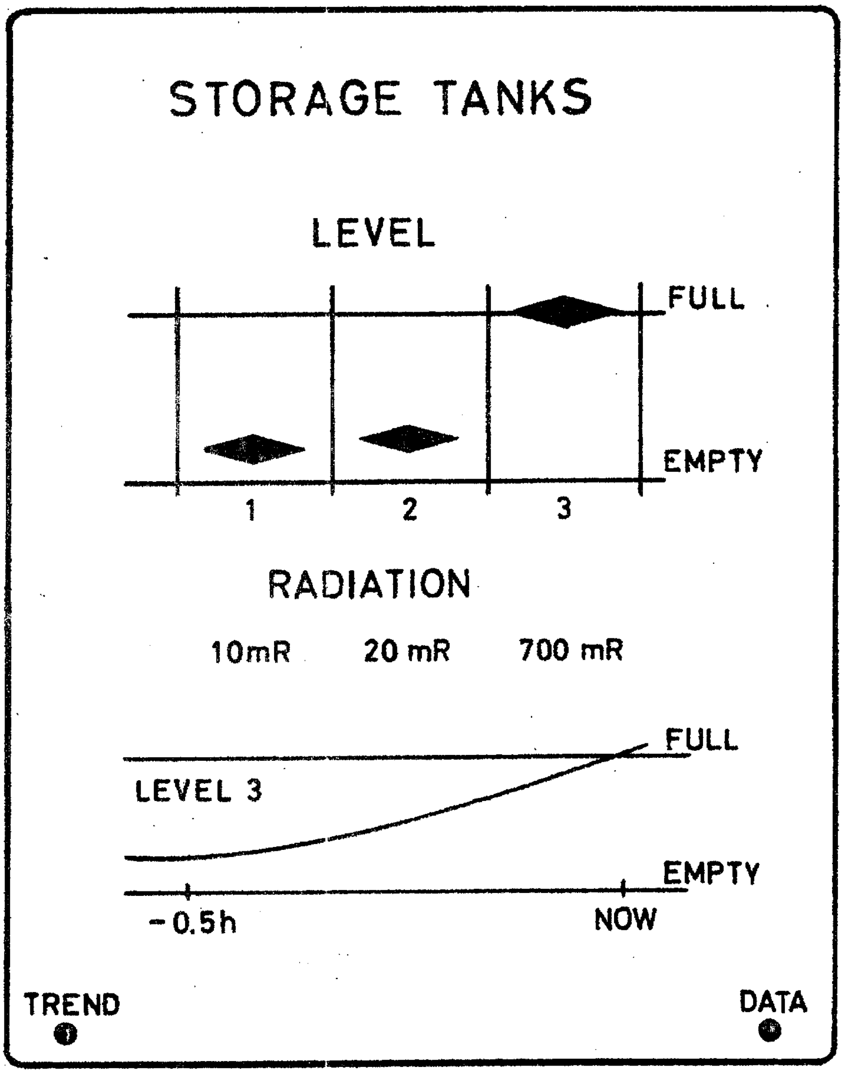

Fig. 5

Survey display for active storage tanks. An alarm has indicated tank 3 full. The operator has then called the display by means of a keyboard and has ordered the indication of the trend in the data field by the light pen. The display combines the information necessary for the operation of the tanks. The radiation levels are shown in digital form as they should not be intercompared, but related to the instructions.