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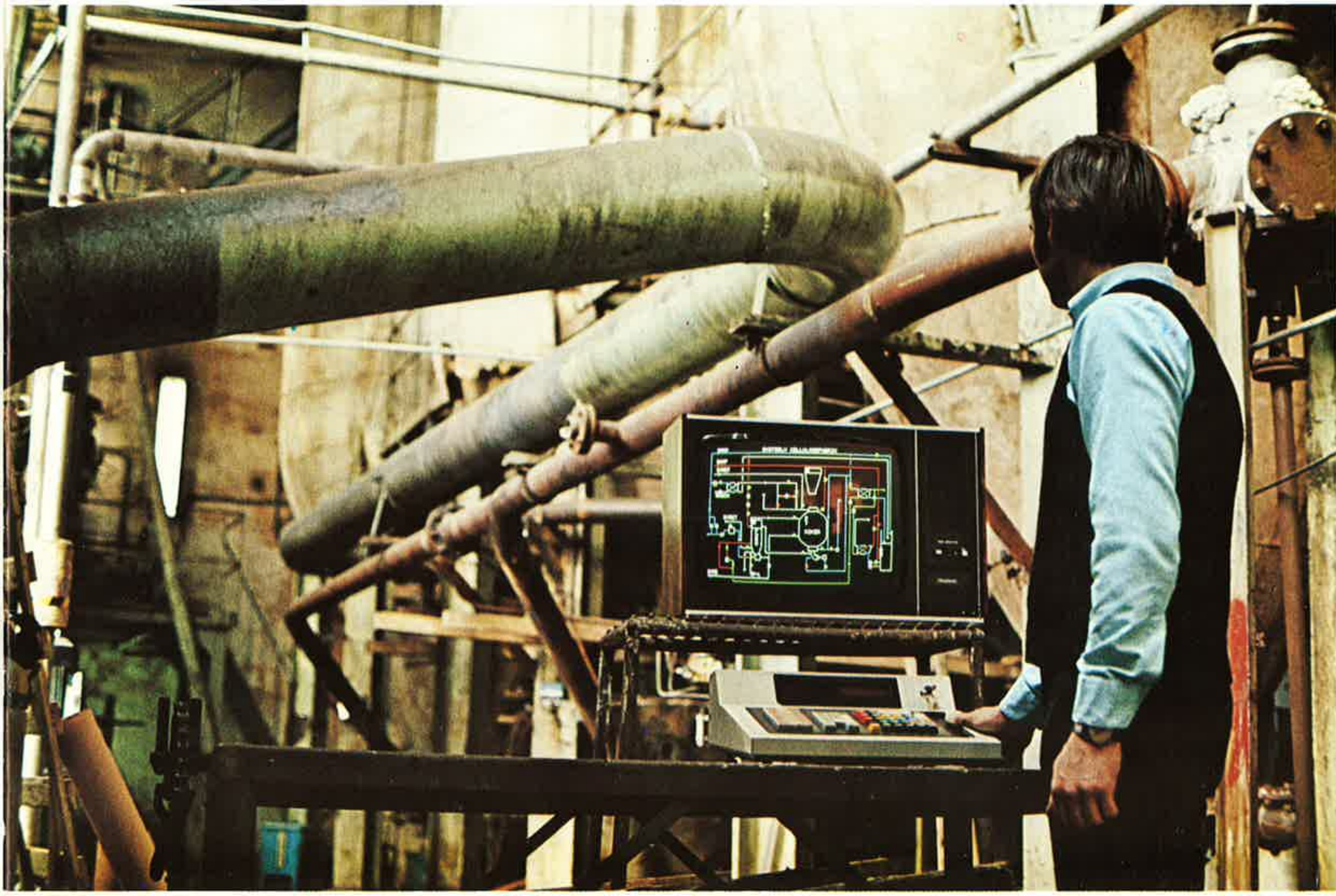

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SPECIAL ISSUE ON PROCESS CONTROL

ND NEWS

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A General View of the Computer as a Tool for Technical Use

BY DISPONENT KAI FR. MARTINSEN, DATA LOGIC A/S

The computer is used in most technical areas and in nearly all types of business by todays industrialized world. Most people who are effected by the computer criticize it, but very few would be without it. In many cases people are totally unable to do their jobs without access to a computer.
Computers exists in many shapes and sizes but the most common areas of applications for what we understand as computers are for control of industrial processes or in pure administrative routines. Even 5—10 years ahead, the development of computer applications is believed will be consentrated around the two above mentioned broad categories. The look of the equipment may change, so also the price, but the actual application will remain the same.
We have gone through several generations of computers since they were introduced some 25—30 years ago but research on the technical side is today more intense than ever. The engineers are looking for technical solutions that can justify better-selling names such as "mini-computers" and these days even "micro-computers". These names, however, tell more about the size of the equipment than its actual function. Although much attention is paid to the technical solution of computer equipment, the suppliers are continuously looking for new applications where their equipment may be used.
This in one way is dangerous for the customer especially when the supplier offers a "pilot-project". The customer must be prepared to go through a lot of hard work if he accepts a "pilot-project". Very often such exercises will cost a lot more than originally expected.
On the other hand there are projects that are labelled "pilot-project" just as a sales argument. Another pitfall when selecting computer equipment is when the supplier offers a computer which is designed according to the customers cost expectation rather than his actual needs.
Another sales argument in the computer business is "cycletime", "channel speed", etc. Many of these technical specifications are of limited importance for most applications. Where the detailed technical specifications really matter the user normally has sufficient expertise to understand them.
In selecting computer equipment attention should be paid to the following points:

a) How will the supplier organize the installation of your systems? Guarantee of quality, cost, time, etc.
   It is essential to have a time schedule. Any later alteration to the time schedule should be justified.
   By-weekly or monthly situation reporting is essential.
b) Who is to be assigned to your project from the supplier?
   Ask for references.
   No matter the size of the suppliers organisation you will depend upon only a few of its staff, the ones assigned to your project.
c) Technical service?
   Response time.
   Size and expected quality of service function.
   Type of service (Round the clock, office hours, etc.)
   Cost of technical service.
   Are the following items included in the price?
   — spare parts?
   — expenses?
   — travel?

The above questions are just a sample of types of questions that should be put to the supplier of computer equipment rather than detailed technical figures. There are, however, applications where the technical specifications are of absolute vital importance. In such cases "bench-mark" tests should be carried out in addition to careful research.
After having done your groundwork thoroughly and selected your computer equipment you start the development. If you have not sufficient expertise inhouse to select your equipment it might be a good investment to use a consultant who is not linked with any supplier of equipment or data processing power (servicebureau). The cost of such assistance is at present in Norway from N.kr. 10.000,— in smaller companies.
In recent years the introduction of computer equipment has gone relatively smoothly in most cases where you have made the right choice. The problems start when you feel you have been cheated or the supplier feels you are unreasonable in your demands. This frustration may be eliminated if you take

minutes of your talks with the sales representatives and make sure that the essential points appear in the final contract. The people selling the equipment are not normally the ones who are going to be developing your routines.
If you have started with justifying the application which requires a computer instead of the cost of the computer itself, followed by a careful selection of your supplier and made sure you have got a well organized project team reporting to a steering committee by-weekly or monthly you are on the right track and the chances of succeeding are considerably improved.

NB! The man who is authorized to write out the cheque is not necessarily the man capable of choosing the machine.

The computer industry appears at present to be in a consolidation period without introduction of any revolutionary techniques. New machines and models are continously presented but without exeption these have been machines with new names or with slightly improved specifications. It is not believed that this situation will change significantly in the next 2—3 years. In the same period a lot of effort will be put into finding new applications for already known equipment. There are no signs of computers being cheaper in absolute terms even if the storage cost per character will decrease provided you choose a configuration with larger storage capasity. Obviously certain suppliers will introduce equipment which will fill "up the gaps" in their present product range. It is not believed that any such releases will introduce significantly new techniques or capabilities over the next few years.
A popular slogan in the computer world today appears to be "decentralised data processing power".
Many people talk about "power stations". Even if this is a technical possibility it is very doubtful if it is imminent although a datanet is under development in most countries. Personal integrity and authorisation controlled by laws will prevent this with very few exceptions. The trend is believed to go towards local logic (computers) which will eventually be superimposed on a larger network.
Inhouse computers are becoming a more and more attractive proposition for the smaller companies. Earlier a frequently used argument against having inhouse equipment was the difficulty in recruiting staff. Such arguments are rapidly becoming obsolete since all industrialized countries have a continuously improving education in data processing which will enable the companies to recruit sufficient expertise.
The development of applications in the immediate future appears to be within sectors or branches of business e.g. newspapers. Newspapers have identical problems: they have a deadline to meet (old news is no news) which is a technical problem but they also have administrative problems such as invoicing, accounting, etc. To solve this computer systems will be developed centrally to take care of both the technical and the administrative aspects of the business.
Each newspaper — apart from those having a combined production — will have its own computer within a very few years.
Similar applications will appear in an increasing number of branches.
Certain workshops have in the past bought a number of expensive numeric controlled machines. The present small computer is capable of handling a whole workshop centrally.
In the past several yards of control panels has been the only solution to control advanced technical processes. One or two TV monitors might do an equally good job if not better if they are connected to a suitable small computer. The input to the computer will come from suitable detectors etc. — which will give appropriate signals to the computer.
The typical cost for systems working as indicated above ranges from less than N.kr. 500.000,— software inclusive.
Many companies will find above investment interesting just in order to:

- motivate people
- ensure stable staff
- ensure clean/noiseless surroundings (noice is increasingly becoming a disturbing factor)
- ensure safety (certain production)
- easy recruitment of staff (education will help this).

In many cases a modern computer will prove cheaper than traditional equipment.
One major drawback of above mentioned development is the loss of certain interesting jobs. On the other hand it can create a lot of possibly more interesting jobs.
In recent years there has been a trend, towards stirring up public opinion against the further development of data techniques. This opinion, not totally unjustified, has had the effect of slowing down the process of putting super effective computer systems into operation.
However, it should not be impossible to set at effective legislation (this is already done in some countries) to protect the private individual in the widest sense. The slowdown in developing "super systems" may be used to develop D.P. so society as a whole can benefit from it.

Computer Systems for Process Control — a User's Requirements and Recommendations

BY SIV.ING. ARNE SVALHEIM, FALCONBRIDGE NIKKELVERK A/S, KRISTIANSAND S

INTRODUCTION

The use of computers for process control is increasing though it has not obtained the wide acceptance that was expected ten years ago. One of the reasons for this has been, in my opinion, the lack of complete, attractive systems for this purpose.

The following discussion has special relevance to the control of continuous chemical processes, but many of the aspects discussed will apply to a variety of processes. There will be emphasis on some features that until now have not received sufficient attention. The various processes will of course put different requirements on the control system with respect to control functions, operator communication, capacity, reliability and future development.

When designing a control system for a specific process, you must take the following question into account: Is it a process which you know how to control and run at sufficient optimal conditions, or is it a new process which will need further investigation and development during a rather long running — in period?

The latter case will demand extra services from the control system with respect to flexibility and power.

DISCUSSION

The points that require attention may be summarized:

1) Necessary control functions
2) Process operator communication
3) System operator communication
4) Background capability
5) Modularity
6) Availability
7) Backup instrumentation
8) Documentation

We shall discuss the above points in more detail.

To perform direct digital control (DDC), which is often desirable in continuous processes, the system must include, in addition to a multiprogramming real-time operating system, the necessary control functions. This may be simple closed-loop control, cascade, ratio and feed-forward control, or more advanced functions as multivariable and optimizing control, depending on the process needs and the level of ambition.

However, it is not satisfactory to let the computer control the process without the operating personnel knowing what is going on, or having interacting possibilities. Display and logging functions are required and the process operator must be able to ask for the information he needs, and give commands, i.e. check and change parameters, open and close loops etc.

Today's semigraphic and graphic display systems are powerful tools that should be extensively used for displaying process status, flow sheets, trend curves etc. Further discussion of the process operator communication would be beyond the scope of this article.

A second online communication capability that is often required is that for the system operator. This facility is especially useful in processes subject to frequent modification and expansion. It should include tools for recalibration of measurements and control loops and changing of parameters that are not available to the process operator. Further, it should cover online possibilities for establishing new measurements, reconstructing and building new control loops, at least up to a predetermined limit. This communication facility should act in a convenient, interactive and failsafe fashion through a terminal.

To facilitate documentation it should be possible to request updated printouts showing current status of DDC-tables, which identification numbers exist, which input/output channels are occupied, how much free space is left, etc.

Processes under continuous development will need the above communication facilities, but in addition background capability should be provided for making new programs. This might be done on a second computer, if available. Background work would require memory protection features and a mass memory, but, as we shall see later, a disc or drum will provide additional benefits.

Today it is very common to make systems modular. In fact this is a great advantage. It facilitates fault-finding and repair, and it also makes it easier to modify and expand the system.

Thus, modularity should exist both in hardware and software. It is, of course, also necessary that programs are compatible with the hardware, that they fit together.

If a process control system does not fill certain reliability requirements it will be a failure, no matter how excellent it is in every other respect. Breakdown in the central control system may result in large economic losses. Thus, it is vital to have maximum availability or minimum downtime. This will also reduce the need for backup instrumentation.

Availability for the central process control system can be enhanced in different ways. Methods partly aim at minimizing the number of total breakdowns, and partly try to shorten the time needed to recover from system breakdowns. It is assumed that basic features like power failure/power restart mechanisms are standard, further, if main memory is volatile, provisions for no-break supply has been made.

The following is a discussion of different factors that affect the availability of the total system:

1) *Duplication*

Duplication of equipment is a possible but expensive solution. On the other hand, alternative ways of getting information in and out should exist, particularly as peripheral devices often are less reliable than central parts of the system.

2) *Mass Memory Independence*

A process control system is often expected to run 24 hours a day, all the year round. In that case there will be little chance of doing preventive maintenance on central equipment. Vital functions should be independent of devices needing regular maintenance, e.g. moving head discs. Hermetically sealed discs and drums are probably good enough in many applications. Personally I like to talk about core — *based,* but disc — *backed* systems (core may be replaced by semi-conductor memory). This means that the first level of process control, process operator communication and other important functions are core resident and in operation even though a connected disc is out of operation for maintenance or repair. Less important tasks and background system would be laid on the disc.

3) *Automatic Restart Mechanism*

An additional recommended use of a disc (or another mass memory) is that of keeping an updated spare program. This combined with an automatic restart mechanism has proved to be a valuable feature for overcoming spurious malfunction and external disturbances.

You will avoid stops and loss of accumulated process data as would be the result if you had to enter a new program. Automatic restart requires that you keep an updated image of main memory on the mass storage. Restart will normally be initiated by a watchdog, but it should be possible to initiate it manually and from software in case of software error indication.

4) *Diagnostic Software*

If the restart mechanism can not tackle the difficulties, the system is brought down and a fault-finding procedure must be started. Why not let this be done automatically if the error is not too serious? Most diagnostic programs run in offline mode and should locate the error effectively and advise corrective action. It might be desirable to have some basic hardware tests running online. This might in some cases give a warning before the system stops.

5) *Spare Parts*

Having traced the error to a certain module, a new module is needed to replace the defective one. Fault-finding on modules is time-consuming and should be avoided. It is, then, advisable to keep spare modules, one of each type, on site, and have defective modules repaired by the manufacturer. Keeping other spare parts should also be considered, particularly vital electromechanical parts.

6) *Environmental Precautions*

Taking environmental precautions will pay off in the long run. The manufacturer's recommendations should be followed. Good filtering of the mains supply is advised. Normally air conditioning equipment should be installed, in some industries it may be recommended to remove traces of corrosive gases in the computer room using active coal filters.

7) *Program Maintenance*

After a computer breakdown the program system may be lost, even the updated spare program on a disc. It is thus necessary to keep an additional spare program offline. This may be on paper tape, cards, a removable disc cartridge, cassette or magnetic tape.

In a cartridge disc configuration it might be convenient to work on the fixed disc, keeping a duplicate on the removable one. An updated copy could then be put on the shelf whenever it was found necessary.
For safety reasons one might wish to keep a copy also on paper tape. This copying might be done les frequently.
Provision for online dumping of the program system should be made. This would ensure quick restoring with a not too old program version, after a serious breakdown with loss of program. The necessary software for reloading and initializing the system must, of course, be included.
Even though the above factors are taken into account to achieve maximum availability of the central control system, there may still be a need for backup instrumentation. This may be for security purposes, or for maintaining sufficient control to keep the process running for a shorter or longer period without the computer.
We shall not deal much with the backup philosophy here. However, provisions should be made for switching backup instruments in and out without getting "bumps". This may be easier with an incremental type of output, which, however, normally requires feedback of valve position to the computer. On the other hand, with absolute type of output, on startup with a new program in memory, one should update valve positions in core before unlocking the connection to the output (D/A — converters). This connection should be broken automatically to "freeze" the outputs if the watchdog trips. In addition, the watchdog should switch all backup instruments from "Computer" to "Local" mode to let them take over control. Having restored computer control backup instruments should be switched to "Computer", one at a time.

Finally, I will emphasize the need of having a well documented system. This will, of course, be of great importance to maintenance personnel and to other people working with the system.

CONCLUDING REMARKS

Considerations are made for a stand-alone process control system. There will probably be a trend towards interconnecting computers, building decentralized and hierarchial computer networks. These will require a somewhat different design philosophy. However, one should always take system failures and their consequences into account and provide for system redundancy and error recovery from the different situations that may occur. In process control one should always have Murphy's law in mind: 'If anything can possible go wrong, it will'.

SINTRAN III

BY CAND. REAL. ROY JENSEN, A/S NORSK DATA-ELEKTRONIKK

The first commercial operating system available for the NORD Computers was named SINTRAN and has been in operation since the end of 1969.
The system was designed for real-time applications and especially process control systems. During 1970 the system also allowed simple back-ground processing and real-time programs to be written in FORTRAN. This was a great improvement at that time when assembly language had been the only tool for implementing process control applications. In 1971 the system was also extended with a general file system and a subsystem for batch processing, NORDOPS.
Although SINTRAN allowed some simple interactive processing, the system had not yet the ability to service several users concurrently for program development and interactive problem solving.
These types of services were handled by the NORD Time-Sharing System which was developed in parallel with the SINTRAN system. The NORD-TSS allowed multi-lingual timesharing activities and was intended for use where many people required immediate access to a computing system. In such a situation NORD-TSS provided more services to each of many users than a stand-alone computer could provide for one user.
By utilizing the new hardware capabilities of the NORD-10 computer and the experiences gained with the SINTRAN and NORD-TSS systems, A/S NORSK DATA-ELEKTRONIKK made the SINTRAN III operating system in 1974 by combining the best properties of its two predecessors, then allowing one operating system, the SINTRAN III Operating System, to concurrently perform

— real time processing
— time-sharing processing
— local batch processing and
— remote batch processing

The system is highly modular and may be used for a wide range of NORD computer configurations. Modularity allows memory resident systems of only 8K words, expanding to mass storage resident systems including 256K words main memory, disks, drums, and so on, and connections to other NORD computers, thus allowing multiprocessing systems.

The philosophy behind SINTRAN III makes it especially suited for:

— Process control systems
— Business oriented on-line systems
— Scientific Engineering time-sharing systems
— Data communication systems
— Data acquisition systems

and combinations of these processed concurrently. The many sub-systems offered under SINTRAN III equips the user with powerful tools for solving their applications.

Multiprogramming

Through multiprogramming SINTRAN III allows numerous users to execute many different programs concurrently. The number of programs that can be processed concurrently, depends on such factors as hardware configuration, processing modes and applications involved. The programmer, however, uses the computer as if it was his own private machine.

Real-time Processing

Real-time processing allows the user to perform time dependent and time-critical work that requires very rapid information processing. A real-time program, generally responds to or controls external events. Under real-time processing there are four principal ways of scheduling programs;

— hardware requests
— program requests
— operators requests
— time scheduling.

The programs may have a full range of execution times, frequencies and start conditions. The system ensures that the most important real-time program will always be run first by providing 250 program priorities with any number of programs on each priority.
Real-time processing is used primarily in applications where data gathered during a physical process must be input and operated upon so rapidly that the results can be used to influence the process as

it develops. Real-time processing is also used in many on-line commercial applications.

Time-Sharing Processing

In time-sharing, the programmer interacts conversationally with the computer, receiving immediate response to his input. Many users on remote or local terminals can program on-line and make use of SINTRAN III subsystems. This type of interaction where each user received an equal share of time, in a round-robin fashion can be used for program development, information retrieval, interactive problem solving, and many more applications where the user will be best serviced by accessing the system directly. Program development may concurrently take place in the FORTRAN, NODAL, BASIC, NORD PL and MAC programming languages.

Batch Processing

Batch processing lets the user submit program jobs for computation to the computer. Each job contains all control commands, program statements and data required for its execution.

Batch jobs are divided into two categories. Those compiled and executed on the local NORD-10 computer's, local batch, and those compiled and executed on a host computer on which the local NORD-10 act as a remote terminal, remote batch.

In principle there may be an unlimited number of batch processes running in parallel with each other, and the other activities in the system. SINTRAN III outputs the jobs locally on a device such as a line printer, or disk file. If one job temporarily halts, another enters execution immediately.

PROGRAMMING LANGUAGES

To let the user implement his applications as easily and economically as possible, SINTRAN III accepts programs written in the following languages:

FORTRAN IV	following ANSI STANDARD FORTRAN and with ISA Real-Time Extensions.
NODAL	interpreting higher-level interractive language especially suited for real-time applications.
BASIC	interpreter following Dartmouth College 71 specification.
NORD PL	medium-level language especially suited for systems programming. SINTRAN III is written in NORD PL.
MAC	Assembly language and debugging package for the NORD computers.

Each language translator is accessed by a unique SINTRAN III command.

SUBSYSTEMS AND UTILITY-PROGRAMS

SINTRAN III is offered with many subsystems and utility programs which will be extremely efficient tools for the users of the system.

FILE SYSTEM offers the user a general-purpose file system for use of permanent files, scratch files, and peripheral device files. The system provides a very flexible file security mechanism that allows the programmer to specify the degree of security desired.

SIBAS data base system where efforts are especially put on the users' possibilities of representing complex data structures and on the separation of application programs from the data base.

SINTRAN III Communication makes it possible for different SINTRAN III systems to communicate with each other through a well defined, reliable and efficient line control procedure. The system is intended for computer networks.

RT-LOADER enables the user to load new RT-programs while real-time processing is running.

QED interactive program for editing symbolic text. QED is extremely efficient for on-line program development.

RUNOFF will help the user to write reports by processing the raw text information held in a computer file, and provide a printed document of a quality acceptable for publication.

DDC Package gives the user extensive tools for implementing process control applications on his NORD-10.

NORD IDT Package allows the user to communicate with Honeywell 6000, IBM 360/370, CYBER 74 and UNIVAC 1108/1110 machines through remote job entry terminal simulators.

In addition subsystems also include scientific and statistical program libraries.

Program Packages for Direct Digital Control (DDC)

BY SIV.ING. TERJE GRINI, NORATOM - NORCONTROL A/S

Introduction

The earliest process control programs for direct digital controll (ddc) were one and all "tailored" to fit the actual application. This was perhaps sufficient as long as no process extensions or modifications had to be done. But if so, it was a rather tedious and expensive job both to modify the programs and to add new functions.

Later on, in the late sixties and the early seventies, when sufficient experience was gained, a lot of process control functions were gathered and put into so-called program packages. Such packages are normally characterized by great flexibility and modularity. Usually they consist of a program part and a data part (the data base). The program part, which is modular, is independent of the application, while the data part is application dependent. Therefore, it is only the data base that have to be changed (modified) when going from one application to another.

The construction of the data base is done by using a ddc table generator. The job is then greatly simplified as shown below.

Advantages of Program Packages

Some of the advantages by using program packages for process control may be summarized as follows:

— Rapid implementation of standard functions like data acquisition, proportional + integral + derivate (PID) control, cascade control, ratio control, feedforward control, output of control variables, limit checking, etc.

— A cheaper control system because of reduced installation time and the fact that program packages are cheaper to buy than a "tailored" program system because the development costs may be shared by a number of applications.

— You normally buy something that is well-proven and well-documented and therefore works (perhaps it is already running in a number of installations).

— The process engineers do not have to learn programming. Instead, they may concentrate on their main task, which is the controlling of the process.

— The system implementation is simple. You only have to fill in some forms using a fill-in-the-blanks technique. At the same time, these forms give a good documentation support of all the analog points, controllers, output signals, etc. The filling-in is done in engineering units which is a "language" that the process engineers are familiar with.

MEAS, PROCSY, PROSO*

In the following, three such program packages are described. They may all be running in a NORD-computer (NORD-1, NORD-10, NORD-12, NORD-42) under control of the SINTRAN Operating System. They are:

MEAS — which is a program package responsible of reading analog signals from the process into the process computer and performing processing functions like measurement correction, measurement conversion (scaling), linearization, digital filtering, instrument limit check, rate of change limit check, process variable limit check, etc. When alarm situations are detected, the operator is warned and details about the alarms are logged or displayed.
The MEAS system is provided with a set of communication routines to enter or extract parameters in the system data tables.

PROCSY — which is a program package capable of doing a lot of process control functions like PID-control (or variations of PID), cascade control, ratio control, feedforward control, simple multivariable control, setpoint limit check, deviation limit check, etc.
The PROCSY system is also provided with a set of communication routines to enter or extract parameters in the system data tables.

PROSO — which is a program package capable of outputting both absolute and incremental output values. It also contains processing functions like output conversion (scaling), output position limit check, output change limit check, output dead-

* These program packages were developed when the author was at SINTEF, division of Automatic Control.

band limit check, etc. When the control variable exceeds one of its limits, it is clamped and the violated limit value returned to the calling program (PROCSY) to avoid controller wind-up. PROSO is also provided with a set of communication routines to fetch or change parameters in the system tables.

The three program packages work together as illustrated in Figure 1. The process variables are scanned by MEAS either periodically or at demand. PROCSY uses these variables as input to its control algorithms, thereby generating a set of control variables that in turn are handled over to PROSO who checks them for reasonableness which usually are determined by actuator specifications. At last, the accepted control variables are sent to the actuators in order to have the process running as near the prescribed values (setpoints) as possible. Together with the operating system SINTRAN, the three program packages MEAS, PROCSY and PROSO form a complete process control system (basis system). Around this basis system, the user can build his own application dependent programs/subroutines either in RT-FORTRAN, NORD-PL or assembly language as shown in Figure 1.

DDC Table Generator

The program packages MEAS, PROCSY and PROSO work on a set of tables (database) that contains all the data necessary for controlling the process. To save core space, these data are strongly packed. Therefore, it will be a rather difficult and tedious job to manually fill the tables with relevant data. Moreover, a lot of the numbers are the result of some computations, and manual set-up often results in errors which may be difficult to detect.

Therefore, a small compiler called the DDC TABLE GENERATOR is offered together with the MEAS, PROCSY and PROSO packages. It takes input data largely in engineering units and outputs a paper tape containing the necessary tables.

Previous to running the DDC TABLE GENERATOR, some forms ought to be filled in. As an example, this is shown in Figure 2 for an analog signal which is to be scanned by MEAS.

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1. MEAS II — An Analog Input Program System for Process Control. Application Manual. SINTEF Report STF48 A73023.
2. PROCSY — A Real-Time Process Control System. Application Manual. SINTEFF Report STF48 A74003.
3. PROSO — An Analog Output Program System for Process Control. Application Manual. SINTEF Report STF48 A74005.
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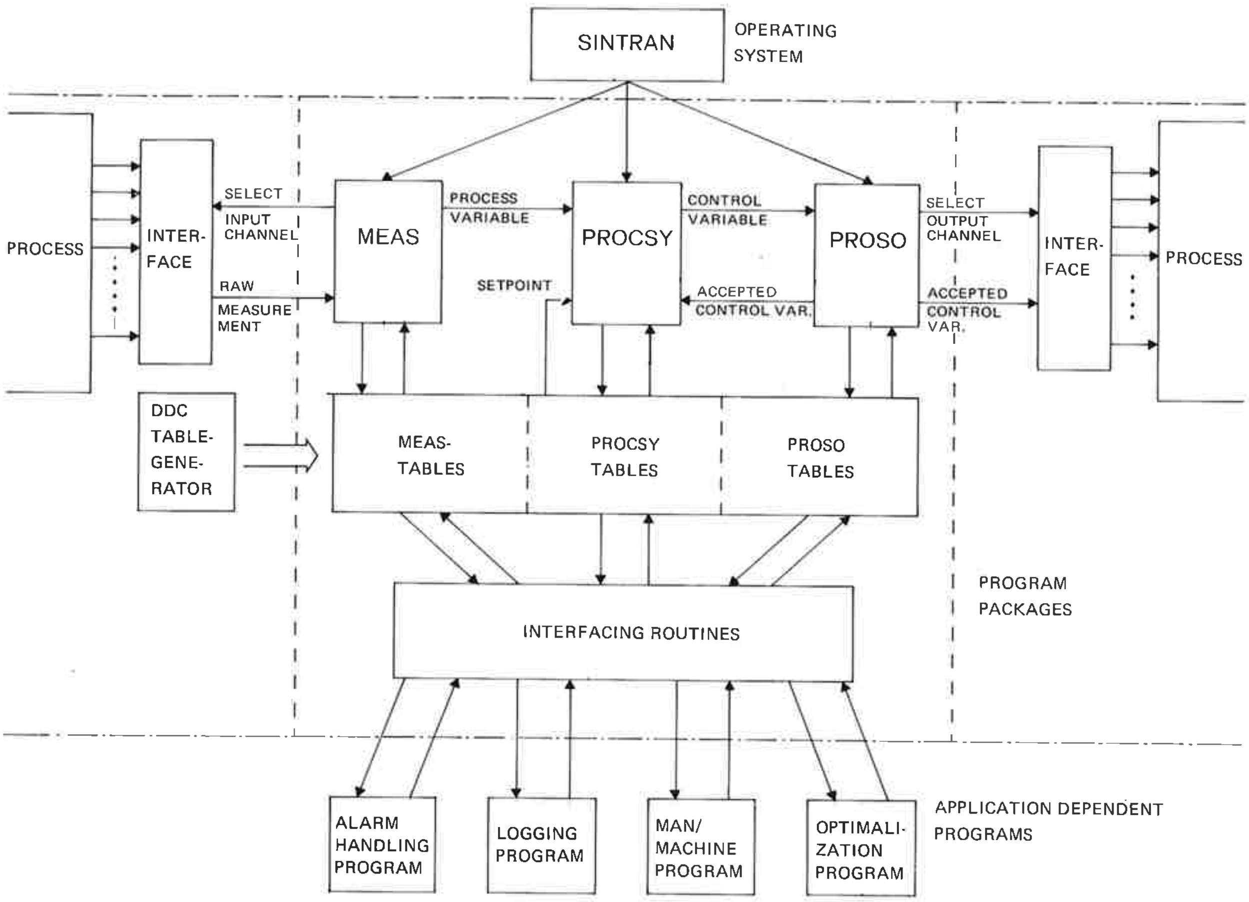

Figure 1. Showing MEAS, PROCSY and PROSO.

FORM 2. PROCESS VARIABLE SPECIFICATION

GENERAL INFORMATION

	Flow 9sw
NAME OF VARIABLE	Process section A
DESCRIPTION	

T,A,B,L,E   M,E,A,S

A/D CONVERTER

ABSOLUTE LOWER LIMIT IN VOLTS:	0	Real
CORRESPONDING COUNTS:	0	Integer
ABSOLUTE UPPER LIMIT IN VOLTS:	5	Real
CORRESPONDING COUNTS:	1023	Integer
NUMBER OF CALIBRATION GROUPS:	2	Integer
CALIBRATION VOLTAGES		
LOWER:	0.5	Real
UPPER:	4.5	Real

G,R,O,U,P	G,R,1	S,A,M,P,L	1.0	P,R,I,O,R	1,2,8
	GROUP NAME		SAMPLE TIME IN SEC.		PRIORITY (0 - 255)

SPECIAL INFORMATION

IDENTIFICATION

00 [3] ANALOG POINT NUMBER (0-2047)

CONTROL BITS

01	0	OFF SCAN (0 = normal, 1 = off scan)
02	0	CALCULATED VARIABLE (0 = scanned variable, 1 = calculated variable)
03	0	NO CONVERSION (0 = conversion, 1 = no conversion)
04	1	SQUARE ROOT (0 = normal, 1 = square root)
05	0	EXTERNAL LINEARIZATION (0 = no linearization, 1 = linearization)
06	1	DIGITAL FILTER (0 = no filtering, 1 = filtering)
07	0	INHIBIT ALARM (0 = normal, 1 = inhibit alarm)

SCANNED VARIABLE

SOURCE

08 [2] MULTIPLEXER ADRESS WORD (- 32768 - 32767)

INSTRUMENT LIMITS

09	1.00	INSTR: LOW. LIM.	Volt
10	4.05	INSTR. UPP. LIM.	Volt
11	0.4	INSTR. LOW. LIM.	Eng. Units
12	6.15	INSTR. UPP. LIM.	Eng. Units

PROCESS VARIABLE LIMITS

13	0	PV LOWER LIMIT	Eng. Units
14	5.0	PV UPPER LIMIT	Eng. Units
15	0	PV RATE LIMIT	Eng. Units

INITIAL VALUE OF PROCESS VARIABLE

16 [2.5] PV (Eng. units)

REFERENCES

17	1 0	UNIT INDEX (0 - 31). REFERS TO "TABLE UNIT" (FORM 3)
18	0	FILTER CONSTANT INDEX (0 - 7). REFERS TO "TABLE FILTR" (FORM 4)
19	4	ALARM DEADBAND INDEX (0 - 7)

LINEARIZATION SUBROUTINE

20 [ ] SYMBOLIC NAME OF SUBROUTINE (only if EXTERNAL LINEARIZATION = 1)

CALCULATED VARIABLE

SOURCE

08 [ ] CALCULATED VARIABLE NUMBER (0 - 2047)

ABSOLUTE LIMITS

09		DUMMY	
10		DUMMY	
11		ABSOLUTE LOW. LIM.	Eng. units
12		ABSOLUTE UPP. LIM.	Eng. units

Figure 2.

Computers in Industry; what are the Social Effects?

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Use of computers in industrial automation has recently received a great deal of attention from workers and labour unions. Typical of this interest is the Norwegian Iron & Metal Union's project aimed at studying the consequences of the increasing use of EDP for their members. One of the reports from this project, written by a local union group, is quite critical regarding the latest development and list several negative aspects:

— closer control of workers
— loss of skill and challenge
— less freedom in the choice of methods
— less contact among workers

Constructors of automatic systems have often been met with criticism, but earlier they were mainly accused of taking the jobs away and creating mass unemployment. That side of automation does not give a great deal of worry to-day, but instead the interest focuses on what we could call the social effects of automation. How do the systems affect job content, social situation and industrial organization?

These are complex questions and have no simple answers. Let us start out by analyzing the nature of computer-based automation. What kind of tasks is the computer fit for, and can we se any future trends? When comparing man and computer, it is evident that man has his greatest advantage in flexible use of senses, hands and feet and use of his brain as a general purpose problemsolving organ. The computer's strong side is its ability to handle large amounts of data and perform fast calculations on these data, i.e. pure information processing and problem-solving. We would therefore expect automation of pure metal work to go faster than automation of work involving flexible use of senses and limbs, or "complex eye-brain-hand sequences" as the American sociologist H. A. Simon calls it.

What are the consequences of a trend like this for industrial automation? Many industrial jobs consist of a combination of mental work and complex eye brain-hand sequences. A typical example is the operation of lethes in the metal industry. The operator traditionally starts out with blueprints that describe the wanted piece, he plans the work, chooses the methods and tools and finally performs the necessary operations. A central part of his work is planning and decision-making, and it is exactly that part which is being automated. Left for the operator are operations like positioning the workpiece, putting in the tools and watching over the process in case anything goes wrong. The total result is reduction of challenge and the level of skills needed, and also a loss of an important part of the job; decision-making. In the extreme cases the operator is reduced to some kind of an automaton who performs simple manual operations, but w h y and w h e n these operations should be performed is decided upon by computers.

In other industries we can see the same trend. Great efforts are taken to automate the planning and decision-making processes, and this is made possible by progress in mathematical model-building and development of better control strategies. A great deal of the mental work formerly done by operators like information processing, problemsolving and decisionmaking is taken over by computers. There are of course situations where the work load is heavy and a reduction of responsibility is wanted. But a general reduction of responsibility and transfer of decisions to computers will lead to a loss of challenge and meaning in work. It will reduce the worker's importance in the production process and increase his powerlessness and alienation.

Labour unions have begun to react against a development of this type, and constructors and planners of computer systems are taking a greater interest in the social consequences of the systems. Maximum automation should no longer be a goal in itself. Instead one should try to obtain the right balance between automation and operator responsibility. Man has a great capacity for making the right decisions, even when data are uncertain, and it would be unwise not to make use of this capacity. Instead of taking over decisions, computer systems can be constructed such as to aid operators in their planning and decision-making. Modern technology gives the operator great possibilities for

— increased insight into the technical processes
— better understanding of his own job and what it means in the production process
— better information about the whole process, not only about his part

— developing his abilities and learning while working

But these possibilities must be built into the systems, i.e. a great deal of attention has to be given to them in the planning phase. The operators also need a motivation to use the existing information. If they are not given responsibility for a certain amount of planning, problemsolving and decision-making, where information is needed, it might be looked upon as uninteresting and of no use.
So far we have considered the effect of automation on the single operator's job, but it is also evident that it might affect the whole social situation and the organization of industrial work. In some cases the computer systems have led to less contact between workers, and also between workers and supervisors. The information flow in a computer system is formal and limited, and it is a great difference between getting a job assignment from a computer terminal and getting it from a person in face-to-face contact. The importance of such social contact is often neglected, and the result is a situation where people feel isolated and solidarity is low.

Introduction of avanced automatic equipment may also lead to a split-up of workers into different status-groups. A well-known example is the situation with a high-status group in the control room and low-status jobs elsewhere in the production process, and where there is very little contact among the groups. A situation like this is highly undesirable, and a result of too little insight and planning. Another aspect is the old worker's situation, who have a great deal of skill and experience but less capacity and motivation than young people for learning new techniques. Do we make room for old workers, too, when designing computer systems?
There is at present a growing concern for the social effects of industrial automation. Social scientists have started to study these problems, and engineers and designers are beginning to take greater interest in how computer systems affect jobs and social situation. An important trend is the rising concern among workers and labour unions, who want to take part in system planning and design. This interest should be welcomed as an important contribution. User participation is an important principle for better system design, and it is a challenge to make this participation successful.

System Engineering Aspects of the Man-Machine Interface

BY K. NETLAND, OECD HALDEN REACTOR PROJECT

SUMMARY
The increasing size and complexity of today's processes, the more severe requirements to the safety and the wish to improve quality of control and supervision of these processes have caused a considerable growth to the amount of information to be digested by the human operators. The use of process computers provides a technical basis for improvements in control room design essentially through the application of graphic display units and function consoles as major tools for communication between the operator and the process.
The increasing complexity and the necessity of computers for control, supervision and digestion of process data have caused more effort to be put into the design of operator interface equipment. It is in order to try to avoid the occurrence of mismatch between the capability of man and his environment that the study of *ergonomic* has developed the last years.

THE OPERATOR — HEART OF PRODUCTION
When installing process control computer systems, very often too much emphasis is placed on sophisticated control theories as compared to handling of the exeptions and abnormal situations, and on the necessary communication with the people responsible for the production. Effective and proper man-machine interfaces are a necessity for a successful implementation of any process control system, computer-based or conventional. Perhaps as much at 10 % of a process control scheme should consist of control theory and the remaining 90 % the exceptions, abnormal conditions, alarming and communication between the computer, management, the operators, and the process.
Two levels of operations are normally necessary for processes above a certain complexity.

- *Control.* Control of process parameters, e.g. temperature, pressure, flow, level etc.
- *Supervisory.* Supervision and optimization of control strategies and parameters, e.g. setpoints, amplification factors, etc.

At the lowest level the operator will maintain the different control loops, i.e. change setpoints, change valve positions, adjust alarm limits, supervise process variables, etc. Because of the large amount of data, it is desirable that the system is designed in such a way that only necessary and valuable data from the current operating condition are presented to the operator.
At the next level the operator or supervisor, is likely to want access to more data than at the control level and he will want to look at it over a longer period of time to establish trends. He may wish to look at parameters which are not directly measured, but which have been calculated by the computer from measured data, like integrated flow averages, power consumption, temperature profiles and product quality.

The operator's tasks can be classified in three groups:

- tasks during normal operation
- tasks when change in operating conditions are necessary
- tasks involving supervision, detection, and repair of faulty conditions.

The first two groups can be described and formulated in the design phase, while the last group includes the operator's tasks in abnormal situations, i.e. events not previously known or described. To handle new events, the operator should be well prepared and trained and the operator/process interface should support him with relevant data to detect, identify, and evaluate the fault. In abnormal situations, it is of great importance that the operator has sufficient routine from operating the plant in normal situations, this lead to well-known question about the optimal *degree of automation.* The limitation of fully automatic control is becoming more and more evident. If the selection of the best decision has to be made fully automatic, the constraints and the process status must be defined in terms of mathematical models. This fact often restrict the scope of application of automatic control. Since the operator is a necessity to handle the process when not automized events occur, then he needs experience from normal operation, thus a semiautomized system is often the most practical solution for a process of some complexity.

HUMAN ENGINEERING — FACTORS IN CONTROL-BOARD DESIGN

In the past, human engineering considerations played a relatively minor role in the design of human operated equipment. Today, however, very often the terms "Ergonomics", "Human Factors", "Human Engineering", and "Antropotechnics" are used in description of man-machinesystems. The terms have not in all publications the same definition. In this paper the terms will have the following meanings:

- *Ergonomics.* The science of human relation to the machines, described in terms of psychology, physiology, sociology, pedagogy, and technology.
- *Human Factors.* Intention to fit man to machine by selection and training.
- *Human Engineering.* Adaptions of machine to men.
- *Antropotechnics.* This term is almost synonymous to Human Engineering. The first is normally used in Europe, while the latter is common in the U.S.

Since man began to develop technical equipment to support himself, he has endeavoured to adapt it to his nature. At first he began to approach this problem in a less systematic but a more intuitive manner, or according to the trial and error method. Today, in our rapidly growing and technical minded environment, this evolutionary approach proves inefficient, so that we are forced to treat the elements in man-machine systems in a more scientific way.

To optimize the man-machine interaction, there are two different approaches. As a first stage, one can adapt the human operator to the machine. This discipline, which is oriented towards the *human factor,* tries to adapt man to his role in a man-machine system by selecting the most suitable personnel to perform a specific task as well as by appropriate training and monitoring. Since man has largely been firmly established during the long process of human evolution, the capabilities of this approach are, however, inherently limited.

The second approach that will normally go hand in hand with the above described method, is the adaption of the machine to given human characteristics, i.e. *human engineering* in a more restricted sense. The scope of this approach is of cource extremely wide and is in essence only limited by the state of technology and by cost — effectiveness considerations.

EXPERIENCE FROM OPERATION OF A NUCLEAR REACTOR BY A COMPUTER- AND COLOUR TV BASED CONTROL ROOM

To explore the practical consequence of the ergonomic principles mentioned above a system for operator/process communication has been developed as a co-operation between A/S Norsk Data-Elektronikk and Institutt for Atomenergi. The system comprises a console with functionally defined push-buttons, a keyboard, and four colour TV-displays. All units are controlled by a minicomputer, which in turn is connected to a main process computer. The design of the existing NORDCOM system was based on the hardware and general software developed for experimental operation at the Halden Project. The main components in the configuration are shown in Figure 1. The NORD-1 computer reads process

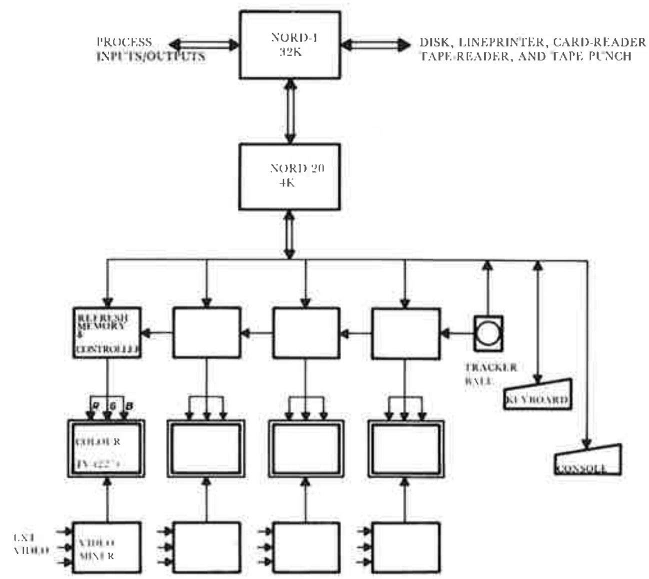

Fig. 1. NORDCOM Structure for supervision and control of the Halden Reactor.

variables (flows, temperatures, levels, pressures, etc.), analyzes the current status and eventually displays alarms or messages to the operator. This computer will also build up trend curves, circuit diagrams, bargraphs, etc. when requested. In addition, the NORD-1 will handle manual and automatic control actions such as operation of pumps, valves and control rods.

The communication computer is a NORD-20 with 4K of memory connected to the main computer via a data channel. The NORD-20 will generate graphic- and alpha-numeric pictures and serve the operator's console and the keyboard. The user programmes transfer graphic data as coordinates with colour information and alpha-numeric data as FORTRAN format strings with information about colour and size of characters to the NORD-20 computer.

An 8K memory for each of the four individual channels contains the information for a fully graphic picture. A controller is capable to refresh each picture (256 by 384 points) every 20 milliseconds, synchronized by pulses from a sync. generator. For the graphic mode of operation, one bit in the memory corresponds to one intensity point on the TV-screen. For alpha-numeric mode of operation, the controller contains a character generator. In this case alpha-numeric data storage needs only the first 800 words of the refresh memory. The version of NORDCOM has no semigraphic mode.

The operator's console consists of function push-buttons and alpha-numeric displays built up from light emitting diodes. For direct addressing on the TV screens, a tracker ball moves a square mark over the screen. The mark is hardware generated and when pressing a read-button, the position of the mark is transferred via the NORD-20 computer to the NORD-1 computer.

A maximum of three video signals can under programme control be mixed on the screen with the computer signals. The signals can be ordinary broadcasting TV-pictures, output from a video recorder from a TV-camera, etc. Four possible intensity levels can be programme controlled.

Fig. 2. Part of Control-Room for experimental operation of the Halden Reactor Project.

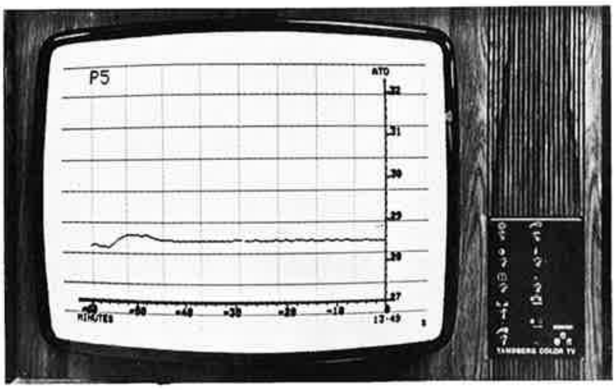

Fig. 3. Change of reactor pressure the last hour.

Experimental Operation of the Halden Reactor

At the OECD Halden Reactor Project, an international research and development programme on computer control of power reactors is being conducted. The programme aims for demonstration of advanced plant supervision as well as direct digital control functions. The reactor is a small, boiling, heavy water reactor with an operating pressure of 33 ato and a maximum thermal power of 25 MW. A research and development programme on computer control has been carried out since 1967 and the studies of the human operator aspects has from the beginning been a main activity.

To evaluate the performance of the previous described equipment, experiments involving direct computer operation of the reactor plant have been conducted. An experimental control room has been established beside the conventional control room, which has been in operation since 1958, and operators from the old control room have been trained for operation of the plant from the computer- and TV-based control room. The selected operators followed a 30 hours course before starting to operate the plant, first passive (supervision of the plant status and trends) and later complete start-up and shutdown of the plant.

The objectives for experiments were to:

— Demonstrate that it is possible to implement the most important functions of the old control room in an acceptable way and show that the graphic display formats and the control philosophy of the system can be used.
— Demonstrate the positive features offered by colour TV displays and computers to create a new man-process interface which is easier to be dealt with for the operator.
— Demonstrate that possible drawbacks of the new system do not affect it so much that the ultimate results are not better than before.

Preliminary Results from the Experiments

During operation of the plant from the new control room, a number of technical, functional, and ergonomic aspects were observed. Not all observations are of general interest, some are still rather vague, and most of them will need a more detailed evaluation before they are reported on. Some of these observations are listed below:

— For experienced operators with process knowledge, only a short training period is necessary.
— Even for not so experieenced operators, an easier introduction to the process was experienced due to better visulization and group display of related information.
— A designer of a computer and colour TV-based control room should be careful in use of available features such as colours, blinking, intensity, messages in different colours, light in push-buttons, etc., and not "overplay" such features. The simplest solution is often the best one.
— Bad design of picture lay-out will easily increase the requirements for more TV-units, while careful thinking when composing the different formats may give remarkable results with respect to hardware requirements.
— For TV-based control rooms one has to pay special attention to light conditions, the operators complained about headache from time to time. It should also be emphasized that watching TV for a too long period at a time may be exhausting
— The centralizing of the operator's functions in one compact console has turned out to be a "bottleneck" in the system, since addressing and operation of plant components are performed by means of this device. A number of improvements for the

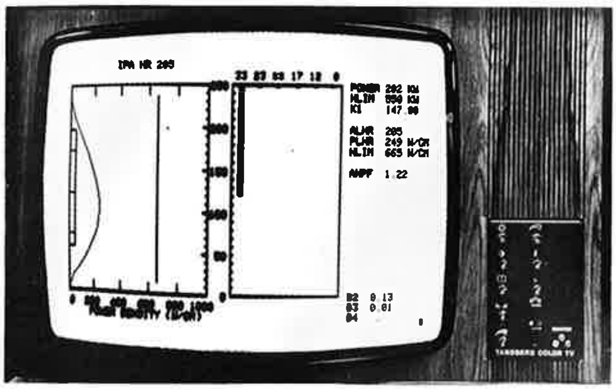

Fig. 4. Flux Profile for a fuel element.

input functions will, after further investigations and experiments, be proposed.

— The implemented functions satisfied with few exceptions the requirements for operation of the Halden reactor during normal conditions. (The process has many similarities to other processes, i.e. valves, pumps, flow, levels, etc.).

— The response time from the computer system to the operator requests is of great importance to the performance of the system, i.e. immediate response is desired.

CONCLUTIONS

System engineering of man-machine interfaces calls for wide interdisciplinary knowledge covering a multitude of subjects such as technology, psychology, physiology, information theory, process theory. Thus, general guidelines for lay-out and design of controlboards into well engineered units from an operator's point of view are difficult to give and the final product will often be a compromise. Anyway a very important subject is the user of the interface, i.e. the operator(s) involved at the different applications. He should therefore to a large extent be consulted and involved in the design phase. If he can be well motivated, the introduction of new man-machine interfaces will in most cases be successful.

The already performed and planned experiments at the OECD Halden Reactor Project are expected to give valuable data for investigations of the performance of computer- and TV-display based control rooms. This work will not necessarily give specific, quantitative experimental results. However, by comparing the operation of the process performed from the conventional control room and from the new control room valuable quantitative results will be obtained, results which will form a basis for further developments.

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