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Abstract

The report reviews the development of instrumentation for Risø experiments, research in system techniques and nuclear geophysical methods, and work in the service area. Publications issued during the half-year period are listed.

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CONTENTS

1. SYSTEMS TECHNIQUES

This section covers system work, control, man machine relations, reliability, and minicomputers.

Separate chapters will describe: graphics terminal, reactor model, kidney simulation, analysis of control tasks, and the DR 2 computer experiment.

A study began on alarm presentation. Large parts of the operations performed by a human in highly automated plants will be initiated by alarms, and modern display techniques have rather interesting aspects in relation to the alarming, the diagnosis, and the remedy phases. The aim is to communicate signals and plant data in a way fitting the real operator needs.

1.1. Off-line Graphics Terminal

A graphics terminal has been acquired and installed in the department. Its purchase was a natural consequence of the results of earlier work, which indicated the need for carrying on man machine experiments both in an industrial (or quasi-industrial such as the DR 2) milieu and in an off-line environment where closer experimental control could be exercised.

After a study of the available equipment on the market, which ranged from low-cost storage CRT configurations to refreshable systems, the decision was made to purchase an IMLAC PDS1 Display Computer. This consists of both a conventional digital processor and a display processor, which time-share a common core memory. This permits a good deal of computing to take place in the terminal itself. The configuration consists at the moment of a 14" CRT, 8k of core memory with a 2 μs cycle time, keyboard, lightpen and a 2400 baud link to the host computer. The display processor utilizes software character generation for flexibility and can also draw lines, curves, etc. by means of appropriate absolute and incremental beam-positioning orders.

The terminal is at present connected to the PDP8 programming system which has now been extended to include 8k of core, 96k of disc, and DEC-tape. The PDS1 is used daily as a replacement of the ASR33 Teletype since its fast and silent operation is generally quite attractive. Sometimes, however, the lack of a hard copy of current (and earlier) progress is felt; in addition, the very considerable acoustic output of the ASR33 can be extremely useful as an indication of program status.

An operating system has been created which provides the required communication facilities between the PDS1 and the PDP8. In addition, a PDS1 assembler including a macro facility has been written and runs under the PDP8 Disc Operating System. This utilizes all relevant facilities of the programming system and produces listings, block-formatted PDS1 paper-tape, etc. Programming for the PDS1 is currently being carri d out in the following fields:

- Interactive text editing
- On-line drawing and editing.

Experiments utilizing these and other general-purpose programming tools are expected to be specified during the coming period.

Fig. 1. Graphics terminal (left) and PDP computer system.

Fig. 2. Lightpen operation.

1.2. Development of a PWR Power Station Model

A project group consisting of two engineers from the Reactor Department, one from the Reactor Physics Department and one from the Electronics Department has started the development of a model of a PWR power station including the steam power plant. The work is estimated to take two years.

The intention is, in the final state, to connect some sort of display system and operator knobs to the model, enabling the operator to follow, in real time, the main variables for normal operator manipulations of the main control loop set points. A hybrid machine has therefore been chosen for the simulation. The available equipment will be an EAI 680 analog computer, a PDP8 digital computer with 8k core store, 812k disc store and floating point processor. The two machines are connected to 16 A/D converters and 16 D/A converters. More D/A multiplying converters will be installed.

The main parts of the model will be:

a) The reactor tank and core with boron and control rod reactivity control. A one-dimensional model with about 16 nodes will be used making it possible to study the axial power distribution.

b) The primary cooling system with main circulation pumps (one or two) and tubes.

c) The steam generator (one or two). A simple model consisting of a few nodes must be used as a more sophisticated model would need too much calculating equipment and time. A more detailed model for separate analysis of the steam generator is also being developed.

d) The pressurizer in the primary system.

e) On the secondary side the main part will be the steam turbine and the generator providing connection to the power grid.

The bypass system, the pressure relief valves and the feedwater pumps must also be included in a simple form, but it is doubtful if the condenser, feedwater tank and preheaters can be included, considering the limitation of analog equipment.

f) Control systems for power, pressure and water level must be connected to the model but need not be simulated on the computers.

Hybrid calculations will mainly be used for the power and temperature distribution calculation for the reactor core. The other parts in the station will mostly be represented by point models simulated by analog components.

The model may be used for investigations of the dynamic characteristics by normal operation and some accident simulations with limited excursions of temperature and pressure. Some cases are mentioned:

a) Analysis of stability and control characteristics in the normal power range. Transients of power, temperature and pressure by power changes of varying rates.

b) Analysis of normal operator manipulations and the corresponding transients in the main variables.

c) Analysis of the station's frequency control characteristics and its ability to follow power demand changes from the power grid.

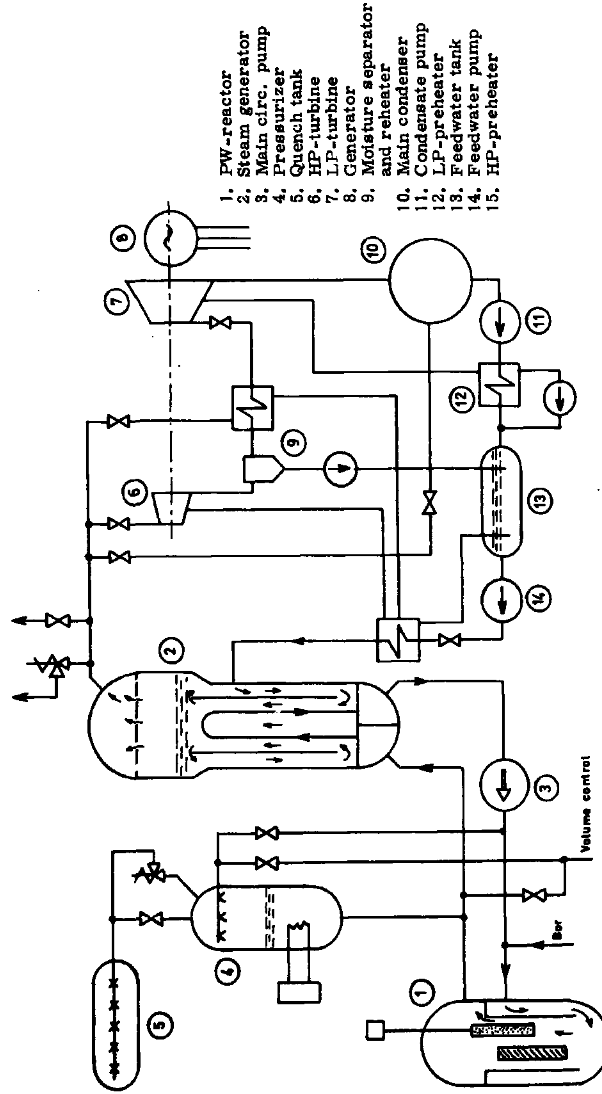


Fig. 3. PWR station flow diagram showing the main components in the primary and secondary loops. The model of the secondary side may be simplified by omission of the preheaters, the condenser and the feedwater tank.

d) Qualitative analysis of transients due to fault situations, e.g. reactor trip, turbine trip or loss of one main circulation pump. Further malfunctioning control loops and the consequences of the malfunctioning may be investigated.

In the model development the main emphasis is put on real time simulation and easy communication between operator and model. These demands exclude pure digital simulation at a normal digital computing centre. On the other hand severe limitations in computer power are introduced by hybrid simulation, thus making dispensing with accuracy and detailed modelling necessary.

1.3. Hybrid Computer

In co-operation with the Vejle County and Municipal Hospital the kidney simulation work has continued [3]. Parameters describing the kidney dynamics were determined automatically by means of curve fitting (fig. 4). The work has also served as a test of the pattern search and the accelerated random search optimization methods.

In the renogram test considered, the course of radioactivity is detected over each kidney region with a detector probe and a ratemeter or counter system after an intravenous injection of radiohippuran. In addition one detector is placed over the heart and another over the bladder region.

The mathematical model used is based on a compartmental model in which the kidney is considered a system of fluid-filled containers interconnected by means of tubes with forced fluid transport (fig. 5).

On the basis of curve fitting realized earlier by means of hybrid and digital computers, a digital computer program is developed for the automatic determination of kidney parameters. These parameters include rate constants (reciprocal time constants) and assisting parameters for the realization of the model. - The new program determines more parameters than the earlier procedure in one computing process; it takes into account the information provided by the extra detector placed over the bladder region.

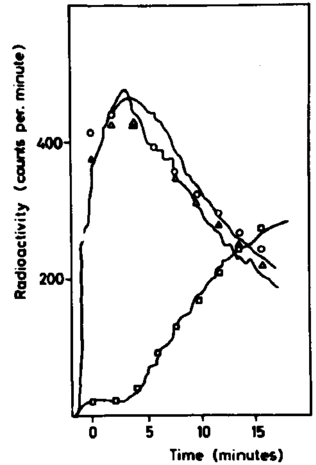


Fig. 4 Curve-fitting results for the kidney and bladder renograms.

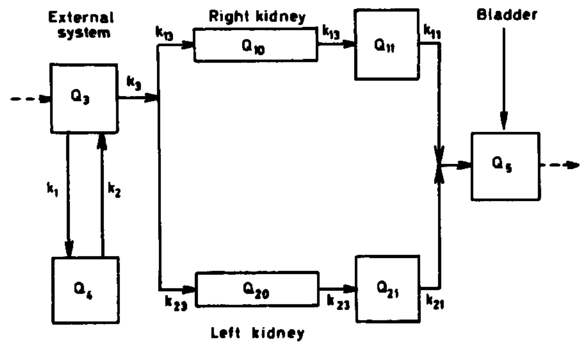


Fig. 5 Compartmental model for renogram test simulation.

1.4. Analysis of Power Plant Control Tasks

The work has been done in co-operation with members of a power plant staff. The aim has been to provide a basis of information to be exploited in running and future studied of the topics: structures of computer control systems and systems ergonomics.

The automatic and manual control tasks of an oil-fired power plant unit were classified and described. Within each class the number of tasks and their extent were estimated and the interplay between tasks and classes was investigated. It was attempted to trace the control actions, set points and quality criteria back to their origins in the primary specifications and process problems. The functions of the control room operators and their interaction with the instrumentation were described.

The following classification of control tasks is used:

A: Maintenance of optimal conditions in the main process during normal plant operation.

B: Similar to A, but of secondary importance to optimality.

C: Co-ordinating tasks taking care of changes of the operational states of plant components and systems.

D: Protective tasks.

E: Check and start-up of new and/or repaired equipment.

F: Collecting data for the planning of plant operation.

This classification, although without well-defined boundaries, has been found useful, possibly reducing overlapping to a minimum; it might thus constitute the basis of a more systems-directed control task terminology.

A main purpose of control is reduction of losses. From a systems point of view it is useful to recognize the variety of loss categories controlled, e.g. small, frequently occurring deviations from optimal efficiency controlled by closed-loop regulation, and serious, very infrequent abnormalities with risk of plant breakdown, resulting in trip actions. Between these two extremes of loss types, more sophisticated controls around the turbogenerator limit losses to, though significant, yet acceptable and specified, levels in transient operational situations. Controls of this type may improve future plant availability.

The operational conditions for the boiler do not for the time being provide any stimulus for start-up automation. However, the infrequent

occurrence and the types of operator tasks have motivated a feasibility study of possible future aids utilizing computer controlled displays. In order to clarify and describe the operator tasks and the display requirements extensive use has been made of tape-recorded verbal descriptions given by the operators during their start-up manoeuvres, and of discussions with the operators. This method of providing information for the description of the operators' working situation has given valuable experience for the systems ergonomics work.

The alarm annunciator with one integral class of operator information, consisting of several hundreds of alarm-indicating lamps, seems to be an unsatisfactory type of display, particularly in complex situations involving a great number of alarms and/or a high frequency of occurrence. A separate study is investigating new possibilities of presenting the alarm information in a way yielding better operator aid.

This problem is closely related to that of formulating the mental procedures of the operator in diagnostic situations.

1.5. Man Machine Experiments at DR 2

The digital instrumentation installed at the DR 2 reactor was after the first experience [9] extended to comprise a two-computer system. The new configuration was put in operation one year ago and the first adjustments have been made. Recently the DR 2 operators have been introduced to the system.

The experiment originated in general work on reliability, and one of the topics to be studied with the DR 2 equipment was operator communication. During the last years we have in several ways tried to throw some light on this matter. The troubleshooting analysis [1] focused on algorithms and mental models in electronics repair work.

Ref. 2 reports on work closely related to the computer experiment: during studies in the DR 2 control room we "peeped into" the daily routines to gather the real mechanisms in reactor operation. Thus we are better prepared to discuss with the operators as they join our experiment.

As seen from the operator side the DR 2 computer system features a nearly 100% duplicate of the measurements accessible in the nearby control room; but the communication is quite new, and control of the process cannot yet be performed. To the operator this means

1. acquaintance with new techniques - CRT and lightpen instead of meters and handles,

2. modification of the communication procedures. Especially he must select information with lightpen and buttons instead of just move his eyes; and he has no other sources of information than the 2 CRT screens and a lamp arrangement giving condensed alarm status ("power, max. or min. alarm" etc.);

3. the operative status is quite different; he is not able to operate the process.

The operators are currently being trained in console operation.

During our work we learnt a great deal about man faced with computer systems. The DR 2 operator brings with him a rather detailed image of what is going on behind the computer system: he knows the reactor and the measuring channels quite well, but the face upon which he operates has been changed radically.

In studying the operator who gradually acquires new procedures we may point out some of the weak points of the system: do the main troubles stem from the buttons, the picture, the composition or the instruction or from something else?

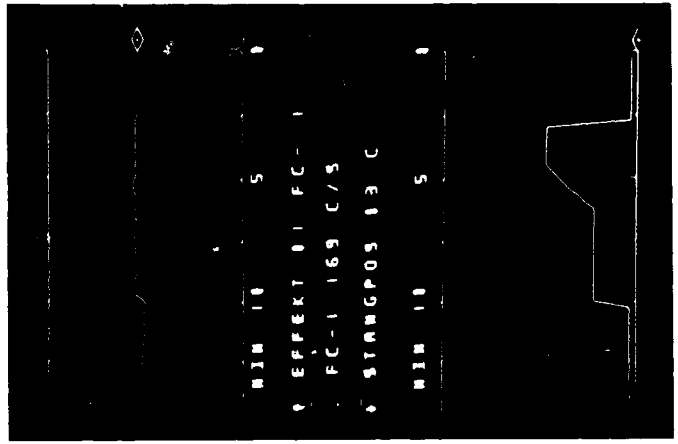
Our first experience, based on some hours exercise per operator, is:

a) keyboards and lightpen must be highly reliable, and in particular when operated by unexperienced users;

b) when new methods of presentation are used, the operator will immediately understand pictures resembling common pointing instruments and recorders. The same applies to diagrams following conventional rules but using unfamiliar symbols. More abstract ways of presenting data, however, cause some trouble (fig. 8);

c) details in the appearance of a symbol may easily mislead the operator in his conception of the whole picture. The shape of alphanumerics, component symbols, etc., must be followed critically to the last;

d) the operator may be highly dependent on the way he usually experiences environment. The sequence in which some components appear on a route through the plant may be more adequate than the correct, geographic map. Recorder curves have a very rigid orientation in the mind of the operator; a well-known curve shape is not always recognized if turned on its vertical and horizontal axes (figs. 6 and 7).



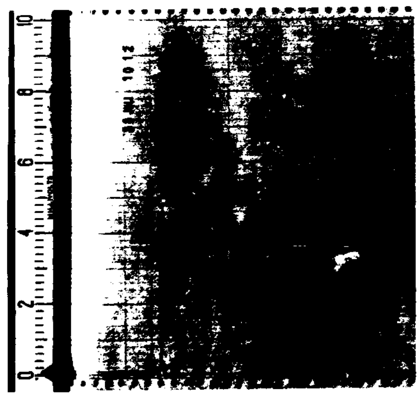


Fig. 6. Conventional display of signal evolution with time: the signal increases horizontally from a left zero, and time grows upwards. Actual time corresponds to the highest value of time marking on the paper.

Fig. 7. Computer-generated display of "recorder curves". To compare a signal's appearance in the two cases, one must first turn the recorder ninety degrees left and then study the paper from its back. Note also that actual time is shown with the lowest value.

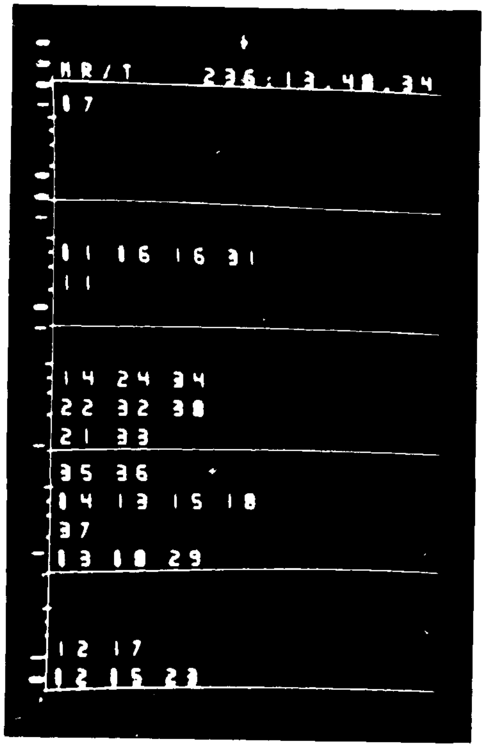


Fig. 8. is a rather abstract presentation of a large signal group. A radiation monitor is represented by its two digit identification number, which is placed in one of four lines in each decade. The picture is "frozen" at the time shown in the top line. One may find that the four monitors 01, 06, 16, and 31 signalled approximately 40 mR/h at that time.

2. NUCLEAR GEOLOGY

The flight data obtained over parts of Central East Greenland last summer have been transferred from analog to digital form. First, the original paper charts were traced on transparent paper. Then the analog data were digitized using an optical curve follower coupled to the department's hybrid computer installation. Finally, the punched tape produced was transferred to magnetic tape by means of the B6700 computer.

An improved software system has been developed for the processing of γ-spectrometric data recorded with the automatic sample changer. The raw data are registered on punched tape, from which one punched card is derived for each single analysis by means of the B6700 computer. By combining all punched cards obtained in replicate analysis, a realistic estimate of the overall experimental precision can be made. A special computer program is used for the conversion of the three-channel γ-spectra into equivalent contents of uranium, thorium, and potassium. All assay values are permanently saved in the form of punched cards.

Radioactive concrete slabs have been constructed for the calibration of field γ-spectrometers. The four slabs are each 3 m in diameter and 0.5 m thick so that they simulate infinite rock layers. Three of the slabs were given an admixture of uranium ore, monazite sand, and potassium feldspar respectively, while the fourth only contains the natural radioelements in the concrete.

The high-resolution Si(Li) x-ray spectrometer has been used extensively for various geochemical purposes. It has been demonstrated that the instrument is very suitable for the determination of average atomic numbers.

3. RESEARCH INSTRUMENTATION

Besides the work described in the following sections the group has worked on a number of subjects. The work on laser anemometry has led to the formulation of a general fourier-optical model. The signal/noise ratio was calculated for a number of configurations. Some fundamental limitations were found and partially verified through experiments. Signals from the natural aerosols in the laboratory air were detected in the meteoroiogical anemometry experiments.

The stationary micrometeorological equipment was installed in the rebuilt Meteorology Building. The mobile equipment was installed in the bus, see fig. 9, and the final testing is to be finished early this summer.

The interfaces between the multi-channel analysers and the data handling system for the Isotope Laboratory were tested. The data handling system itself should be ready late this summer, although a considerable amount of software work still has to be done.

The master program for the three heat transmission experiments is finished. The programming of the remaining two experiments was started in co-operation with the programming group. The data transmission between the heat-transmission-in-liquids experiment and the computer is in preparation.

A pneumatic tube system for the irradiation of mineral samples in the DR 2 reactor was planned and is now being installed. The system will cut the time of analysis from several hours per sample to a few minutes.

The development of programs for the plotting and processing of γ-spectra measured with scintillation or semiconductor detectors continues. A transcription from Gier - ALGOL to Borroughs B6700 has increased the computing power and the presentation possibilities considerably.

3.1. Triple-Axis Spectrometers - CAMAC

The new triple-axis neutron spectrometer TAS6 is now in operation. The instrumentation system for TAS6 was described in [10]. The control part consists of a 4K PDP-8/e connected to a CAMAC interface, while the neutron detector measuring channels are in the NIM standard. The whole instrumentation is housed in one 19" rack.

The principle of operation was outlined in [10] so we shall confine ourselves to a short enumeration of the specifications of the 7 new CAMAC modules designed for TAS6.

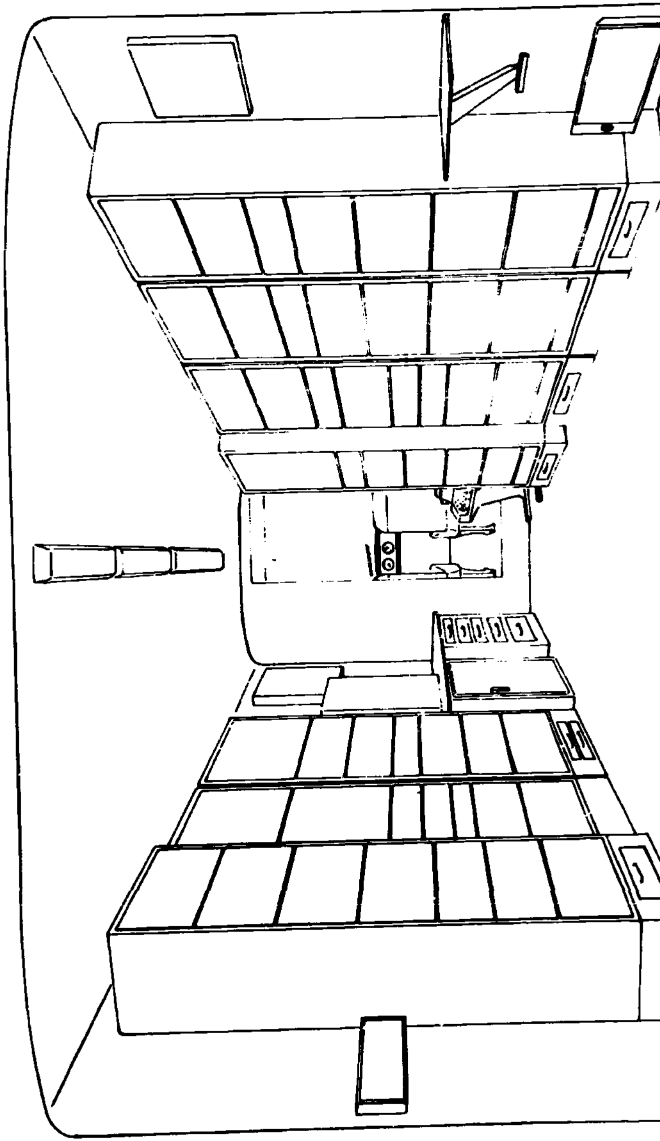
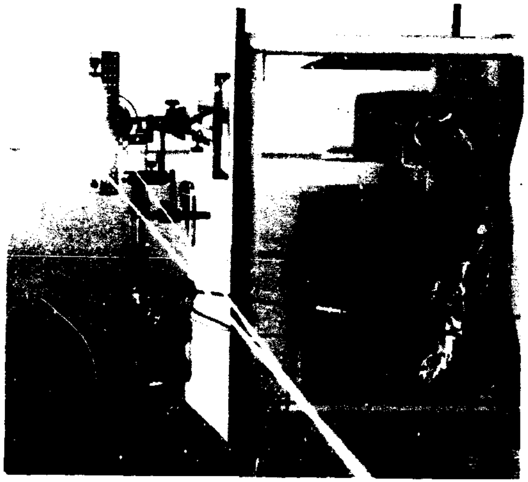
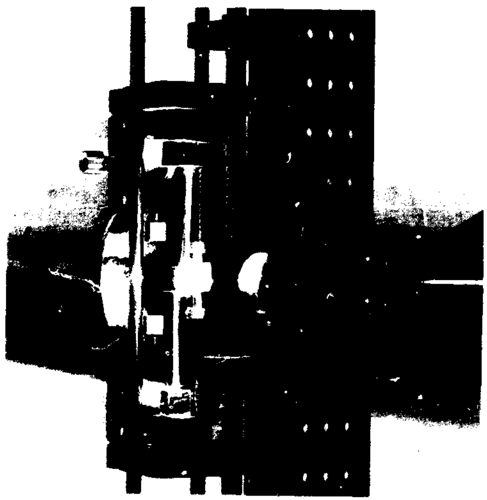


Fig. 9. The interior of the micrometeorology bus. The racks on the right contain 60 digital measuring channels and a magnetic tape deck. The racks on the left contain 16 wind measuring channels and 7 analog recorders. An analog magnetic tape recorder is placed on the desk.





The optical part of the laser anemometer comprises the argon laser, seen below the table in the right picture, the beamsplitter shown in the left picture, the mirror for the detector and the detector itself. The back of the mirror is seen between the outgoing beams in the left picture. The backscattered light from the particles in the range where the two beams intersect is focused by the mirror on the detector seen in front of the beamsplitter in the right picture. The signals from the detector are treated in a spectrum analyzer.

8-Decade Scaler, P801a

This is a 10 MHz, 8-decade synchronous scaler. It can be preset to 10, 10^2 -- 10^8 by CAMAC commands. A Look-At-Me signal is produced when the preset count is reached unless the LAM is disabled. Start, stop and reset are controlled by CAMAC commands or via patch pins. The decades are read out one by one over the dataway by means of CAMAC commands. Indicators on the front panel show the preset count and whether the scaler is counting.

Real Time Clock, P802a

The clock stores the number of the day, the hour and the minute in a 7-decade register. The register is read or preset one decade at a time via the dataway by means of CAMAC commands. Subaddresses are used for the single decades. 100 Hz and 1 Hz pulses are available on the front panel.

5-Decade WRD/BCD Converter P805a

The module converts into the BCD code Watts Reflected Decimal (WRD) code, which is used for Hilger and Watts digitizers. The converted code is held in a buffer and can be read by CAMAC commands via the dataway one decade at a time selected by subaddresses.

LAM Generator P803a

The module generates LAM signals with a frequency adjustable between 1 kHz and 50 kHz. The signal is enabled or disabled by CAMAC commands.

Step Motor Control P800a

The module acts as a step pattern generator and driver for up to two SLO-SYN bifilar step motors. The drivers are isolated from the logic; their power is supplied via a front panel connector and the connections to the motors are also taken via the front panel. The step pattern is controlled by CAMAC commands. Each command changes the pattern so that the selected motor makes one step.

Parallel Input/Output Gate P813a

This unit provides 6 input and 6 output lines. The inputs are integrated by 20 msec. The status of the lines can be read by CAMAC commands, and a change of status causes a LAM signal to be generated unless LAM is disabled. The output lines are controlled by a register which is set by CAMAC commands. They are able to drive 100 mA to ground.

Display Control P804a

The module controls an 8-decade display P812a, which is not a CAMAC unit. A switch setting on the display is buffered to the module from where it can be read by CAMAC commands, thereby selecting the station number of the module to be displayed. The display control module also has an 8-decade register, which can be loaded by CAMAC commands. The contents of the register is shown on the display.

TAS6 is the first CAMAC system which is put into operation at Risø. Our experience was that the adoption of CAMAC as a standard for digital systems at Risø facilitated design and installation considerably.

3.2. Rain-fall Measurements

An automated rain-fall and run-off measuring station is needed for the motorway fly-over, "Bispeengsbuen", in Copenhagen. One wants to know the loading of the sewers and the intermediate buffer-basin by the run-off from the wearing surfaces of roads. The specifications have been prepared in collaboration with the State Road Authorities, the Technical Departments of the Municipalities of Copenhagen and Frederiksberg, the Department of Earth and Water Construction of the Agricultural University, two firms of consulting engineers and the Electronics Department of Risø. The specifications are now put out to tender. The station should be ready the first half of 1973.

3.3. Measurement of Flow by Cross-Correlation Techniques

The possibilities for using cross-correlation techniques for flow measurements have been investigated. Especially the possibilities for two-phase flow measurements are of interest. However, we have also worked within a more general scope than that given by the flow application.

Correlation is the process of relating one phenomenon or quantity to another. The quantitative relationship between the two quantities is called the correlation coefficient.

A correlation function is a function which describes the statistical connection between time-separated sections of the signal(s) to be correlated. The correlation function is a function of the time separation.

The auto-correlation function, which establishes the relationship between a signal and a time-shifted version of itself, might be defined as [11]

$$R_{xx}(\tau) = \overline{x(t)\,x(t+\tau)} = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{T} x(t)\,x(t+\tau)\,dt\,,$$

where x is the signal and τ is the time shift.

The cross-correlation function establishes the relationship between two signals x and y as a function of the time shift introduced between them, and is defined as:

$$R_{xy}(\tau) = \overline{x(t)\,y(t+\tau)} = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{T} x(t)\,y(t+\tau)\,dt.$$

Electrically, the correlation coefficient is obtained by multiplying one waveform by the other and integrating the product for a length of time sufficient to give a steady average. Fig. 10 shows the operation.

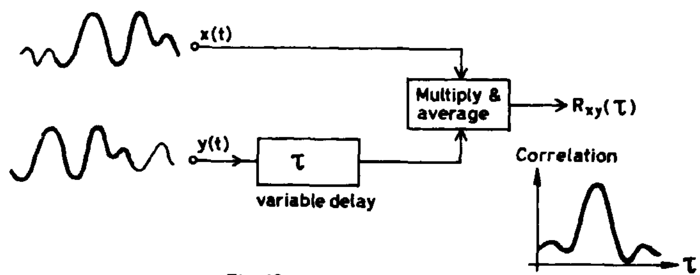


Fig. 10.

To make use of the simplicity of the integrated digital technique, a zero-crossing correlator was built, where the analog signals are quantized to the logical levels "o" and "1" according to

$x(t) \curvearrowright \text{sign } x(t)$ and

$y(t) \curvearrowright \text{sign } y(t)$.

It can be shown [12] that the "loss of information" by the 1-bit correlation only produces a correction factor to the analog - "true" - correlation function $R_{xy}(\tau)$.

If the conditions of stationarity, normal distribution and normalization are fulfilled, the relationship is

$$R_p(\text{sign } x, \text{ sign } y, \tau) = \frac{\tau}{\pi} \text{ Arcsin } R_{xy}(\tau) .$$

The correlation function reaches its maximum - for a certain time lag - when the signals have the greatest similarity.

Let us consider a flowing medium (fig. 11). Two random signals, ob-

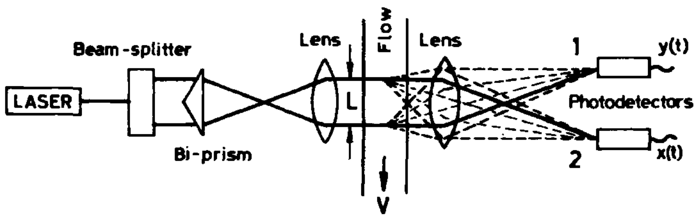


Fig.11. Optical set-up for flow measurement by cross correlation.

tained by two transducers separated a distance L in the flow direction, will - provided stationarity is fulfilled - be equal except for a time lag, which is equal to the transit time between the two transducers. When the distance between the transducers is L and the transit time is T, then the flow velocity is given by

$$v = \frac{L}{T} = \frac{L}{\tau} ,$$

where τ is the argument for which the computed correlation function reaches its maximum.

An electrooptic system is used as signal transducers. Two parallel laser beams are focused on two volumes separated a distance L in the flow direction (fig. 11). Optical inhomogeneities in the flow medium will cause scattering and intensity modulation. The scattered and modulated light is collected by a lens and focused on two photodiodes.

The photocurrent from these diodes provides the input to the correlator. It is readily seen that if the flow is stationary, then the "signal" caused by a specific volume element on detector 1 will be repeated on detector 2 a time period later given by the transit time between the two beams.

It is a notable feature of this transducer set-up that the load imposed on the flow by the measuring instrument is negligible.

A one-bit correlator has been built according to fig. 12.

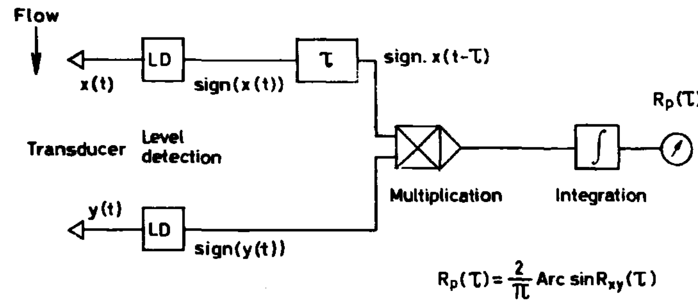


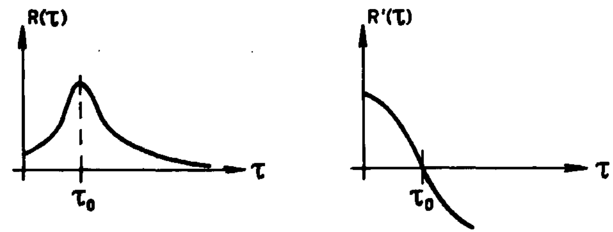
Fig. 12. Zero crossing correlator.

It is noted that the one-bit digital correlation function $R_p(\tau)$ has maximum and zero-crossing for the same values of τ as $R(\tau)$. The time lag is easily realised in a shift register as

$$\tau = \frac{n}{f} ,$$

where n is the number of storage elements and f is the shift frequency.

Concerning velocity measurements we are only interested in the value of the time lag τ_o belonging to the maximum of the correlation function. Differentiation of one of the input signals gives the differentiated correlation function itself[11].



$$R'_{xy}(\tau) = R_{xy'}(\tau)$$

Fig.13.

Utilizing this [13], the zero-crossing correlator could be developed to the configuration shown in fig. 14, where the integrator output enters as an error signal in a servo-loop.

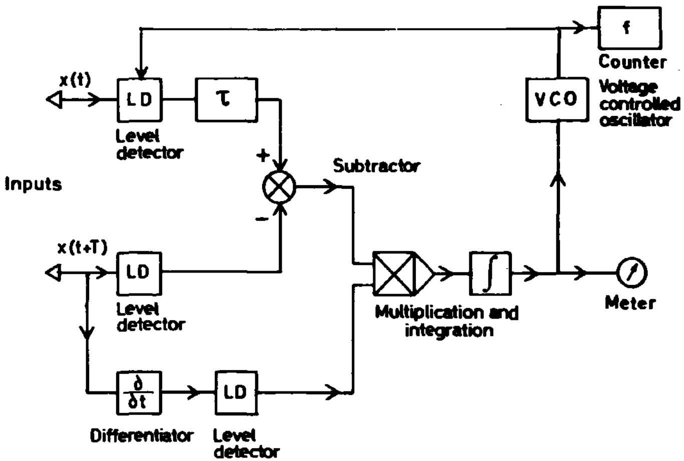


Fig.14. Tracking correlator.

The subtractor compensates for the necessary finite integration time. The dynamic range of the VCO is 1:1000, which corresponds to the capture range of the tracking correlator.

The signals handled range from audio-frequency to 500 kilohertz, with possibilities for further upper extension depending on the construction of the time delay.

Since the shift register is sampling the signal it contributes to the information loss beyond that given by the extreme clipping of the signals. But the total information loss using the zero-crossing principle compared with that of analog correlator is not, for most applications, a restriction of the usefulness of the simple technical and the economical advantageous zero-crossing correlator.

Until now we have accomplished the following concerning "flow measurements by cross correlation":

1) Measured the velocity in various types of flow, e.g. laminar turbulent and specific types of two-phase flow, using a Hewlett-Packard correlator and Risø-made optics.

2) Built a zero-crossing correlator and confirmed the measurements by means of the developed theory and the correlator.

3) Made a "tracking" correlator based on the zero-crossing correlator.

4. MAINTENANCE AND CONSTRUCTION

In the field of maintenance and construction the following new schemes have been carried out in this half-year period.

Standardization

On account of the steadily increasing use of digital equipment, the construction and maintenance group has become aware of the missing standardization of logic diagrams. To fill this gap, all logic symbols have been standardized in accordance with the coming Danish and IEC standards.

Furthermore, some work has been carried out in the field of digital system documentation in regard to which types of diagrams and descriptions are necessary.

Data Collection System

Owing to the increasing amount of electronic equipment, and hence the increasing number of repairs, it has been desirable to computerize the repair-record system.

A repair-record system for the Borroughs computer capable of storing and sorting data from repairs and overhauls is under development. The system comprises the instruments (the majority of all Risø instruments) repaired by the maintenance group. Part of the system is a new service report, intended to be used by the service man when reporting failures and overhauls.

By use of this system, it will be possible to obtain lists of failures and statistical information for one separate instrument, for groups of instruments and for all instruments at Risø. The system also supplies check-lists for routine-overhauls.

Some of the data obtained will be forwarded to Syrel Reliability Data Bank, Risley, England.

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