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LABMAT - Data Acquisition and Retrieval in a Clinical Laboratory Using the DESY On-Line System

by

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Abstract

A system for the automatic aquisition and retrieval of data for a clinical laboratory has been made operative by a collaboration of the Deutsches Elektronen-Synchrotron DESY and the University Hospital Hamburg-Eppendorf. This LABMAT system is based on the DESY on-line system, which is a computer network consisting of two big central computers and a number of small computers. The system serves for aquisition of patients data, control of measurement devices, data aquisition from the measurement devices and retrieval of the data. It is characteristic for the system that it is decentralized and that any action of the system is performed in real time. At present the system is successfully running with five measurement devices.

Key word: on-line data aquisition
on-line data retrieval
clinical chemistry
information system

1. Introduction

Since 1970 there exists a collaboration between the Deutsches Elektronen-Synchrotron DESY, Hamburg, and the University Hospital Hamburg-Eppendorf (UKE) for the application of electronic data processing in medicine. This collaboration is motivated by the fact that concepts which have proven to be most effective in data handling for High Energy Physics experiments may be usefully applied to medical data processing problems.

It is generally agreed that, due to the multiplicity of techniques and forms of data, computer science finds an extremely wide field of application in medicine. Nevertheless, the results are related to one common destination, the patient. The integration of all activities into one system is therefore desirable, but we are still far away from the solution of this problem. It still seems the best approach to restrict oneself to partial solutions which may serve as model studies for final solutions.

We have started our activities with two topics which seem to be simple compared to the whole mass of problems and therefore are worked on at several other places (see, e. g., Ref. 1):

1) data acquisition and retrieval in the clinical laboratory
2) data processing for image devices in nuclear medicine[6]

The data processing system used is the DESY On-Line system, which has been developed for real time acquisition and evaluation of data in high energy physics. This paper gives a general description of the project (1), which has been named LABMAT. Details will be published in the appropriate journals. Readers who are more interested in the medical and laboratory aspects of the project, may restrict themselves to chapters 2 and 4. More detailed information about the hardware and the software used is found in chapter 3.

2. Properties of LABMAT

2.1 Aims of LABMAT

In a clinical laboratory the flow of data is as follows: On his reception at the hospital the patient's personal data are recorded. The physician may now decide that a blood sample has to be taken. The blood sample is sent to the laboratory together with a request sheet containing personal data and information about the measurements to be made. In the laboratory the sample is put into a measuring device, which normally delivers results in the form of a curve. The final value has to be calculated from an analysis of the curve using calibration values, which have to be taken in short time intervals. The measurement is checked using control samples. The results thus gained are recorded and sent back to the ward. In the laboratory the values are saved in the laboratory journal. As we may easily see, the whole procedure is very uneffective, since a major part of time is spent writing. This is also a dangerous source of errors. Furthermore the evaluation of curves can best be done by a computer. Thus, the aim of LABMAT is

1) acquisition of personal data under computer control,
2) automatic acquisition and control of measurement data.

Besides that, electronic data processing opens up a new possibility for the user of the clinical laboratory:

3) automatic retrieval of laboratory data for routine or scientific analysis

When planning the system we were faced with the fact that the organisation of the University Hospital was not prepared for the introduction of electronic data processing. Therefore, the current version does not start at the hospital entrance, but at the entrance to the laboratory. Although this fact reduces the effectivity of the system, we decided not to wait for the adaptation of organisation, which is necessarily a slow process.

2.2 The Hardware of LABMAT

The nucleus of the system (see Fig. 1a) is a PDP-8/I computer with a 16 K core memory (see Fig. 1b). Peripheral equipment consists of 4 DECtape-Units, 4 ASR 33 Teletypes, an IBM-73 typewriter and a Hewlett-Packard 1300A display unit. An ADC with a 32-channel multiplexer serves for data acquisition from devices with analogue output. A telephone line connects the PDP to the DESY computer center (IBM/360-75/360-65, see Fig. 10). It thus becomes part of the DESY On-Line system (see 3.1).

The task of the PDP is the acquisition of personal data, acquisition and control of measurement data and intermediate storage of data. The central computers at DESY are responsible for the permanent storage and retrieval of the data.

The measurement devices are located in different buildings 200 to 300 m apart from the PDP-8/I computer. The connections used are coaxial cables for the analogue signals and telephone cables for the digital signals. The teletypes are installed in the neighbourhood of the devices. Five devices are connected at this time:

3 Technicon Autoanalyzers

1 Coulter Counter S

1 LKB 8600 Reaction Rate Analyzer

They serve for measurements in serology (e. g., Calcium, Phosphor in the blood serum) or hematology (e. g. white or red blood cell count).

2.3 Using LABMAT

For a number of samples to be measured, the technician must type a list containing the identification of the sample, such as surname, first name, sex and date of birth of the patient (see Fig. 2). The identification must be entered at any time before, during or after the measurement. The list, which is stored on magnetic tape, is given an arbitrary number between 0 and 9 by the technician.

There are 4 different sorts of samples: Calibration samples, from which the calibration curve is taken automatically, control samples, which are compared to given values, empty samples and finally the patient's samples.

When the measurement is started the technician has the choice between two modes of data acquisition. In the first mode the results are stored for printing at any time thereafter. In the second mode the results are printed immediately. The first mode is used if more than one measurement device is controlled from one teletype, since during output no commands can be given to the computer without stopping the printout. The first mode is also used when personal data are recorded during the measurement.

Fig. 3 shows an example of a result list as printed out during an Autoanalyzer measurement. The header shows the dialogue between operator and computer. It is followed by the sample printout. The samples marked by an "E" are calibration samples, which automatically generate the calibration curve. Samples labelled by a "K" are control samples. They are compared with fixed standard values and alarm is given if the measured values exceed a predetermined range. The samples marked by a "P" are the patients' samples. A similar list, shown in Fig. 4, is produced for the Coulter Counter S. Fig. 5 shows a list for the LKB 8600 Reaction Rate Analyzer, in which every possible error has been produced artifically. The computer program recognizes illegal deviations from standard values as well as bad samples.

If the control values are within the allowed range and if the measurements look plausible the command "RELEASE LIST" is given, which transfers the data to the disk storage of the DESY computer center. At this point the acquisition part is completed.

The stored data are now available for routine and scientific purposes. They may be presented by the computer in form of lists or plots. For example the laboratory physician may request the distribution of control values for any device and any time interval. For routine use one can call for patient-, ward- or laboratory-oriented information. Fig. 8 shows a patient's report. For scientific purposes it is possible to select data according to selection criteria chosen by the operator. Figs. 6 and 7 show distributions of patients' measurements and the corresponding control values of the Coulter Counter as printed in the laboratory. Fig. 9 shows the list of parameters which may be used to compose selection criteria for the retrieval.

3. Organisation of LABMAT

3.1 The DESY On-Line System

The organisation of LABMAT is characterized by the fact that it is linked to the DESY On-Line system[2], which is now described briefly. This system consists of two central computers (IBM/360 Mod. 75 and 65, further referred to as central computers) and 15 small computers (PDP-8, PDP-8/I, PDP-8/E, CII C90-10, further referred to as satellite computers) connected on-line to the central facility. The central computers (see Fig. 10) run independently but share one model 2314 disk storage unit. The satellite computers may be switched to any of the two central computers. Fig. 11 shows the cascaded structure of the on-line connection. The satellite computers are linked to the center via a 2701 data adapter unit. This path is multiplexed four ways to service four submultiplexers spread out over the DESY area. Each submultiplexer can service 7 satellites. In the special case of the satellites installed in the University Hospital the data are buffered in a special PDP-8 on the DESY site to adapt the low speed of the telephone line (1200 baud) to the requirements of the DESY On-Line system (50 kwords/sec).

To understand the software interface between the satellites and the central computer we first consider the memory map of the central computer shown in Fig. 12. Three regions are of interest in this context, PDA1, INITK, INITL;

these are the regions in which the operating system OS-MVT executes user jobs. INITL and INITK are regions in which two batch jobs are run in parallel. PDA1 is a never ending job with the highest priority, which runs all on-line programs as subtasks (see Ref. 5) when there is a request of a satellite computer. On-line programs are normally non-resident.

If several requests arrive concurrently from different satellite computers they are satisfied in the order of arrival. The allowed real computing time per request is 1 second. The response time is in the order of milliseconds if no other user is active; otherwise a delay of some seconds may occur. The programs may be written in FORTRAN or assembler language and must be inserted off-line into a "PDA-Library" before execution. There is restricted access to remote batch entry from the satellite computers.

The satellite computer communicates with the center via a fast data channel. The dialogue is always initiated by the satellite computer. PDP programs normally run under the control of the DESY Multitasking Supervisor (see Ref. 3). The transmission of one record is thus reduced just to two supervisor calls. Programs are coded in assembler language using a display and tape oriented editor (see Ref. 4).

On the whole the DESY On-Line system may be described as a system which combines the advantages of small dedicated computers (independence, exchangeability, low cost) with the storage and computing power of large computers.

3.2 Structure of LABMAT

As has been previously stated LABMAT is strongly influenced by the DESY On-Line system. Accordingly the work to be done is divided into two groups: tasks, which require quick response, moderate storage facilities, and a small amount of computing are performed in the PDP-8. Tasks, which do not need fast reaction but require big storage facilities and computing power, are performed by the central computer. Measurement of samples and personal data acquisition is done by the PDP-8, whereas long-time storage and data retrieval is performed by the IBM/360. Typically the small computer is considered rather as a programmable interface than as a computing machine. As a consequence the standardized interface is not between the measurement equipment and the PDP-8 but - in contrast to other systems - between the PDP-8 and the IBM/360. PDP-8 programs are used to control the measuring devices with a minimum of hardware. This saves the expenses for hardware development and gives flexibility, which is particularly useful during the initial stages of system development. The realisation of this concept is decisively supported by the existence of the DESY Multitasking Supervisor for the PDP-8.

3.3 PDP-8 Programs

3.3.1 The Multitasking Supervisor

As a simultaneous action of different terminals and different measurement devices is required, a multitasking operating system is necessary. In our case the DESY Multitasking Supervisor is used (see Ref. 3). It allows the definition of any number of tasks, which may have one of three priority levels. The tasks execute concurrently, queuing for resources such as CPU time, magnetic tape units etc. according to their priority. The progress of a task depends on events. An event may be external as an interrupt from a measurement device or internal as, e. g., the release of a resource by another task.

A task has three possible states:

1. WAIT	The task is waiting for an event, e. g. for an interrupt, which indicates that measurement values have to be read in.
2. READY	The task is ready to proceed, but a task with higher priority needs the CPU.
3. In CONTROL	The task is in possession of the CPU.

A special task is the LOOP task, which normally drives the display unit when no other task is ready.

A control block is associated with each task, containing information about priority of the task, pointers to next task in the queue, start (continuation) address and other locations to be saved at the time another task obtains the CPU. Reenterability of programs used in different tasks is ensured if the programmer uses a working space, which is defined in a control block and thus is saved at the time of task switching. The supervisor also contains a set of service routines for input and output.

3.3.2 The Tasks of LABMAT

Fig. 13 shows the task structure of the system LABMAT. Action is initiated by any one of three sources of events, the clock, the operator and the measurement devices. In Fig. 13 the first row contains tasks, the progress of which is determined by external events, whereas the second row consists of tasks which are triggered by other tasks. The measurement task may be started from outside as well as by the timer task.

3.3.2.1 The Timer Task

The timer task initializes the actions which have to be done in fixed time intervals. Every 5 minutes the "save control blocks - task" is triggered. It saves the control blocks on tape and thus enables a system restart after breakdown. Every 10 seconds the "result output task" is triggered, which scans the result buffers for measurement results and dumps them on tape. Also, the timer task starts the "measurement task" every second, which takes measurement values from the active devices.

3.3.2.2 The Terminal Tasks

The terminal tasks serve for commands to the computer for input of patients' data, for output of data during measurement, or for data retrieval. The list of commands accepted by the terminal task is shown in Fig. 14. These commands are either processed by the terminal task directly as in the case "SL" (list input), or they start other tasks, as in the case of "FG" (release list), which starts transfer of data to the central computer. The terminal task itself generates patient data lists as well as the result output and offers facilities for correction and copying. Since this part of LABMAT is the largest one and since it is used by several terminals at the same time, this part has been coded in reentrant form. This means that any number of terminals may be implemented as long as there is storage available for 250 words of buffer space for each terminal.

The terminal routine is by far larger than the measurement module because of the extensive checking of the operator input during the dialogue.

3.3.2.3 The Measurement Task

In contrast to the terminals there is only one single task for all measurement devices, since the computing and real times required per measurement values are small compared to the sampling interval. So the devices may be serviced sequentially. Depending on the device type (Autoanalyzer, Coulter Counter, R.R.-Analyzer) different routines are run to compute the final values. Two types of devices may be distinguished for timing purposes: devices, which present data at their own rate such as the Coulter Counter,and devices, which are read out at times determined by the computer (Autoanalyzer, LKB 8600). The measurement task is the same for both cases, since it may be started at random times.

Except for the Coulter Counter the measuring values are obtained by interpretation of curves produced by photometers. In the case of the Autoanalyzers (see Fig. 15) the distance of the peak from the base line is related to the final value. To find the peak values it is necessary first to find the start of the first peak. Depending on the measurement method two techniques are used. If the peaks are very weak and the baseline is straight, the starting point is defined by a definite threshold value (threshold mode). If the baseline is noisy but the peaks rise steeply, the start is defined at that time at which the increment between two measurements exceeds a given value (differential mode). Once the start is defined the maxima in equidistant regions starting from the start point are taken, the final values are computed via a calibration curve which is evaluated automatically from the calibration samples.

In the case of the LKB 8600 Reaction Rate Analyzer (see Fig. 16) the slope of the linear region of the sawtooth is computed. For the data from the Coulter Counter no computation is necessary. Whenever a measuring value has been obtained, it is stored into the double buffer which is associated with the measurement device.

3.3.2.4 The Result Output Task

This task is initiated every 10 seconds to scan the output buffers for data to be stored on tape. If full buffers are found they are copied on tape in sections the addresses of which where specified when the list was defined by the terminal task.

3.3.2.5 Magnetic Tape Task

Since the list handling is done in dialogue with the computer, unnecessary delays by queuing and tape running times are to be avoided. Thus a separate task controls the I/O of list data, when requested by the terminal task.

3.3.2.6 IBM-Transfer Task

This task plays the same role for the IBM-360/75+65 as the magnetic tape task does for the magnetic tape. It is started whenever an operator has released a list of measurements. It transfers the data from tape to the IBM where they are stored on disk. The list is marked as transferred when the entire list has been stored properly by the main computer.

3.3.2.7 Retrieval Task

The retrieval task manages the input of retrieval parameters, their transmission to the central computer and printout of results on a typewriter (later a line-printer) or any teletype in the laboratory. Asking the PDP-8 for data retrieval is the only request where a user may experience some delay caused by somebody else using the retrieval facility at the same time. This is a consequence of the fact that there is only one large computer, which is connected to the small computer by a relatively slow transmission line (1200 baud), and so time delays are unavoidable. For this reason the retrieval program has not been made reentrant.

3.3.2.8 Loop Task

The loop task is the lowest priority task. It normally drives the display unit. The display image in Fig. 17 shows the content of the I/O buffers for the different teletypes, the last three measuring samples for the measurement devices and the content of the IBM transfer buffer. In this way the operator can follow the progress of LABMAT.

3.4 IBM/360-Programs

The programs for data storage and retrieval make intensive use of the IBM/360 data management and the direct access features of FORTRAN IV.

The programs work on two disk storage datasets: an intermediate dataset and the master dataset. Data coming from the PDP-8 are stored in the intermediate data set before insertion into the main dataset for the following reasons: The insertion must not take place before an entire list has been transmitted, since the information necessary for the proper insertion is distributed over several records. The original data may be copied on tape, the user thus being able to repeat the insertion procedure in the case of changes of data organisation, program errors or system breakdown.

The master dataset contains patient data as well as measurement data. The structure is such that both are stored in one block. The header of personal data needs 46 bytes, for every measurement 18 bytes are used. Control values and calibration values are treated in the same manner as patient data. The inserting program automatically generates a "patient's name" for them which is distinguished from the real patient's name by the fact that it contains digits. If a patient's name already exists, the new data are added to the old data; otherwise a new patient's section is opened.

When the capacity of the dataset is nearly exhausted those patients' sections, which have not been accessed for the longest time, are written on tape. At the moment about 20000 patients' data with approx. 5 measurement values can be stored in the master dataset.

The insertion and retrieval programs are two different load modules. The insertion program works in the PDA-region (see Fig. 12). Since the allowed computing time per request is only one second the program is sliced in parts of approximately one second in such a way that after the computation of one slice a code is sent to the PDP-8 which simply triggers the PDA-Module again. Thus other satellite computers have a chance to contact the central computer.

The retrieval program in its current version does not fit into the PDA-region. It is therefore run in such a way that the PDA-program inserts this module into the queue of batch jobs. This on the one hand increases the response time, on the other hand it makes the full power of the large computer available to the remote user.

The data retrieval facility has been designed in a straightforward way. To find the optimum conditions a routine is being implemented which gathers statistics about the frequency of utilisation of the parameter combinations. This will enable us to redesign the data organisation according to the gained experience.

4. Conclusions

The system has been brought into operation in autumn 1970 with 1 Autoanalyzer; it now (end of 1971) controls five measuring devices. After a running-in period the system now works without major trouble and is used effectively. To adapt LABMAT to the needs of the laboratory the technicians were asked to run at least one device all the time, even where this provided an extra burden. In this way teething problems could be determined and solved quickly. Now the technicians are unhappy if the system is out of action - an indication that LABMAT is of good use.

LABMAT has one major disadvantage: Since there is no general patient identification number and no connection of the system to the reception of the hospital, the full personal data of the patient have to be entered for each sample at a terminal. This disadvantage will be overcome when the organisation of the hospital will be adapted to the needs of electronic data processing in 1972*.

* The plans of the Abteilung für Medizinische Dokumentation und Statistik of UKE are in an advanced stage.

Nevertheless, there are some striking advantages compared to the conventional method:

1) The measurement values are as exact and reproducible as the measurement method allows.
2) The work to be done by the technicians decreases.
3) Clerical errors are reduced.
4) The measurement values may be retrieved and checked at any time.
5) Later retrieval of data for scientific analysis is facilitated.

With regard to data processing, we conclude that the multitasking concept for the small computer provides high efficiency at low cost. Looking at the whole system, which also includes a PDP-8 in the Department for Nuclear Medicine and probably one more PDP for the Clinical Chemistry, we have a system which is vertically and horizontally decentralized. Vertical decentralization means that the work to be done is shared by large and small computers, horizontal decentralization means that more than one computer of each type is utilized. We believe that a decentralized system like the one described is very well suited to meet the requirements of electronic data processing in medicine, since it exhibits some properties which are particularely interesting for application in medicine:

1) Elements may be added independent of the surrounding elements. This property is important, because it is hardly possible to foresee all the consequences of automatic data processing in the relatively new field of medicine. (Example: interaction between offer and inquiry in the clinical laboratory.)

2) Safety of the system is high. The failure of one component does not affect the entire system. The DESY-On-Line system is working round the clock more than 350 days per year which, as far as we know, is unique for medical data processing in Germany.

3) Programs can be tested on some other PDP-8 without affecting routine operation. This is important when during a full time routine use of the system development work is to be done.

4) The satellite computers can be adapted best to the required applications.

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Figure Captions

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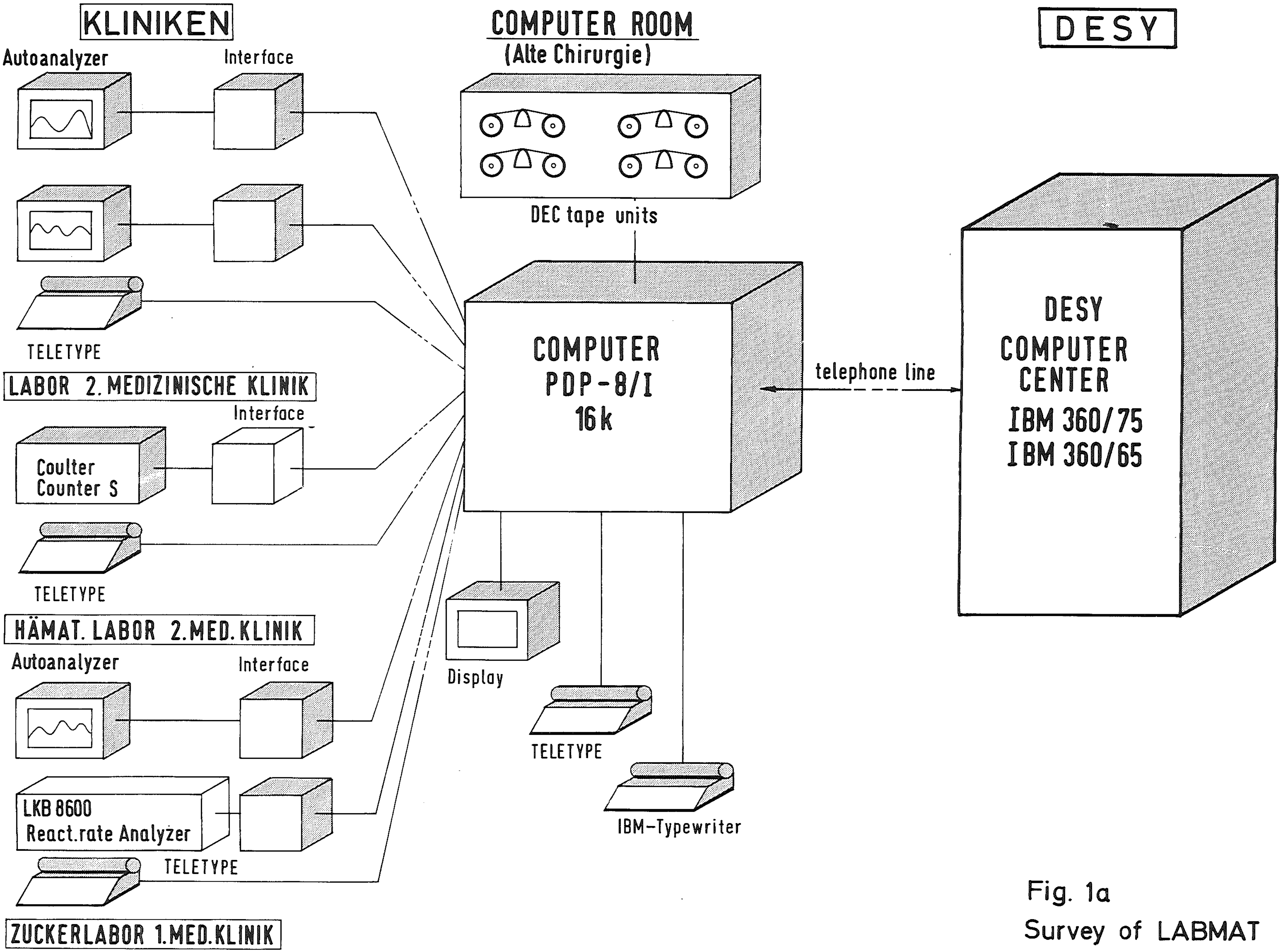


Fig. 1a
Survey of LABMAT

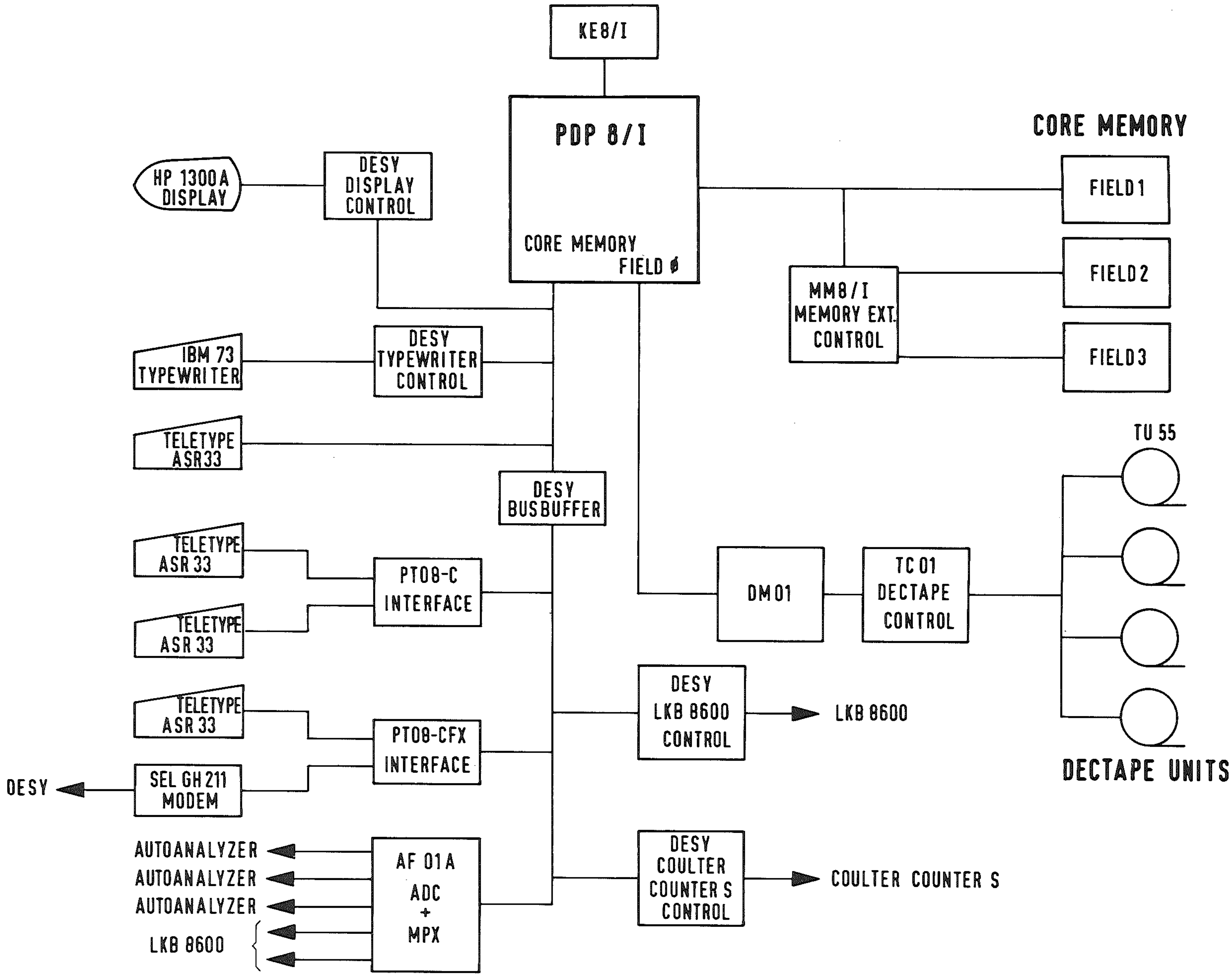


Fig. 1b) Configuration of the PDP-8/I

```
* SL = START LISTE
-------------------------------------.
+ NENNE LISTEN-NUMMER = 1
+ RICHTIG? (J/N):  J
+ DATUM = 23.5.1971
+ ART DER MESSUNG = A.PH

+ ØØ1) E 6E

+ ØØ2) E 13E

+ ØØ3) E 2ØE

+ ØØ4) E 27E

+ ØØ5) E 34E

+ ØØ6) K

+ ØØ7) P
+ MAIER,OTTILIE,F
+ 12.3.1923
+ Ø8-MRC1Ø

+ ØØ8) P
+ SCHULZE,EMIL,M
+ 3.4.1936
+ Ø8-33
```

Fig. 2 Example of patient's data input

```
* SF = START ERGEBNISSE
-----------------------------------------------------------------------.
+ NENNE LISTEN-NUMMER = 2
+ LISTEN-NUMMER RICHTIG: JA(J) ODER NEIN(N): J
DATUM = 21.1Ø.1971
ART DER MESSUNG = CA
                   ----
                                                  - ERGEBNIS IN MVAL -
E ØØ1                                       ØØ3E     AA = ØØ3.ØE
E ØØ2                                       ØØ4E     AA = ØØ4.ØE
E ØØ3                                       ØØ5E     AA = ØØ5.ØE
E ØØ4                                       ØØ6E     AA = ØØ6.ØE
E ØØ5                                       ØØ7E     AA = ØØ7.ØE
K ØØ6  *** KONTROLLE ***...............     1ØØE     AA = ØØ5.ØE
P ØØ7  [redacted],MARTIN,M...............   1ØØE     AA = ØØ3.4E
P ØØ8  [redacted],FRANZ,M................   1ØØE     AA = ØØ4.3E
P ØØ9  [redacted],MARIA,F................   1ØØE     AA = ØØ4.5E
P Ø1Ø  [redacted],IRMA,F.................   1ØØE     AA = ØØ4.4E
P Ø11  [redacted],U,U...............        1ØØE     AA = ØØ4.2E
P Ø12  [redacted]....................       1ØØE     AA = ØØ6.ØE
P Ø13  [redacted]....................       1ØØE     AA = ØØ4.ØE
P Ø14  [redacted]....................       1ØØE     AA = ØØ4.3E
P Ø15  [redacted]..................         1ØØE     AA = ØØ4.5E
P Ø16  [redacted]...................        1ØØE     AA = ØØ4.3E
P Ø17  [redacted]...................        1ØØE     AA = ØØ4.2E
P Ø18  [redacted]................           1ØØE     AA = ØØ4.1E
K Ø19  *** KONTROLLE ***..............      1ØØE     AA = ØØ5.ØE
E Ø2Ø                                       ØØ3E     AA = ØØ3.ØE
E Ø21                                       ØØ4E     AA = ØØ4.ØE
E Ø22                                       ØØ5E     AA = ØØ5.ØE
E Ø23                                       ØØ6E     AA = ØØ6.ØE
E Ø24                                       ØØ7E     AA = ØØ7.ØE
K Ø25  *** KONTROLLE ***..............      1ØØE     AA = ØØ5.2E
P Ø26  [redacted],MAX,M...................  1ØØE     AA = ØØ3.ØE
P Ø27  [redacted],GEBHARD,M.............    1ØØE     AA = ØØ4.6E

K Ø58  *** KONTROLLE ***..............      1ØØE     AA = ØØ5.2E

* ENDE DER LISTE
-----------------------------------------------------------------------
```

Fig. 3 Printout of results for the Autoanalyzer

```
* WAEHLE AUFGABE

* ME = MESSUNG + ERGEBNISSE
------------------------------------------------------------------------
+ MESSUNG AUF GERAET-NR = 4
+ NENNE LISTEN-NUMMER = 1
+ LISTEN-NUMMER RICHTIG: JA(J) ODER NEIN(N): J
+ STARTE GERAET: JA(J) ODER NEIN(N): J
* DIE MESSUNG IST GESTARTET


DATUM = 14.10.1971
ART DER MESSUNG = COUL
                  ----
                                                    - ERGEBNIS IN    -
                                             MCHC HBE  MCV  HK   HB   ERY  LEUK
                                             %    UUG  /U3  %    G%   **6  **3
                                             ------------------------------------
L 001   LEERPROBE                            01.6 01.7 091. 03.0 01.1 0.29 00.7
K 002   *** KONTROLLE ***................... 33.2 31.1 093. 38.3 13.0 4.09 03.8
P 003   [redacted],MARGARETHE,F............. 33.9 34.8 102. 31.4 11.0 3.06 16.5
P 004   [redacted],IRMGARD,F................ 33.0 26.7 081. 47.0 15.7 5.86 07.3
P 005   [redacted],WALTER,M................. 33.6 30.0 089. 45.0 15.3 5.06 05.9
P 006   [redacted],BRIGITTE,F............... 32.2 29.3 091. 35.8 11.8 3.94 09.6
P 007   [redacted],OTTO,M................... 34.3 31.6 092. 45.8 15.9 5.00 08.8
P 008   [redacted],JUTTA,F.................. 33.8 30.5 090. 40.9 14.0 4.54 05.5
P 009   [redacted],F........................ 33.6 31.2 088. 44.8 15.2 4.99 08.8
P 010   [redacted],F........................ 33.5 33.8 099. 55.8 18.7 5.60 09.4
P 011   [redacted],JUERGEN,M................ 34.1 31.3 096. 50.1 17.1 5.46 09.0
P 012   [redacted],EGON,M................... 33.9 32.1 096. 47.9 16.3 5.08 06.4
P 013   [redacted],KARL,M................... 34.0 31.2 094. 39.8 13.8 4.40 03.9


K 030   *** KONTROLLE ***................... 33.1 30.5 088. 37.6 12.8 4.11 03.8

* ENDE DER LISTE
------------------------------------------------------------------------
```

Fig. 4 Printout of the Coulter Counter S during measurement

```
* BETRIEBSBEREIT

* WAEHLE AUFGABE

* ME = MESSUNG + ERGEBNISSE
------------------------------------------------------------------------
+ MESSUNG AUF GERAET-NR = 3
+ NENNE LISTEN-NUMMER = 1
+ LISTEN-NUMMER RICHTIG: JA(J) ODER NEIN(N): J
+ STARTE GERAET: JA(J) ODER NEIN(N): J
* DIE MESSUNG IST GESTARTET


DATUM = 20.10.1971
ART DER MESSUNG = SGOT
                  ----
                                          - ERGEBNIS IN MU/ML -
K 001   *** KONTROLLE ***......................---------007.4
P 002   [redacted],GERHARD,M...................024.1
P 003   [redacted],DIETER,M....................      PROBE ZU DUNKEL
P 004   [redacted],RENATE,F....................074.4
P 005   [redacted],PETRA,F.....................030.3
P 006   [redacted],BEATE,F.....................      PROBE ZU HELL
P 007   [redacted],ANSELM,M....................044.5
P 008   [redacted],FRIEDA,F....................012.7
P 009   [redacted],GERLINDE,F..................      KEINE PROBE
P 010   [redacted],HEINRICH,M..................045.7
P 011   [redacted],YVONNE,F....................014.8
P 012   [redacted],MARTHA,F....................012.0
K 013   *** KONTROLLE ***......................---------009.2

* ENDE DER LISTE
------------------------------------------------------------------------

* WAEHLE AUFGABE
```

Fig. 5 Printout of the Reaction Rate Analyzer during measurement

```
HAMBURG, DEN  o7.12.71   16.48 H

   44      I                      1 X
   42      I                      X X
   4o      I                      X X
   38      I                      X1X1
   36      I                      XXXX
   34      I                      XXXX
   32      I                      XXXX
   3o      I                      XXXX
   28      I                      XXXX
   26      I                      XXXX
   24      I                      XXXX
   22      I                     XXXXX
   2o      I                     XXXXX
   18      I                     XXXXX 1
   16      I                    XXXXXX1X
   14      I                    XXXXXXXX
   12      I                  1 XXXXXXXX
   1o      I                1 X XXXXXXXX
    8      I                XXXXXXXXXXXXX
    6      I                XXXXXXXXXXXXX1
    4      I                XXXXXXXXXXXXXX
    2      I1     11 1     XXXXXXXXXXXXXXXXX1  111
  ERY      +----+----+----+----+----+----+----+----+----+----+----+----+
           o.o       2.ooo     4.ooo     6.ooo     8.ooo     1o.ooo MILL

                               1 12434311
           1oooo11o1ooooo2981862374757852 21oo111oooooooooooooooooooooo
      MITTELWERT    o.46587E o1       STANDARDABWEICHUNG    o.78485E oo
                ANZAHL DER GEPLOTTETEN WERTE:     294
AUSSERHALB DES PLOT LINKS:        o, AUSSERHALB DES PLOT RECHTS:       o
```

a)

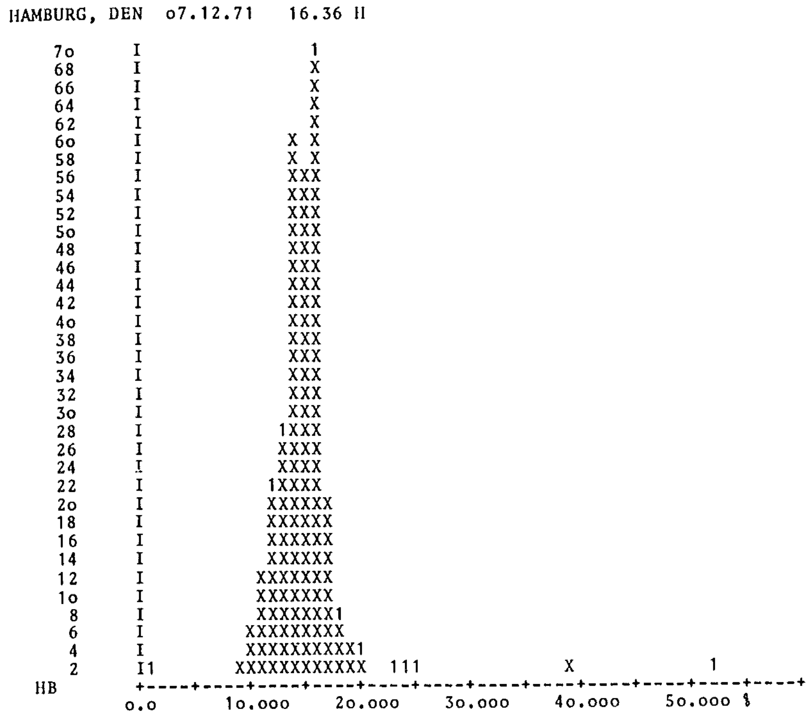
```
HAMBURG, DEN  10.12.71   10.28 H

   16      I                    X
   15      I                    X
   14      I                    X
   13      I                    X
   12      I                    X
   11      I                    X
   10      I                    X
    9      I                    X
    8      I                    X
    7      I                    X
    6      I                    X
    5      I                    X
    4      I                    X
    3      I                    XX
    2      I                    XX
    1      I                    XX
  ERY      +----+----+----+----+----+----+----+----+----+----+----+----+
           0.0       2.000     4.000     6.000     8.000     10.000 MILLIO

                                1
           000000000000000006300000000000000000000000000000000000000000
      MITTELWERT    0.37368E 01       STANDARDABWEICHUNG    0.49109E-01
                ANZAHL DER GEPLOTTETEN WERTE:      19
AUSSERHALB DES PLOT LINKS:        0, AUSSERHALB DES PLOT RECHTS:       0
```

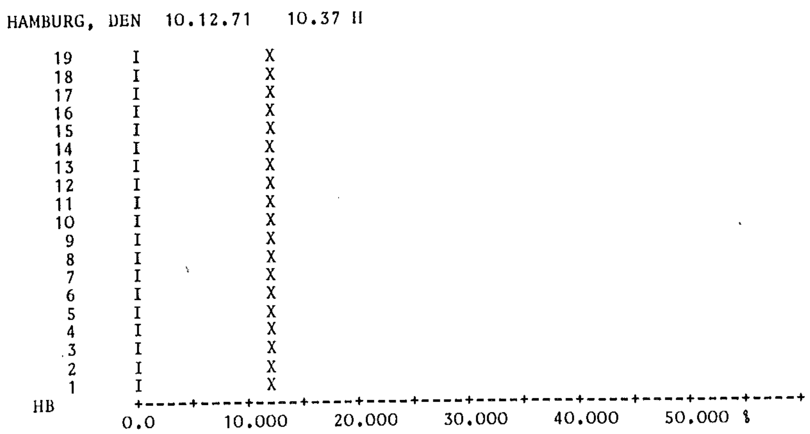
b)

Fig.6 Example of the output of the retrieval facility for the Coulter Counter measurements showing the distribution of patients' results (a) and the corresponding control values (b) for the red blood cell count.



1226562
1ooooooo26217o69o743oo111oooooooooooooo2ooooooooooooo1oooooooo
MITTELWERT o.14937E o2 STANDARDABWEICHUNG o.37665E o1
ANZAHL DER GEPLOTTETEN WERTE: 294
AUSSERHALB DES PLOT LINKS: o, AUSSERHALB DES PLOT RECHTS: o

a)



1
0000000000009000000000000000000000000000000000000000000000000
MITTELWERT 0.12005E 02 STANDARDABWEICHUNG 0.22724E 00
ANZAHL DER GEPLOTTETEN WERTE: 19
AUSSERHALB DES PLOT LINKS: 0, AUSSERHALB DES PLOT RECHTS: 0

b)

Fig. 7 Example of the output of the retrieval facility for the Coulter Counter measurements showing the distribution of patients' results (a) and the corresponding control values (b) for hemoglobin

UNIVERSITAETSKRANKENHAUS EPPENDORF
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II. MEDIZINISCHE UNIVERSITAETS-KLINIK UND POLIKLINIK
KLINISCH - CHEMISCHE ABTEILUNG
==

HAMBURG, DEN 10.12.71 10.42 H

PATIENTENBERICHT

MEIER,OTTO,M 1.7.1939 08-MRC10

MCHC	6.10.1971	COUL	34.20	%	
	12.10.1971	COUL	34.40		
	2.11.1971	COUL	34.90		
HK	6.10.1971	COUL	48.10	%	!
	12.10.1971	COUL	39.70		
	2.11.1971	COUL	39.70		
LEUKO	6.10.1971	COUL	8.20	X1000	!
	12.10.1971	COUL	5.20		
	2.11.1971	COUL	4.60		
HBE	6.10.1971	COUL	29.10	/U/UG	
	12.10.1971	COUL	28.70		
	2.11.1971	COUL	29.40		
HB	6.10.1971	COUL	16.50	%	!
	12.10.1971	COUL	13.90		
	2.11.1971	COUL	14.40		
CA	21.10.1971	AA1	4.66	MVAL	

Fig. 8 Patient's report as printed out in the laboratory

```
* AU = AUSKUNFT

+ ART DER AUSKUNFT(A,L,P,S): A
+ PLOT ODER DRUCK(P,D): P
+ NAME,VORNAME:
+ GESCHLECHT:
+ GEBURTSDATUM VON
                 BIS
+ STATION:
+ MESSART:
+ GERAET NR. :
+ MESSDATUM VON
            BIS
+ MESSWERT VON
           BIS .EINHEITEN
+ AUSGABE AUF FS ODER IBM-SM (F/I)? I
```

Fig. 9 List of possible parameters for data retrieval

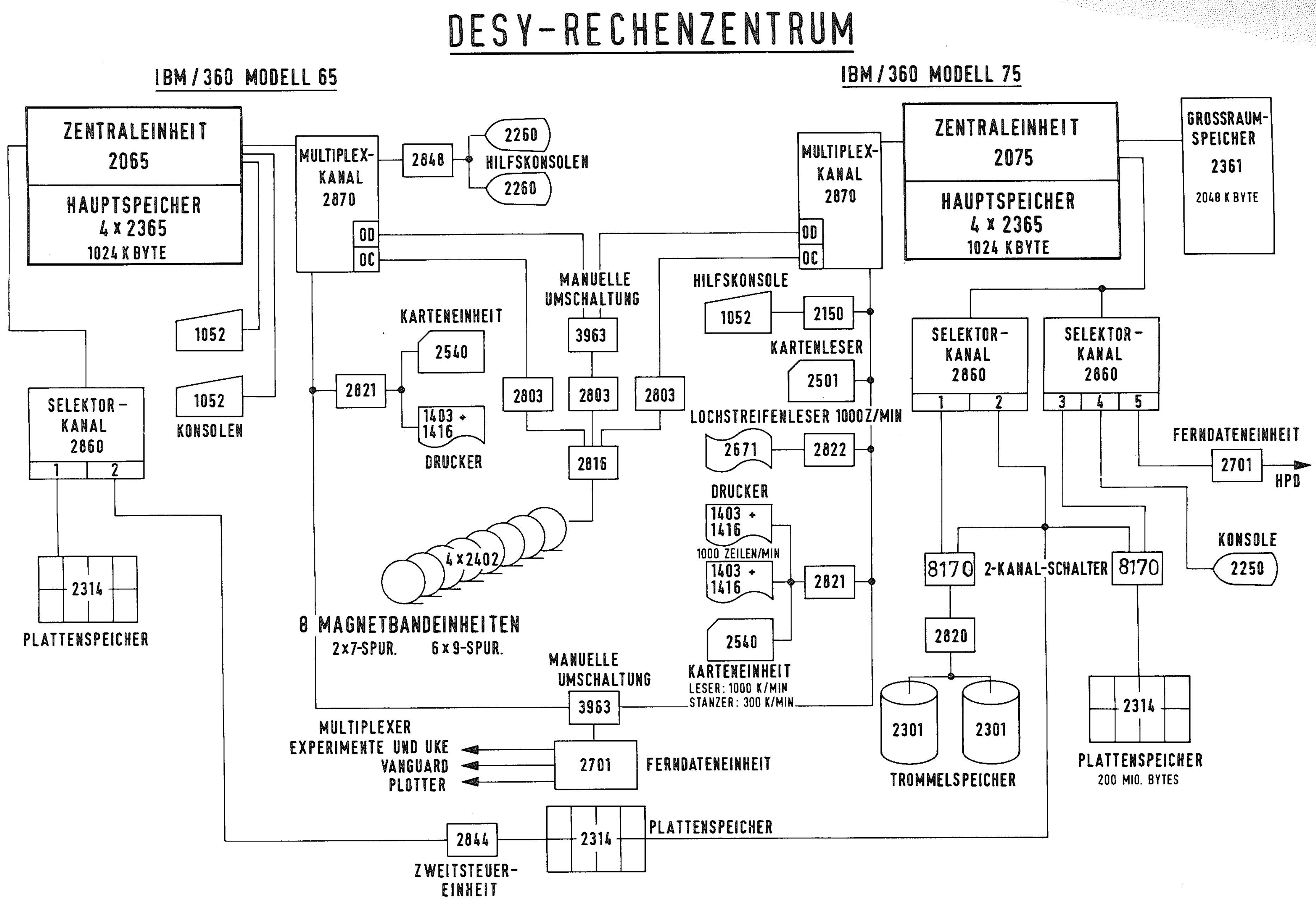

Fig. 10 Configuration of the DESY Computer Center

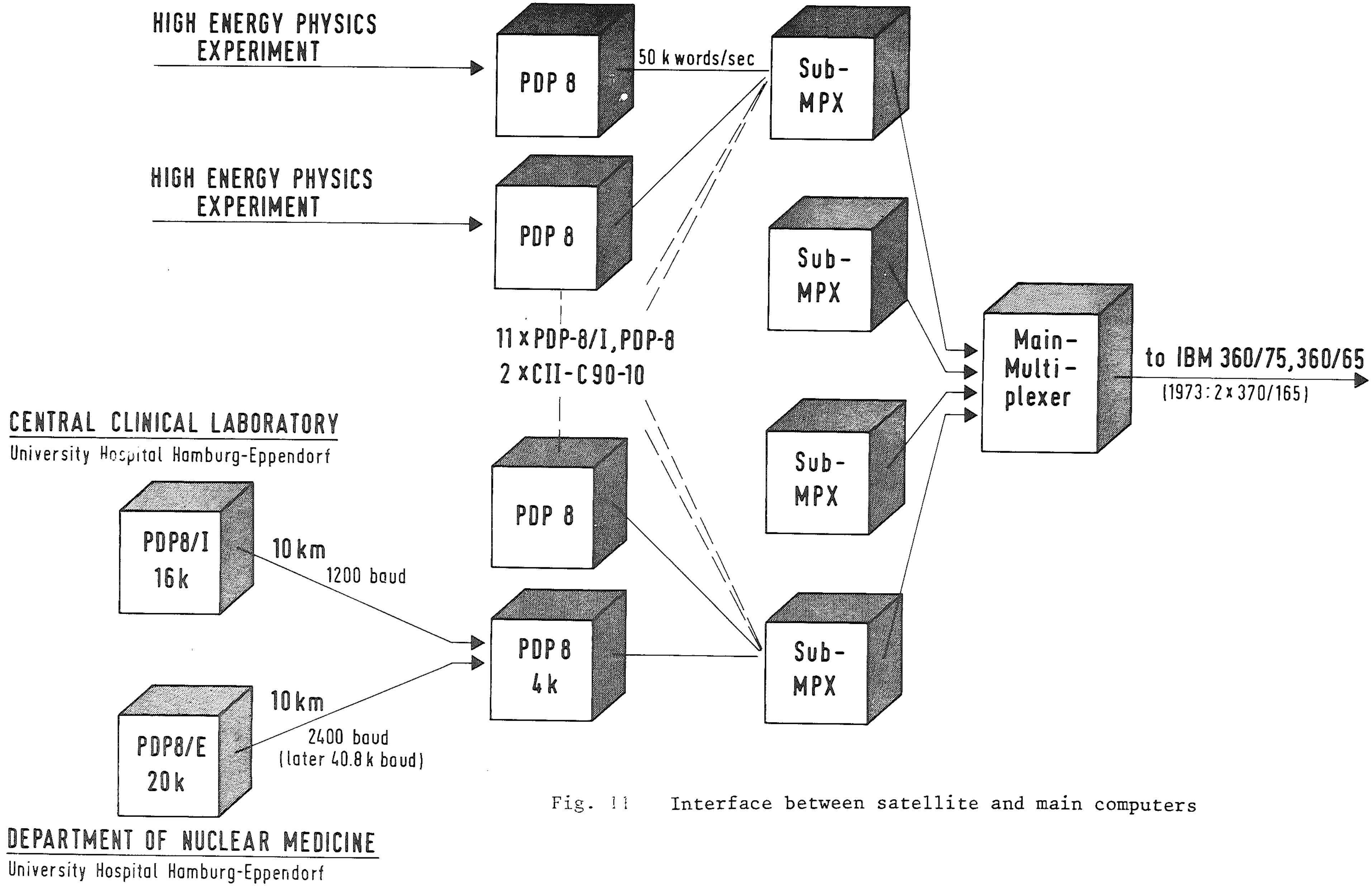

Fig. 11 Interface between satellite and main computers

NUCLEUS	130 K
MASTER SCHEDULER	34 K
WRITER	22 K
READER	52 K
PDA1	100 K
INITK	280 K
INITL	280 K
PLOTTER	100 K
frei	26 K
Total	1024 K

Fig. 12 Memory map of the central computer

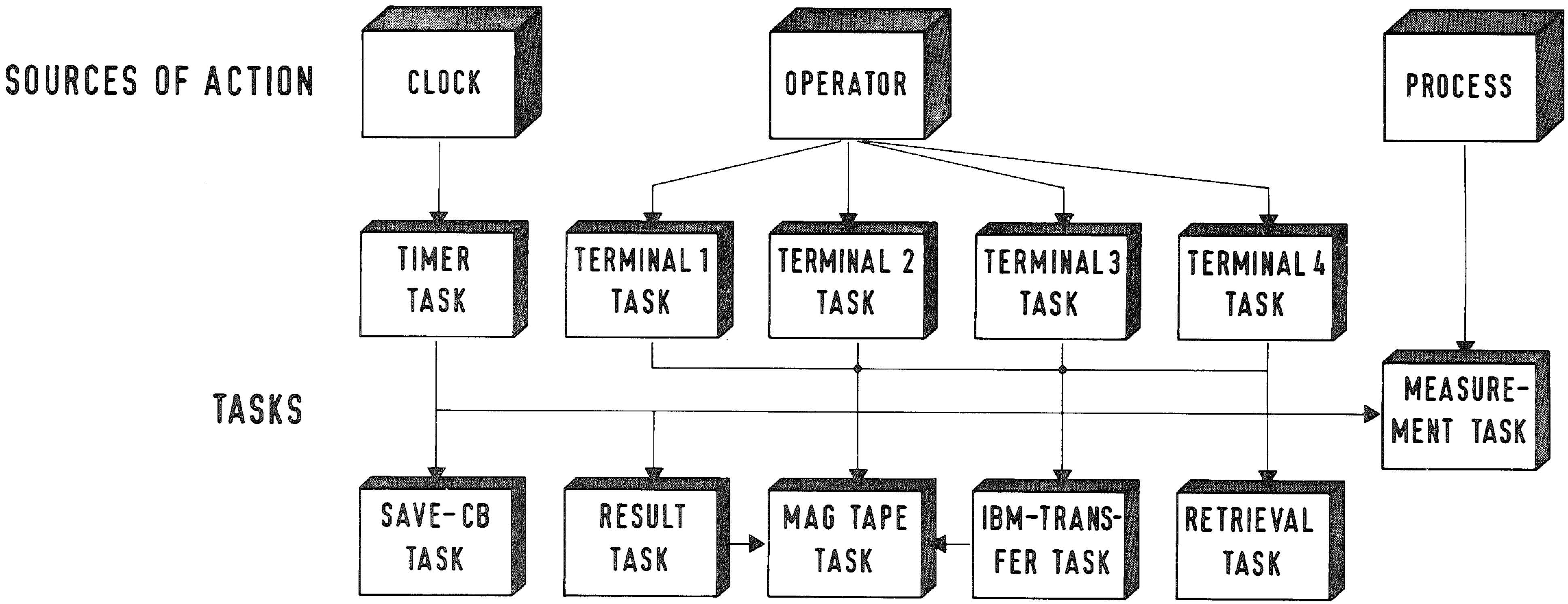

Fig. 13 Task organisation of LABMAT

```
* (MO = MOEGLICHKEITEN)
* SL = START LISTE
* EL = ENDE LISTE
* VL = VERVOLLST. LISTE
* AL = AUSGABE LISTE
* KL = KORREKTUR LISTE
* DL = DOPPELN LISTE
* SM = START MESSUNG
* EM = ENDE MESSUNG
* SE = START ERGEBNISSE
* ME = MESSUNG + ERGEBNISSE
* FG = FREIGABE LISTE
* MA = MESSART
* AU = AUSKUNFT
```

Fig.14 List of commands to LABMAT

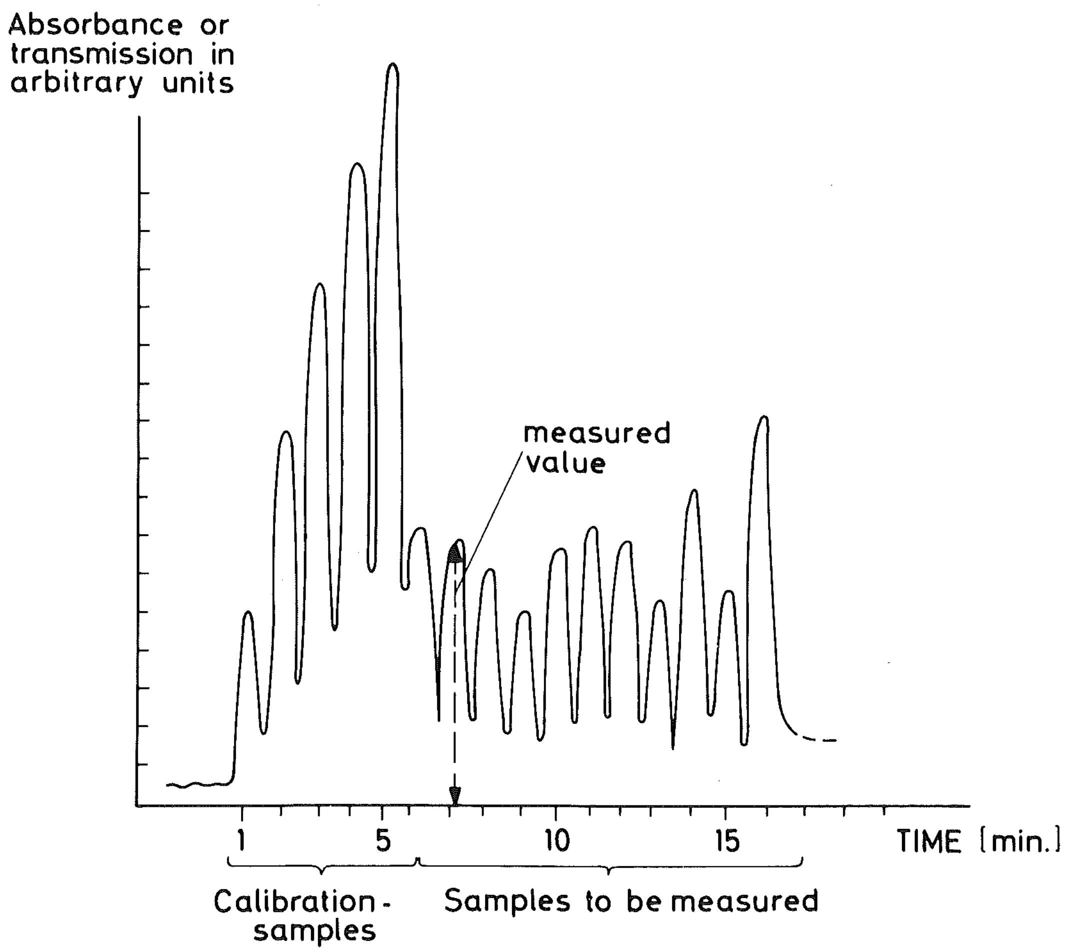

Fig. 15 Example of an Autoanalyzer output

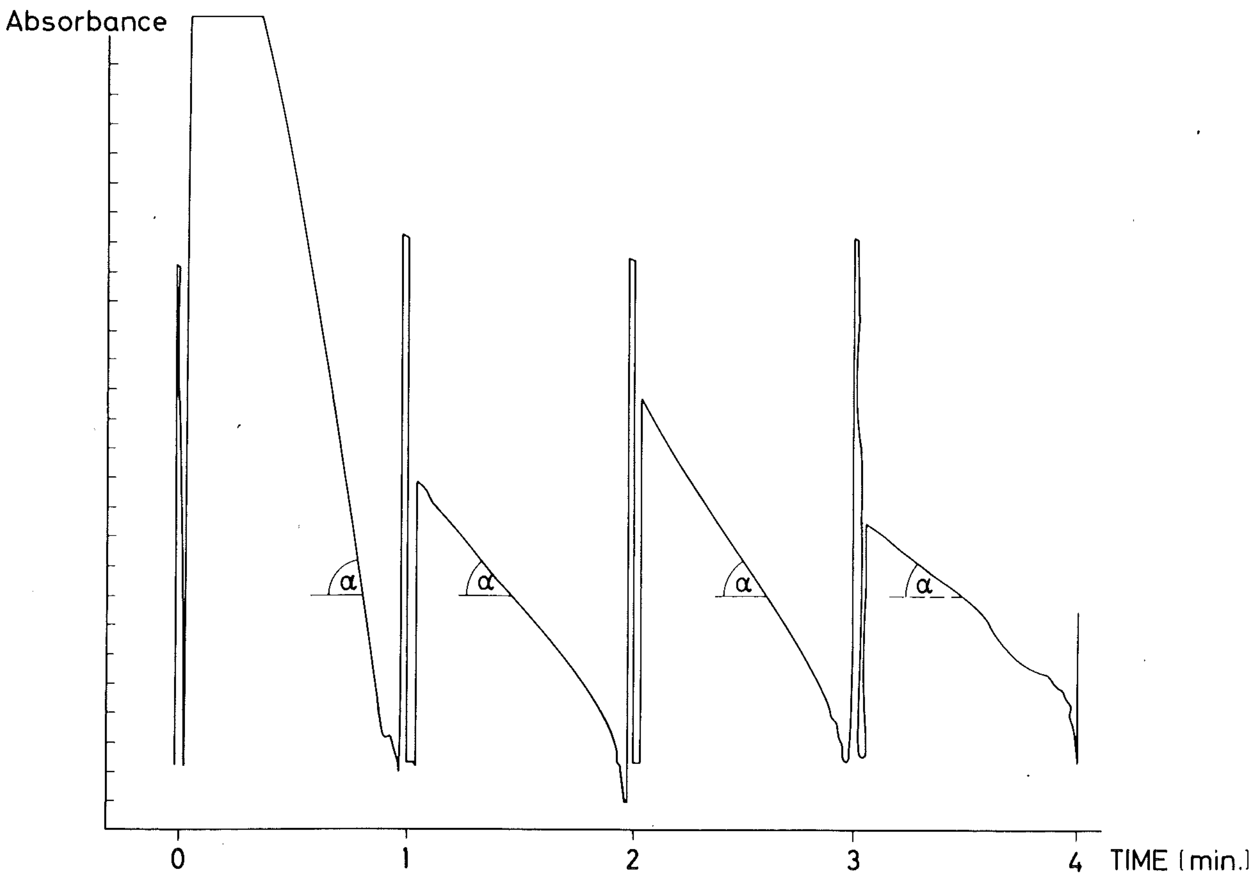

Fig. 16 Example of the output of a Reaction Rate Analyzer

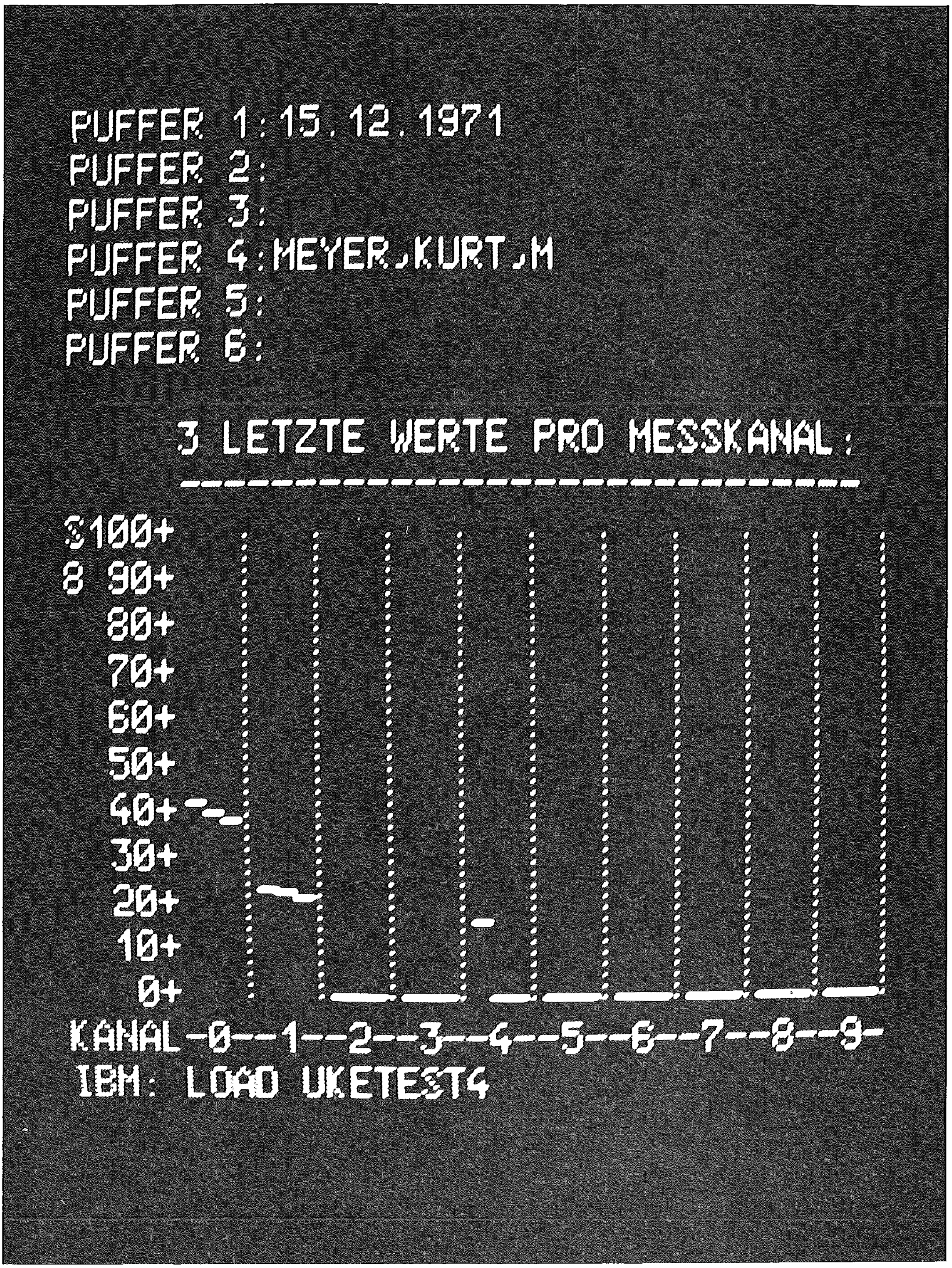

Fig. 17 Operators' console display