CERN COURIER

No. 3 Vol. 12
March 1972

European Organization for Nuclear Research

special issue on computers

CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, theoretical and experimental, in the field of sub-nuclear physics. This branch of science is concerned with the fundamental questions of the basic laws governing the structure of matter. The Organization has its seat at Meyrin near Geneva in Switzerland. There are two adjoining Laboratories known as CERN Laboratory I and CERN Laboratory II.

CERN Laboratory I has existed since 1954. Its experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). Large intersecting storage rings (ISR), are fed with protons from the PS for experiments with colliding beams. Scientists from many European Universities as well as from CERN itself take part in the experiments and it is estimated that some 1200 physicists draw research material from CERN.

The CERN Laboratory I site covers about 80 hectares almost equally divided on either side of the frontier between France and Switzerland. The staff totals about 3000 people and, in addition, there are about 850 Fellows and Visiting Scientists. Twelve European countries contribute, in proportion to their net national income, to the CERN Laboratory I budget, which totals 371.4 million Swiss francs in 1972.

The CERN Laboratory II was authorized by ten European countries in 1971. A 'super proton synchrotron' (SPS), capable of a peak energy of hundreds of GeV, is being constructed. CERN Laboratory II also spans the Franco-Swiss frontier with 412 hectares in France and 68 hectares in Switzerland. Its budget for 1972 is 95 million Swiss francs and the staff will total about 300 people by the end of the year.

CERN COURIER is published monthly in English and French editions. It is distributed free to CERN employees and others interested in sub-nuclear physics.

The text of any article may be reprinted if credit is given to CERN COURIER. Copies of most illustrations are available to editors without charge.

Advertisements are published on the sole responsibility of the advertisers.

Editor: Brian Southworth
Assistant Editor: Philippe d'Agraives
Advertisements: Micheline Falciola
Photographs: PIO photographic section

Public Information Office
CERN, 1211 Geneva 23, Switzerland
Tel. (022) 41 98 11 Telex 2 36 98

Printed by: Ed. Cherix et Filanosa S.A.
1260 Nyon, Switzerland

Contents

Cover photograph : Spot the computer card... A dash of 'pop art' by G. Boixader to introduce our computer issue.

Comment

This month we have a special issue devoted to computers at CERN. It updates the previous review of this broad and varied topic which appeared in September 1967. Since then, the role of computers in the work of our Laboratory (which can be taken as typical of all the big high energy physics Laboratories) has continued to extend — in the physics itself, in the conduct of experiments, in the measurement of film from bubble chambers, in the operation of accelerators and large dectectors, in Laboratory administration. New applications have been found, old applications have been further developed. It remains true that high energy physics could not have sustained its rate of progress without the parallel development of computers and of our abilities in using them. The content of this issue will give a good idea of the important part they play in the life of CERN.

Despite our obsession with computers, we must intervene with a brief announcement on another topic. On 1 March, beam was accelerated to the design energy of 200 GeV in the proton synchrotron at the National Accelerator Laboratory, Batavia, USA. NAL now takes over from the Institute of High Energy Physics at Serpukhov, USSR, whose 76 GeV machine has held pride of place since 1967 as the highest energy accelerator in the world. We send our congratulations to Professor R.R. Wilson, Director of NAL, and his team on this great achievement which we will be celebrating at length in the next issue of CERN COURIER.

Computers: why ?

L. Kowarski

CERN is the favourite showpiece of international co-operation in advanced scientific research. The public at large is, by now, quite used to the paradox of CERN's outstandingly large-scale electromagnetic machines (accelerators) being needed to investigate outstandingly small-scale physical phenomena. A visitor finds it natural that this, largest-in-Europe, centre of particle research should possess the largest, most complex and costly accelerating apparatus.

But when told that CERN is also the home of the biggest European collection of computers, the layman may wonder : why is it precisely in this branch of knowledge that there is so much to compute ? Some sciences such as meteorology and demography appear to rely quite naturally on enormously vast sets of numerical data, on their collection and manipulation. But high energy physics, not so long ago, was chiefly concerned with its zoo of 'strange particles' which were hunted and photographed like so many rare animals. This kind of preoccupation seems hardly consistent with the need for the most powerful ' number crunchers '.

Perplexities of this sort may arise if we pay too much attention to the (still quite recent) beginnings of the modern computer and to its very name. Electronic digital computers did originate in direct descent from mechanical arithmetic calculators; yet their main function today is far more significant and universal than that suggested by the word ' computer '. The French term ' ordinateur ' or the Italian ' elaboratore ' are better suited to the present situation and this requires some explanation.

What is a computer ?

When, some forty years ago, the first attempts were made to replace number-bearing cogwheels and electromechanical relays by electronic circuits, it was quickly noticed that, not only were the numbers easier to handle if expressed in binary notation (as strings of zeros and ones) but also that the familiar arithmetical operations could be presented as combinations of two-way (yes or no) logical alternatives. It took some time to realize that a machine capable of accepting an array of binary-coded numbers, together with binary-coded instructions of what to do with them (stored program) and of producing a similarly coded result, would also be ready to take in any kind of coded information, to process it through a prescribed chain of logical operations and to produce a structured set of yes-or-no conclusions. Today a digital computer is no longer a machine primarily intended for performing numerical calculations ; it is more often used for non-numerical operations such as sorting, matching, retrieval, construction of patterns and making decisions which it can implement even without any human intervention if it is directly connected to a correspondingly structured set of open-or-closed switches.

Automatic 'black boxes' capable of producing a limited choice of responses to a limited variety of input (for example, vending machines or dial telephones) were known before ; their discriminating and logical capabilities had to be embodied in their rigid internal hardware. In comparison, the computer can be seen as a universally versatile black box, whose hardware responds to any sequence of coded instructions. The complication and the ingenuity are then largely transferred into the writing of the program.

The new black box became virtually as versatile as the human brain ; at the same time it offered the advantages of enormously greater speed, freedom from error and the ability to handle, in a single operation, any desired volume of incoming data and of ramified logical chains of instructions. In this latter respect the limit appears to be set only by the size (and therefore the cost) of the computer, i.e. by the total number of circuit elements which are brought together and interconnected in the same computing assembly.

High energy physics as a privileged user

We are only beginning to discover and explore the new ways of acquiring scientific knowledge which have been opened by the advent of computers. During the first two decades of this exploration, that is since 1950, particle physics happened to be the most richly endowed domain of basic research. Secure in their ability to pay, high energy physicists were not slow to recognize those features of their science which put them in the forefront among the potential users of the computing hardware and software in all of their numerical and non-numerical capabilities. The three most relevant characteristics are as follows :

1. Remoteness from the human scale of natural phenomena : Each individual 'event' involving sub-nuclear particles takes place on a scale of space, time and momentum so infinitesimal that it can be made perceptible to human senses only through a lengthy and distorting chain of larger-scale physical processes serving as amplifiers. The raw data supplied by a high energy experiment have hardly any direct physical meaning ; they have to be sorted out, interpreted and re-calculated before the experimenter can see whether they make any sense at all — and this means that the processing has to be performed, if possible, in the ' real time ' of the experiment in progress, or at any rate at a speed only a computer can supply.

2. The rate and mode of production of physical data : Accelerating and detecting equipment is very costly and often unique ; there is a considerable pressure from the user community and from the governments who invest in this equipment that it should not be allowed to stand idle. As a result, events are produced at a rate far surpassing the ability of any human team to observe them on the spot. They have to be recorded (often with help from a computer) and the records have to be scanned and sifted — a task which, nowadays, is usually left to computers because of its sheer volume. In this way, experiments in which a prolonged ' run ' produces a sequence of mostly trivial events, with relatively few significant ones mixed in at random, become possible without wasting the valuable time of competent human examiners.

3. High statistics experiments : As the high energy physics community became used to computer-aided processing of events, it became possible to perform experiments whose physical meaning resided in a whole population of events, rather than in each taken singly. In this case the need grew from an awareness of having the means to satisfy the need ; a similar evolution may yet occur in other sciences (e.g. those dealing with the environment), following the currents of public attention and possibly de-throning our physics from pre-eminence in scientific computation.

Modes of application

In several articles of this COURIER issue, computer uses at CERN are reviewed from the point of view of the user (theoretical physics, processing of data from track chambers, administration, etc.) ; in some others, a special-purpose facility is described. In order to stress here our main point, which is the versatility of the modern computer and the diversity of its applications in a single branch of physical research, we shall classify all the ways in which the ' universal black box ' can be put to use in CERN's current work into eight ' modes of application ' (roughly corresponding to the list of ' methodologies ' adopted in 1968 by the U.S. Association for Computing Machinery) :

1. Numerical mathematics

This mode is the classical domain of the ' computer used as a computer ' either for purely arithmetic purposes or for more sophisticated tasks such as the calculation of less common functions or the numerical solution of differential and integral equations. Such uses are frequent in practically every phase of high energy physics work, from accelerator design to theoretical physics, including such contributions to experimentation as the kinematic analysis of particle tracks and statistical deductions from a multitude of observed events.

2. Data processing

Counting and measuring devices used for the detection of particles produce a flow of data which have to be recorded, sorted and otherwise handled according to appropriate procedures. Between the stage of the impact of a fast-moving particle on a sensing device and that of a numerical result available for a mathematical computation, data processing may be a complex operation requiring its own hardware, software and sometimes a separate computer. Numerous examples of such processing systems will be described in other articles appearing in this issue (in particular those on major uses in the physics programme and on the Omega/SFM and ERASME computer systems).

3. Symbolic calculations

Elementary logical operations which underline the computers' basic capabilities are applicable to all sorts of operands such as those occurring in algebra, calculus, graph theory, etc.

High-level computer languages such as LISP are becoming available to tackle this category of problems which, at CERN, is encountered mostly in theoretical physics but, in the future, may become relevant in many other domains such as apparatus design, analysis of track configurations, etc.

4. Computer graphics

Computers may be made to present their output in a pictorial form, usually on a cathode-ray screen. Graphic output is particularly suitable for quick communication with a human observer and intervener (see the articles on interactive computing). Main applications at present are the study of mathematical functions for the purposes of theoretical physics, the design of beam handling systems and Cherenkov counter optics and statistical analysis of experimental results.

5. Simulation

Mathematical models expressing 'real world' situations may be presented in a computer-accessible form, comprising the initial data and a set of equations and rules which the modelled system is supposed to follow in its evolution. Such ' computer experiments' are valuable for advance testing of experimental set-ups and in many theoretical problems. Situations involving statistical distributions may require, for their computer simulation, the use of computer—generated random numbers during the calculation. This kind of simulation, known as the Monte-Carlo method, is widely used at CERN.

6. File management and retrieval

As a big organization, CERN has its share of necessary paper-work including administration (personnel, payroll, budgets, etc.), documentation (library and publications) and the storage of experimental records and results. Filing and retrieval of information tend nowadays to be computerized in practically every field of organized human activity ; at CERN, these pedestrian applications add up to a non-negligible fraction of the total amount of computer use.

7. Pattern recognition

Mainly of importance in spark-chamber and bubble-chamber experiments — the reconstruction of physically coherent and meaningful tracks out of computed coordinates and track elements is performed by the computer according to programmed rules.

8. Process control

Computers can be made to follow any flow of material objects through a processing system by means of sensing devices which, at any moment, supply information on what is happening within the system and what is emerging from it. Instant analysis of this information by the computer may produce a ' recommendation of an adjustment ' (such as closing a valve, modifying an applied voltage, etc.) which the computer itself may be able to implement. Automation of this kind is valuable when the response must be very quick and the logical chain between the input and the output is too complicated to be entrusted to any rigidly constructed automatic device. At CERN the material flow to be controlled is usually that of charged particles (in accelerators and beam transport systems) but the same approach is applicable in many domains of engineering, such as vacuum and cryogenics.

Centralization versus autonomy

The numerous computers available at CERN are of a great variety of sizes and degrees of autonomy, which reflects the diversity of their uses. No user likes to share his computer with any other user ; yet some of his problems may require a computing system so large and costly, that he cannot expect it to be reserved for his exclusive benefit nor to be kept idle when he does not need it. The biggest computers available at CERN must perforce belong to a central service, accessible to the Laboratory as a whole. In recent years, the main equipment of this service has consisted of a CDC 6600 and CDC 6500. The recent arrival of a 7600 (coupled with a 6400) will multiply the centrally available computing power by a factor of about five and these central installations are the main topic of the next article on computing at CERN.

For many applications much smaller units of computing power are quite adequate. CERN possesses some 80 other computers of various sizes, some of them for use in situations where autonomy is essential (for example, as an integral part of an experimental set-up using electronic techniques or for process control in accelerating systems).

In some applications there is need for practically continuous access to a smaller computer together with intermittent access to a larger one. A data-conveying link between the two may then become necessary ; CERN examples of this mode of use are described in the article on the FOCUS system.

Conclusion

The foregoing remarks are meant to give some idea of how the essential nature of the digital computer and that of high energy physics have blended to produce the present prominence of CERN as a centre of computational physics. The detailed questions of ' how ' and ' what for ' are treated in the other articles of this issue concretely enough to show the way for similar developments in other branches of science. In this respect, as in many others, CERN's pioneering influence may transcend the Organization's basic function as a centre of research in high energy physics.

Computing at CERN

A review of the past, present and future of computing at CERN concentrating on the large central computers which bear the brunt of CERN's workload.

D. Ball

The Past

Computing at CERN started in the Autumn of 1958 with the installation of a Ferranti Mercury, which was, for its time, a modern and powerful European-built computer. It was bought to provide data-handling facilities for CERN's physics programme. Its installation taught CERN that computers are a mixed blessing, requiring a staff of experts to nurse them along particularly during their first year or so of life, but, despite the problems, physicists quickly became addicted to computing and could not get enough.

The increase in workload from bubble chamber and electronics experiments at the proton synchrotron early in 1960, meant that the Mercury was saturated before its successor arrived. This was an IBM 709 which provided a four-fold increase in computing capacity. Since it was a well established machine, CERN was spared a painful running-in period. The FORTRAN era came with it. The problem of the mismatch of mechanical input/output speed to that of electronic computation soon became apparent and a small 'satellite' computer, an IBM 1401, was installed to relieve the 709 of some of the drudgery. In 1962 a flying spot digitizer to measure bubble chamber film was connected to the IBM 709 — the first use of computers on-line at CERN.

By mid-1963, the 709 was saturated and was replaced in September of that year by an IBM 7090 which gave another increase of four in computing capacity. This changeover was painless for the users as the new machine was completely compatible with the 709 and no programming changes were required. It also involved no change in the mode of operation, one program completed its computing cycle before another started.

Inside the computer room where the CDC 6600 has served as CERN's main computer. To the left and in the background are magnetic tape units. In the foreground is the console where the operators are in communication with the computer's operating system. On the displays they can see which programs are running at that time and also the various stage which the programs going through the computer have reached.

CERN 366.8.69

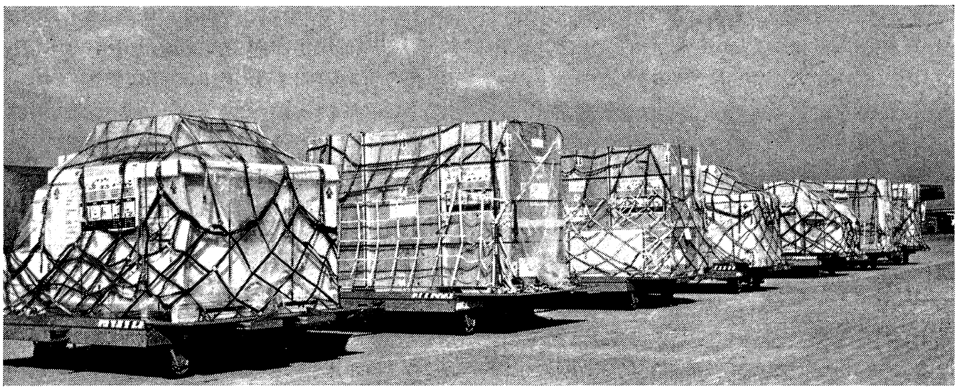
The growth in demand for computing at CERN continued unabated, amounting to a doubling each year, and this situation, plus the increasing importance of computers in the work of the Laboratory, necessitated a jump in computing capacity preferably of the order of a factor of ten. The only computer which could give this increase was the Control Data Corporation 6600 and, in March 1964, CERN placed its order. The 6600 was delivered at the beginning of 1965. It was one of the first of the series and problems came with it. The effect on the Laboratory's computing was eased by using outside computing facilities but the development plans for computing services around the 6600 were delayed for at least two years.

This computer also brought the wonderland of multiprogramming as the next stage in the continuing battle to bridge the gap between computing and input/output speeds. In order to provide increased capacity and a more reliable service, the CDC 6400, a smaller compatible brother of the 6600 was installed in April 1967.

About the same time manufacturers were asked to send information on their future products and technical discussions were started. CERN estimated its future needs as a system which had a potential capacity by the years 1974-75 of ten times that then installed and the discussion revealed that several firms had plans to make machines larger than the CDC 6600. However the possibility of getting a new, large, well-proven machine by 1970 was very unlikely and CERN obviously wanted to avoid any repeat of its 6600 experience. A further conclusion from the studies was that the new system should be based on two compatible machines with an interval of two to three years between their purchase. Thus it was decided to go for an interim solution, either by extending the CDC 6000 system or

CERN's new central computer, a CDC 7600, was flown into Geneva airport mid-February and can be seen being unloaded from the plane and being wheeled across the tarmac.

CERN 181.2.72


CERN 165.2.72

by choosing a medium-sized machine from another manufacturer, the medium-sized machine to be compatible with a larger machine. The first solution was adopted and at the end of 1969 the CDC 6400 was upgraded by increasing the memory and adding a second processor, converting it into a 6500. Extra disk and drum capacity were also added.

In the summer of 1969, there was a further investigation to see what large computers would be available for delivery by the end of 1971. The most economic solution proved to be a CDC 7600 which has a computing capacity about five times that of the 6600. There is still no computer on the European market providing comparable capacity. With the slowing down of the expansion of Laboratory I since the construction of the big new accelerator was approved, it is estimated that CERN will need a second 7600 in 1976 rather than 1974 or 1975. (Laboratory II, incidentally, is a customer of Laboratory I for its large-scale computing). Overall, the demand for computing is continuing to grow but the rate of growth has at least slackened off from a doubling every year, which was the case through to the mid-60s, to a doubling about every two years.

The Present

The present central computing service operates 24 hours per day, seven days per week including most holidays. It is still predominately 'batch-oriented' with the main programming languages being FORTRAN and assembly language. A very large program and subroutine library is available on disk in re-locatable form, and a tape library of some 35 000 labelled tape reels is maintained close to the two computers.

Batch input / output using card readers and line printers is via three remote self-operated input/output stations (RIOS) as well as by card readers and line printers located at the central computers themselves. In addition, there is a car delivery service to a number of remote parts of CERN.

Semi-interactive facilities are available on the FOCUS system which is implemented on a CDC 3100 with channel-to-channel connections to the CDC 6500 and 6600. FOCUS was developed to provide economic facilities for quick sampling of experimental data (collected by small process computers) at the central computers. Thus the 3100 has direct data-links to the experimental halls. It has much wider application, however, since it allows about twenty users simultaneously to manipulate files at terminals and transfer job input files to either 6000 machine for processing (with priority if appropriate) and receive job output files back at their terminals. All terminals are connected to the CDC 3100 via a Hewlett Packard 2116B computer.

An interactive display is attached to the 6600 via a Ferranti Argus 500 computer and is used for interactive work which requires the computing power of the 6600. For graphics work requiring less computing a CDC 3200 is available which has a large CDC interactive display attached. It is used particularly for the re-measurement of bubble chamber events which have been rejected by the off-line chain of programs.

Over the last two years or so an interesting change has taken place in the manner in which many users run their jobs. With the introduction of FOCUS on a wider scale, a number of users changed their working habits. Keeping their programs in the permanent storage system of FOCUS, changes were made directly to this version rather than to the card deck.

The CDC 7600 'main frame' being installed at CERN. It will increase the computing capacity, in comparison with the 6600, by a factor of about five.

With direct access via the 3100, programmers could obtain a larger number of 'debug runs' than was possible with the operator input/output system. Also a number of new applications became practical — for example, maintaining equipment inventories which required frequent changes and periodic listings.

The addition of the remote input/output stations which took place in 1971 brought about a further major change. The RIOS eliminated the delay introduced by waiting for operator intervention and users can now obtain many more runs per day. Within a very short time a substantial proportion of the total number of jobs was being fed to the 6500 and 6600 via FOCUS and the RIOS and already fifty percent is input by the user himself. The number of short jobs has rapidly increased, at present nearly 9000 jobs are processed each week, needing 5000 tapes to be mounted.

The Future

On 15 February the new central computer, a CDC 7600, was shipped to the site. The future of large-scale computing at CERN for the next few years centres around this machine which is expected to be operational by the end of March. The arithmetic power of the computer is such that it can perform an addition in 110 ns, and a multiplication in 137.5 ns. As with the 6600, many instructions can be in process at any time. The effective rate of executing instructions is around 20 million per second. It is instructive, confronted by these figures which represent one of the most advanced computer systems now available, to remember that just thirteen years ago with the Mercury the 'add' time was 180 μs and only one instruction could be in progress at any one time.

The 7600 has two ferrite core memories, one of 65 K words of 60 bits plus 5 parity bits, and the other of 512 K words of 60 bits plus 4 parity bits. Programs are executed in the smaller memory, but can transfer information between the two cores at a rate in excess of 36 million words per second. Input and output operations are carried out via small peripheral computers with access to part of the small core memory.

The problem once again, however, is to feed the information between the processor and the outside world at a sufficient rate since, in general, the peripheral equipment is very similar in speed to that of the 6600 (in some cases it is the same equipment). The one exception is a very fast fixed disk (a 7638) with a large capacity and fast transfer rate. Thus CERN has decided that the *only* peripheral equipment attached directly to the 7600 shall be two of these disks. All other peripheral equipment will be attached initially to a 'front-end' CDC 6400 computer which is connected to the 7600 by a high-speed link. As a result all program input/output is between large core buffers and the 7638s. Thus all files must be created on the disk whether they be ultimately cards, printed output, magnetic tape input and output or permanent files residing on a multiple spindle disk drive.

Copying between the 7638 disk and the external media will be taken care of by the system and is called 'staging'. This is not new for card input/output and printed output (it is used on most large computers including the 6000 machines) but it is new (and unique) for complete magnetic tape reels or disk files. Only the very large capacity of the 7638 disk makes it possible to include magnetic tapes in the staging philosophy - one 7638 disk can hold about fifty complete tape reels. The advantage of staging everything is that input/output for active jobs is done exclusively using a device with a very high instantaneous transfer rate (about fifty times that of the tape units). In fact a sequential scan of a large file on the 7638 is very fast, a complete reel requiring about ten seconds to read through.

The peripheral equipment attached to the 'front end' 6400 reflects the way computing is expected to evolve at CERN (and elsewhere). The major items are :

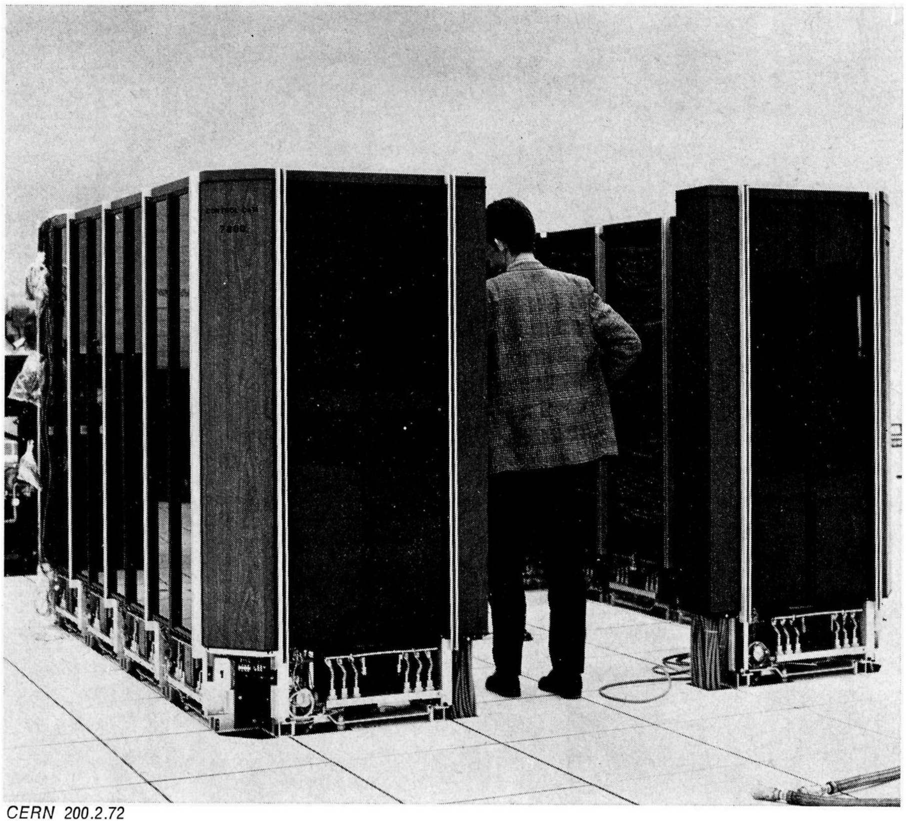
High speed 9-track units for densities up to 1600 bpi illustrating the continuing trend towards higher densities (the present units have densities up to 800 bpi) ;

Multi-spindle disk drives to provide permanent file storage ;

Remote input/output stations based on Computer Technology Model 10 Satellite One computers consisting of processors with 8 K, 1.5 μs core memory, card reader and line printer. Five of these RIOS will be installed initially and are scheduled to be operational around the middle of this year. Another five will probably be installed later in the year. It is interesting to note that, although once again CERN was obliged to buy its large computer from the United States, the best value for money for RIOS was provided by a European manufacturer. An important criterion in making the selection was the expandability of the stations since there is a clear need to attach other peripherals, including tape units, to them in the near future. This implies increasing the speed of the link between the station and 6400 ;

Card Reader, Card Punch, Line Printers to provide the usual peripheral facilities. However, the volume of output generated will be so high that it is planned to attach a high speed alpha-numeric microfilm printer at the beginning of 1973 to handle a substantial part of it.

In comparing the advent of the 7600 with that of the 6600 it is impor-



CERN 200.2.72

tant to note that the serial number of the 7600 is 19, whereas that of the 6600 was 3. Thus there are already many 7600s in operation (all in the USA with the exception of one in the UK which is at ICL's factory for interfacing to an ICL 1904A as a front-end; others will be installed in Europe this year). The first 7600 has been operating for a customer for two years. Also, CDC have obviously used their experience with the 6000 series of machines in the design and manufacture of the 7600. Thus the memories now have parity bits and a lot of thought has gone into the diagnosis and repair of failures. The 7600 is fitted with a maintenance control unit in the form of a peripheral computer which monitors the 7600's operation and diagnoses malfunctions. To repair a fault normally consists of replacing the defective subassembly and, up to now, average repair time has been less than two hours.

The software of the 6600 (or rather lack of) was a major headache for CERN and for the 7600, while the position is very much healthier, it is more of an unknown than the hardware. CERN will be one of the first users of the 7600 software called SCOPE 2.0 (the software in the front-end is modified SCOPE 3.3 which is well established as the normal CDC 6000 operating system). It has been decided to use standard CDC software making only such changes as can be carried over easily from one CDC version to another.

An extensive hardware and software acceptance test was carried out succesfully in CDC's factory in Minneapolis running CERN programs. This is being repeated at CERN prior to having a thirty-day 'live' acceptance period during which users will run their normal work on the machine. All the evidence to date suggests that CERN's 7600 is one of the best.

The disadvantage, from the reliability point of view, of channelling all input/output via a front-end machine is obvious. To overcome this the CDC 6500 will be shutdown in the Autumn and modified in readiness for attaching to the 7600 as a second front-end. The modifications include adding ten more peripheral processors and twelve more channels to bring it into line with the front-end 6400. Peripheral equipment (including that at present on the 6500) will be allocated to one or other of the 6400 and 6500, but, if either fails, its equipment, including RIOS and terminals, can be switched to the other machine.

Interactive facilities will be provided using the subsystem INTERCOM on the front-end machines. CERN's requirements here are, primarily, on-line file editing and job submittal in a batch processing environment. INTERCOM will allow users to have access to files stored in the SCOPE permanent file system, modify files, create new files, and submit jobs to the batch processing system of the 7600. Output files may be retrieved at the terminal for examination. INTERCOM does allow jobs to be run on the 6000 machine with a measure of interaction and this will be exploited for CERN's interactive work, for example the GAMMA system (see the articles on interactive computing). Interactive work will be able to use a large core memory of 500 K words which will be shared between the 6400 and 6500. In particular, it provides a very convenient backing store to which programs can be swapped.

While the permanent file space will be adequate for storage of program and small data sets, it falls far short of the capacity needed to substantially reduce the use of magnetic tapes. It is probable that by 1974 the computing centre will have around 70 000 magnetic tapes. As a first step to increase the capacity of on-line storage it is planned to replace the multi-spindle disk drives by larger capacity units which will become available at the end of this year. However, this will only 'buy time' and CERN is investigating the addition of a 10^{12} bit data bank about the end of 1973 (see the article on data storage). This data bank will be accessible by a number of computers and form part of a network of computers which is being studied.

Quantitative performance analysis of large systems such as the 7600 with the long term aim of performance prediction is an area of increasing importance since intuitive ideas are often wrong. CDC has developed a special hardware monitor for CERN which will be used to study the flow of work through the system.

As mentioned earlier the 7600 is installed in a new computer centre. The building consists of two parallel concrete wings, where there are offices and technical equipment, which

CERN 374.2.72

Installation of the 7600 well advanced in the large hall of the new computer centre. Top left, the shape of the main-frame can be picked out. Then comes the 6400 computer, the large core memory which will be shared by the 6400 and 6500 (Extended Core Store) and, nearest to the camera, a number of controllers which connect peripheral equipment to the 6400. On the right and in the foreground are the operator displays.

enclose the computer hall proper and support its roof. This hall has an area of 1600 m^2 and its height between false floor and false ceiling is six metres. There is also a basement which is occupied partly by air-conditioning equipment and electrical generators and partly by computer supplies. In particular, the bulk of the tapes will be stored directly under the area where the tape units are located. A paternoster is installed for the physical transfer of the tapes.

The equipment in the hall is arranged by function, therefore there is one area for input, one for consoles, etc. Part of the hall is taken up by a 'Cœur Central' which houses all the user facilities. This area has two floors, the ground one will house a remote input/output station and general input/output facilities. Cards, printed output, etc. will be physically moved between the Cœur and the hall via conveyor belts. The first floor houses the Advisory Services, a programmer work area, a conference room and a visitors' gallery.

This splendid new building is now being progressively occupied by the staff of the Data Handling Division.

The smaller computers

So far we have concentrated on the glamorous super-computers which cater for the large-scale computing needs of the Laboratory. A recent survey identified 80 other computers sprinkled around the CERN site. They are from fourteen manufacturers ; 59 of them belong to CERN and 21 have been brought in by visiting groups from research centres in the Member States. Many of the machines are quite small, such as the PDP-8, PDP-9, PDP-11, PDP-15, DP516, HP2116, IBM 1800 but they range as large as the CDC 3100, IBM 360/44, CII 10070.

Almost all of them (with the exception of an IBM 360/30 used in administrative data processing and a PDP-11 coming into use for library needs) are involved in the physics programme. Examples of their applications are — on-line acquisition and control in electronics experiments, on-line data acquisition and control in scanning and measuring system for bubble chamber film, interface and file-handling between a number of computers, control of accelerators and beam transport systems, etc.

There is a strong trend, noticeable everywhere, towards 'distributed computing' — that is, having computers individually assigned to specific functions rather than trying to use one large central installation to cope with everything. Examples of this are the Omega and Split Field Magnet computer system (described later) centred on a CII 10070 and the ERASME computer system (also described later) centred on a PDP-10. In the electronics experiments field and the bubble chamber film measuring field, respectively, these are amoung the most advanced of their kind in the world.

Nevertheless, apart from the big dedicated computers there is growing need of data links between computers. Higher data taking rates and larger total volumes of data to be analysed are expected from the detection systems coming into use. This can only lead to even more extensive use of computers in real-time, requiring either increased computing capacity or more data links to a medium or large multi-programming computer. There are already four data-links into the central computers via the FOCUS system. A considerable number of the 80 computers will require links in the future to larger machines.

The following articles go into the various computer applications in more detail.

Major uses in the physics programme

a) Electronics experiments

H. Overas

In a typical electronics experiment, two particles (A and B) are made to interact (collide) in a region surrounded amongst other things by detectors, some electronic equipment, and one or more spectrometer magnets. At some convenient distance there are more electronics and an on-line computer. The interactions occurring are classified as 'events' of various kinds according to the number and type of particles (C, D, etc.) emerging. The events which we are specifically studying in the experiment are referred to as 'good' ones.

The detectors may be of various kinds — the most common ones are scintillation counters, wire chambers and Cherenkov counters. They provide the basic information about the particles involved in each event. This information is taken care of and checked by the on-line computer, and passed on via magnetic tape to a larger computer for analysis. We shall now follow an experiment from beginning to end to see in more detail what the computers do.

First of all we must be sure that the experiment can be properly done with the proposed apparatus. This tricky question can often be settled only through a Monte Carlo simulation of the experiment on a powerful computer. What is believed to be a correct random sample of artificial events is generated in the computer, conditions corresponding to the details of the apparatus are imposed, and counts are made of how many good and bad events would have been detected. We calculate, in other words, the efficiency of the apparatus in detecting good events and its discrimination power in rejecting bad ones.

Spectrometer magnets are used for accurate determination of the momenta of charged particles. The particles pass through a series of detectors with good space resolution (such as wire chambers), placed in or around the field in the magnet aperture. The magnetic field configuration must be known in detail. It is measured by a small computer controlling the motion of Hall probes and recording the output from them.

During the actual running of the experiment a preliminary sorting of the events takes place even before data is collected by the on-line computer. This is achieved by a fast decision logic which, on the basis of signals from the fastest detectors (such as scintillation counters), decides whether an event fulfils the most elementary criteria to be of interest. At this stage, slower detectors (such as wire spark chambers) may be 'triggered' to provide a full description of the event which is then presented to the computer as a set of binary computer words. Before this transfer takes place, the computer is warned by an interrupt signal to leave aside, if necessary, what it is doing and to prepare itself to receive new data.

The number of words needed to describe an event may vary from about ten to many hundreds, depending on the complexity of the experiment. The average rate at which events are recorded is limited by factors such as the cross-section of the interaction, the beam intensity and composition, time structure in the beam, the recovery time of the detectors, the speed and severity of the decision logic, the speed and memory buffer size of the computer, the speed of the final recording device (for example, a magnetic tape unit). With present equipment the rate can be up to several thousand per second, but is usually up to a few hundred.

We can group the many tasks of the on-line computer as :

— Data acquisition involving buffering, rejection of obviously bad data, format conversion, storing on magnetic tape

— Monitoring and logging to give a running control of the detectors and the read-out system ; in case of suspected malfunctioning, more sophisticated test programs may be called into action

— Preparation and output of graphical data, such as histograms on a CRT, printer or plotter

— Sampling, involving calculation to some degree of sophistication of a certain fraction of the data, making it possible to judge whether any valuable physics results are likely to come out, or what the next move should be

— Communication on-line with other computers to provide more analysis capacity or access to remote files (via the FOCUS system, which is described later) or an exchange of information concerning the beams (such as will soon be possible in experiments on the ISR)

— Control parameter output using the computer to set magnets, etc.

— Background work not related to the current data taking which is under way — for example, program development or display of events for scanning purposes.

Not all experiments require, or can afford, computer systems large enough for all these tasks, but the first two at least are essential. The sample calculations possible on the small on-line computers are, of course, very limited, so most of the experiments depend on an off-line priority service (BOL) on the large computers during their runs. For the analysis of the bulk of the recorded events a powerful computer is practically always needed.

The first part of the analysis consists in sorting out, cleanly, the good events and transforming their description into relevant physical parameters like angles, momenta, etc. The starting point may be addresses (labels) of all wires which have been hit in a row of chambers. From this information it is possible to reconstruct

A computer (IBM 360) operating on-line to an electronics experiment in the East Experimental Hall at the CERN 28 GeV proton synchrotron. Practically all electronics experiments now use computers on-line and several of them are linked to the central computers of the Laboratory via the FOCUS system. This particular one is larger than most on-line computers and is able to do some off-line analysis.

CERN 281.10.67

bits of the particle tracks in space. This is not as trivial an operation as it sounds, since each wire address gives only the projection (one coordinate) of a point on the track, the projections of several tracks may cross each other, one particle may have given signals on several wires in the same plane, a hit wire may have failed to give its signal, and there may be a lot of confusing background. Having, nevertheless, sorted these problems out, the computer program tests whether some of the possible track candidates fit in an acceptable way into all the constraints, derived from first principles, that characterize the good event. For example, in an elastic scattering experiment, A and C, B and D are the same particles. At the PS, B is initially at rest in a target, so the true tracks of A, C and D must meet at a point inside the target volume, and they must lie in a common plane. There is also a basic relation between the momenta of the particles and the direction of the tracks, with which the momenta (determined by spectrometer magnets or other means) must comply. In principle, one should impose all the constraints rigorously in one big 'fitting' procedure, but to save computer time, compromises are made.

When an event is finally accepted as 'good', the physical parameters describing it are recorded on a 'Data Summary Tape'. This tape, which contains all the good events of the experiment in sequence may then be processed by a sorting program, very often one called SUMX. For example, events with nearly the same scattering angle may be grouped together to give the number of events as a function of angle. When corrected for the efficiency of the apparatus, as for example obtained from the Monte Carlo simulation, this gives the angular distribution of the differential cross-section. As far as the experiment itself goes this is a typical final result. However, considerable computer time may still be needed to determine from this such things as parameters in theoretical models for the interaction, etc.

The computers used in electronics experiments fall, as we have seen, rather neatly in two categories : small on-line computers used for data taking etc. and large off-line computers used for data analysis, etc.

The typical on-line computer has a word length of 12 to 24 bits (16 is now usual), a memory of 8 to 32 K words, direct memory access for fast input/output, one or two magnetic tape units, type-writer, paper tape equipment, CRT display, frequently a disk and sometimes card equipment and a line printer. An interface to one or several CAMAC crates is also frequently installed. The CAMAC crates provide standardized two-way communication with all sorts of electronic modules (such as scalers) used by the experiment.

So-called interpretive computer languages, like BASIC, have turned out to be convenient for people 'talking' with the CAMAC modules via the on-line computers at least when setting up and testing equipment. Interpretation is unfortunately slow and therefore the data acquisition programs used during the production runs must be written in the machine language. Test and sample programs, where time is not so crucial, are mostly written in FORTRAN. However, the flexibility of BASIC can be combined with the efficiency of the other languages via subroutine calls from BASIC.

Practically all electronics experiments are now equipped with an on-line computer, and most support groups have access to one. At the beginning of this year the total number involved was about forty (half belonging to visiting groups). About ten computer manufacturers are represented, most of them with several models. This great variety reflects the decentralized nature of decisions, at CERN and throughout Europe, concerning on-line computers. This is an interesting but perhaps not the most economic situation. However, there is growing understanding of the benefits which can come from compatibility.

Some 60 % of the off-line computer capacity needed to analyse data from electronics experiments is actually provided at CERN. This has absorbed nearly half the capacity of the central computers, CDC 6600 and 6500. These computers receive most of the experimental data from magnetic tape, of which some 20 000 are in use for this purpose. Only a small amount, sample data from three ISR experiments, goes direct to the central computers via FOCUS. With FOCUS it is possible to have quick and powerful sample analysis, rather than do data acquisition, so there is always a computer between it and the experiment. When the CDC 7600 has taken over some of the other activities of FOCUS, it is hoped that many more electronics experiments can have use of it.

In the past few years, a number of factors have changed the conditions for electronics experiments. Most of the changes have led to more data and more complex data ; in turn this demands better equipped on-line computers and far more off-line computer capacity.

Last year the Intersecting Storage Rings came into operation, adding to the physics programme at CERN about a dozen experiments of a new kind, in which there is no target in the conventional sense. Both interacting particles, A and B, are rapidly moving protons, one in each of two colliding beams. This means that the kinematical conditions, the interaction rate and the background are quite different from those encountered in experiments using the proton synchrotron, with important consequences both for the experimental hardware and the analysis programs. The on-line computers must in addition provide feedback about the alignment of the two beams, and they must cope with the fact that the ISR beams circulate continuously, which means being ready at all times to receive and store data. Modern computers are, luckily, well equipped to do several input/output operations at the same time and the continuous data taking has the advantage of requiring smaller data buffers in the computer for a given average data-taking rate.

At the synchrotron the main increase in data taking rate comes from the doubling of the burst length in recent years — the beams are now ' shining ' on the targets of the experiments for about 0.4 s every 2 s. Long bursts spread the beam out so that the intensity during the burst does not saturate the detectors. Even then, however, some beams have to be held at reduced intensity. Faster detectors in this situation would immediately produce more data. Of the new detectors the multiwire proportional chamber is the most promising, combining the properties of counters and position measurement devices. The wire spacing is usually 2 mm (about twice that in the usual wire chambers) but time resolution may be down to 25 ns.

Since it is not possible, and generally also not desirable, to record data at that speed, the signals from these chambers go first into a sophisticated decision logic. Even if it takes a few hundred nanoseconds to decide whether an event should be recorded, the MPCs can still give several thousand preselected events per second. Though they are still rather highly priced, such chambers are now installed in several experiments and their impact on computers is beginning to be felt.

The number and size of spectrometer magnets is increasing and there is a tendency to put more detectors both inside and outside the field. The combination of data-taking rates and complexity is presenting quite a challenge to the computers. The most spectacular systems coming into operation at CERN are the Omega and ISR Split Field magnets. These two projects and the computer system they require are described later in this issue.

The use of film as the recording medium in spark chamber experiments is about the only thing to be on the decline. The subsequent measurement procedure is slow and prevents fast feedback to the experiment. It was originally planned to use film with Omega but now TV cameras with pick-up tubes called Plumbicons, will produce data directly in digital form.

The results coming from meson-nucleon scattering experiments using polarized targets have greatly stimulated the interest in phase shift analysis, for which a lot of computer time is needed to minimize complicated functions of many variables. This has however had the beneficial side effect of focusing attention on numerical methods used in similar problems.

The amount of data that can be produced in electronics experiments is still far from an absolute limit and data handling threatens to become the decisive bottle-neck, if it has not become so already. Only a data handling chain pushed to the limit at each stage may relieve the situation — for example, much more advanced decision logic doing even part of the track reconstruction before the on-line computer, very fast special microprogrammed 'superinstructions' in the on-line computer, and well optimized analysis programs after it. Apart from constant improvement of conventional analysis methods, there are also promising new methods being tried for the large spectrometers — for example, one in which the momentum is 'looked up' in a sophisticated table prepared beforehand by a simulation method.

Any data reduction done before the data are even recorded implies, however, the risk of a fatal bias, especially in new types of experiments such as those at the ISR. One can understand the somewhat exotic wish to have an extremely fast recording device with large capacity to record the raw data without much rejection by the decision logic. Afterwards, all these recorded data could be played into the chain described above, but now different sets of sharper rejection criteria in the decision logic could be tried out on the same data if need be. This would almost make the accelerators off-line !

b) Bubble chamber experiments

i) Central computers in the analysis

R. K. Böck, J. Zoll

The photographs of the traces left in a bubble chamber by interacting high energy particles are man's most direct and striking access to the sub-nuclear world. Stereoscopic pictures are taken of the particle events and it is these photographic records which allow quantitative analysis of the phenomena occurring. The phenomena are quantum mechanical in essence (that is to say statistical), hence the precision of the experimental results increases with the number of events, typically hundreds of thousands, which are analysed.

This article outlines the use made of computers in handling this large volume of bubble chamber data. It leaves aside those techniques which bubble chamber physicists have in common with physicists carrying out electronics experiments.

In making the information stored on film available to analysis, the first task is the measurement of the pictures. Until recently hand-operated machines have been used to deliver coordinates of several points of each particle track onto a recording medium which can be fed to the computer. With the growing number of pictures this has become too painful and new solutions in the direction of automatic scanning and measuring have been looked for. The *scanning*, the recognition of interesting particle tracks and interactions, which comes quite easily to the human eye, has proved extremely difficult to master using digital techniques alone. Only with the arrival of a new generation of measuring machines of the track-following type, (machines such as POLLY, SWEEPNIK and, soon, ERASME) which use a computer *and* an operator on-line to help over difficulties, is there hope of separating the wanted events from the background with a satisfactory degree of reliability and economy. At present, the burden of scanning at CERN is still carried by people. Automatic *measurement* on the other hand has been well established for some time ; the next article reviews the role of computers in measuring systems used at CERN.

The second task is the processing of the raw measurements. It starts from typically 100 points measured on the pictures for each track and it gives the 4 vector of momentum and energy of the particle which caused the track. The volume of raw measurements from a single experiment is typically about 10^8 six digit numbers; clearly, this can only be handled with a computer. The processing of a given event passes through three main stages. The first stage converts the measurements into a three-dimensional description of the event, yielding the direction and (from the curvature in the magnetic field) the momentum of each track. The second stage uses the conservation laws to test the various possible interpretations of the event. The third stage picks (under control from the program or from the physicist) the correct interpretation, i.e. correct assignment of mass to each particle, and prepares the event for statistical analysis.

The computer spends most of its time processing un-problematic events. The programmer, on the other hand, spends most of his time foreseeing — or discovering — possible difficulties and programming the computer to deal with them. The computer programs for bubble chamber experiments start with elegant, simple ideas and end up complex and sophisticated. Fortunately, many experiments can share a basic set of programs — fortunately because the effort needed to make them operational far exceeds what may reasonably be invested in an individual experiment. In fact, only a few such programs have been developed in some of the big Laboratories and they have been communicated to some hundred high energy physics research centres all over the world, equipped with not quite as many different computers. Such large scale use of basic programs has been made possible by the use of FORTRAN, the language well established with scientific computers because of its reasonable efficiency and simplicity.

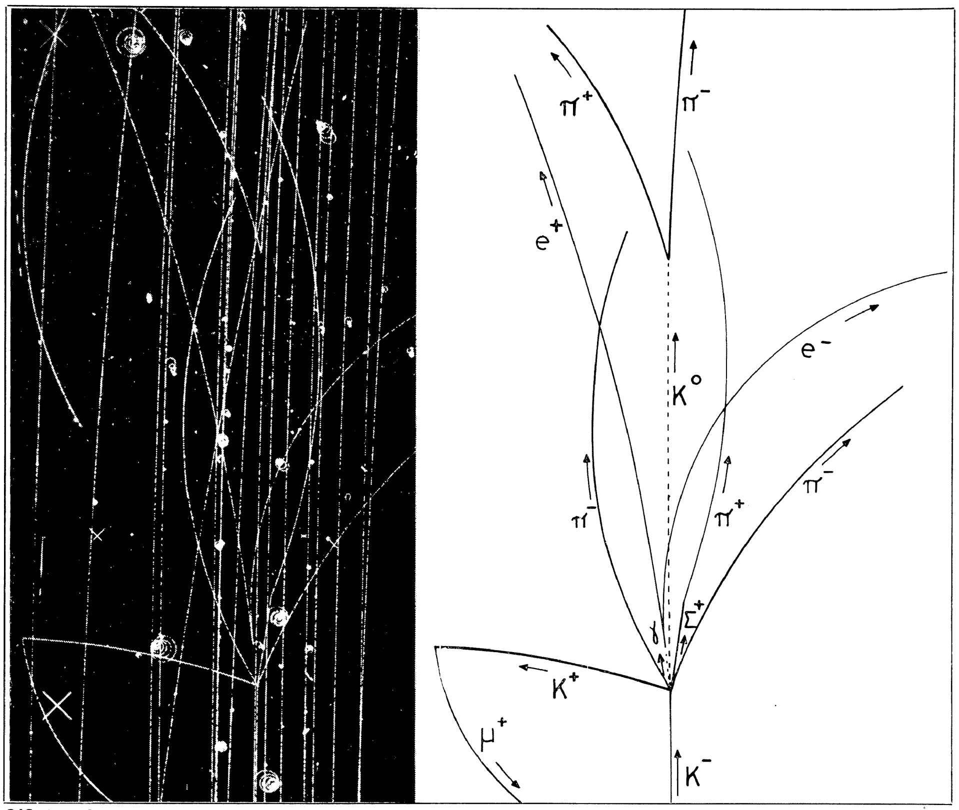
Over the past ten years at CERN, a chain of three programs known as THRESH, GRIND and SLICE (implementing the three stages of geometry, kinematics and decision mentioned before) have been developed and used. Each one is a self-contained FORTRAN program in the conventional sense ; communication of data between the programs goes via magnetic tape. Although different experiments use basically the same program, they still need individual modification. To cope with this, a very general editing program known as PATCHY has been developed, allowing many different versions of the same program to be kept on a single file and a particular version to be composed as input to the compiler.

In 1970, many reasons lead to the decision to make a clean break and to start a new program to replace THRESH, GRIND and SLICE. The primary reason was the preparation for the measurement of photographs from BEBC (the new 3.7 m bubble chamber scheduled to become operational at CERN in 1972) which has an optical system very different from the chambers used so far. The difficulties in grafting this onto the existing geometry program showed up strongly a basic weakness of the programs of the chain - the poor modularity of the insides of the three black boxes. A modification of procedure in a particular place sends waves like an earthquake through the whole program because everything is linked to everything else in a way transparent to an expert but not accessible to documentation.

As a framework for the new bubble chamber program a system called HYDRA was defined. Its purpose was to provide data modularity and program modularity with a maximum of simplicity and a minimum of concepts and, at the same time, to have fast execution and small program size.

The data modularity is realized by grouping *all* the information flowing through the program into addressable super-units (banks) residing in a single dynamic store, rather than scattering it into a multitude of specially allocated FORTRAN variables and arrays. For example : a track-bank contains all the geometry information about a track, a given title-bank contains the parameters of the magnetic field. Banks are generated and abandoned as required, their location in the store is known by its address, and they are not fixed even inside a program. Logical relations between banks are expressed by including the address of one bank in the link-table of an other bank. For example, all tracks of a vertex-point are linked together by each track pointing to the next. Such a *data-structure* contains not only the numeric information but also logical information about the object it describes.

The program modularity is achieved by organizing the program into processors each having a well defined task. This task is *entirely* describable as a transformation applied to a data-structure in the dynamic store : some banks provide the input data to the processor and some contain the desired results. For a given application, a steering program is written to coordinate the operations of the processors needed. Any processor consists of at least one FORTRAN subroutine, its operation being invoked by transferring control to this subroutine. As a matter of internal organization, the processor may be divided up into the primary and several secondary subroutines. The programming of a processor has to observe certain conventions in order to be compatible with the HYDRA system. Precisely these conventions, which are the same through the whole program (indeed through all HYDRA programs) are responsible for the easy documentation and the good readability of the program.



SIS 37 739

An example of a bubble chamber photograph, taken in an experiment by an Aachen/Berlin/CERN/London/Vienna collaboration, with its analysis alongside.

The processors are supported by the HYDRA system. Its services are requested with CALL statements much like the services of the FORTRAN system which are part of the definition of the basic language. In this sense, the HYDRA system is an extension of the FORTRAN language to provide - primarily - dynamic memory management facilities. Some languages contain these facilities in their basic definition, but the HYDRA-FORTRAN combination has two important advantages — the execution speed is that of a normal FORTRAN program, with very little overhead for the HYDRA system, and FORTRAN is a commonly accepted language. Because of the need for machine independence (so that the same programs can be used on a variety of computers) the processors for the new bubble chamber program, as well as the HYDRA system packages, have been written in ANSI FORTRAN which is the internationally accepted minimum requirement expected from anybody's compiler.

The bubble chamber programs of the HYDRA form will come into operation in 1972. They should help to tear down the walls that have sometimes threatened, on the data handling side, to separate physicists from computer specialists, or bubble chamber groups from each other and from physicists using other techniques.

b) Bubble chamber experiments

ii) Data acquisition from film

W. Blair, J. C. Gouache

Having recorded several stereo views of particle interactions in a bubble chamber on photographic film, the next step is to convert the information contained in this photographic record into digital form. As mentioned in the article above, the volume of photographs requiring such treatment has put great pressure on the development of automatic film measuring machines.

Unfortunately, the automation of the full process of scanning for wanted events and of their subsequent measurement has proved extremely difficult to master with efficiency in operation. Although there has been a high degree of success with the scanning and measurement of film from optical spark chambers (where the wanted event is likely to appear uncluttered by background tracks), for bubble chamber film, in general, we have had to back off from full automation to man-machine systems.

This article describes the role of computers in three types of measuring system at CERN. The systems are :

The HDP (or Hough Powell Device, taking its name from its originators) which is a raster-scan system with an optical-mechanical spot scanning the film and recording the photographed tracks of charged particles. Two HPDs have been used extensively for optical spark chamber film and film from CERN's 2 m hydrogen chamber.

The LSD (or Lecteur à Spirale Digitisée, a type developed at Berkeley under the name of Spiral Reader) which performs a spiral scan, around the vertex of the event to be measured, with an optical-mechanical slit. Two LSDs are now in action mainly on film from the 2 m chamber.

A hand-operated system called RAMSES (from ReActive Measurement Scanning and Evaluation System) which is used exclusively for the measurement of film from the Gargamelle 4.5 m heavy liquid bubble chamber.

The HPD system bears the marks of its original conception as a fully automatic device in which software was to carry the entire burden of selecting and measuring the interesting events without human intervention. The existing two units are on-line to the central computers (HPD2 to the CDC 6600 and HPD1 to the CDC 6600) and can measure film of various formats up to 70 mm width. Early environment and computer capacity problems (the systems, when operating, absorb about 15 % of the computers' capacity) made it clear that development of a really automated machine with the Laboratory's multi-purpose computer on-line is not the best economical solution, if the software problems are solvable at all.

The finally accepted less ambitious use of the HPDs has yielded impressive results however ; more events are measured on these machines than on any other automatic film measuring device (both at CERN and elsewhere). In 1971, for example, the CERN total was 200 000 bubble chamber events, bringing the grand total since 1964-65 to over 800 000 events plus over 1 100 000 events from spark chambers.

In the existing HPD system, the bubble chamber film is scanned by human operators on projection tables, known as Miladies, connected to an IBM 1130. Information such as photo number, event type and rough coordinates is collected, cross-checked, formatted and recorded on magnetic tape by this system serving ten scanning tables. After some reformatting to account for the measuring sequence of the HPDs, this information is later used by a program residing, during measuring periods, in the central computer.

This program controls the film advance and the direction of scan. It is meant to reduce the incoming mass of data as much as possible depending on the scanning mode : In the 'road guidance' mode, crude scanning information on track directions and curvatures serves to eliminate the bulk of digitisings that cannot lie on any of the event's track projections. In the 'vertex guidance' mode only vertex coordinates are known, and such a reduction requires tricky filtering methods, an elaborate memory and a time consuming program. The constraints to assign the special 'on-line' privileges to a program are such that, in this mode, filtering is run in a (disk-buffered) semi on-line mode or altogether off-line, and bare reduced amounts of data are transmitted — around 60 000 XY pairs for one view ! Despite the available computing power the constraints in a general purpose environment thus reduce the function of the central computer to that of a small data acquisition machine.

The lack of massive programs on-line communicating with a human operator also makes for a later rejection rate of measured events around 20 %, necessitating a recovery cycle for such rejects through a separate interactive system which was set up in 1970. It consists of a light-pen recovery system (modelled on that first used at Brookhaven) using a CDC 3200 computer with a CDC 250 Display. Satisfactory event recovery proceeds at around 30 events per hour and this is more convenient than a complete second pass of the bubble chamber film on the HPDs.

An obvious improvement of the system would be to have a medium-sized 'dedicated' computer — a big drawback at present is tape communication between programmes. The probable future situation with HPD1 and HPD2 on the CDC 6600, dedicated to the HPDs and to the running of associated production programs will be a healthy evolution from the present arrangement.

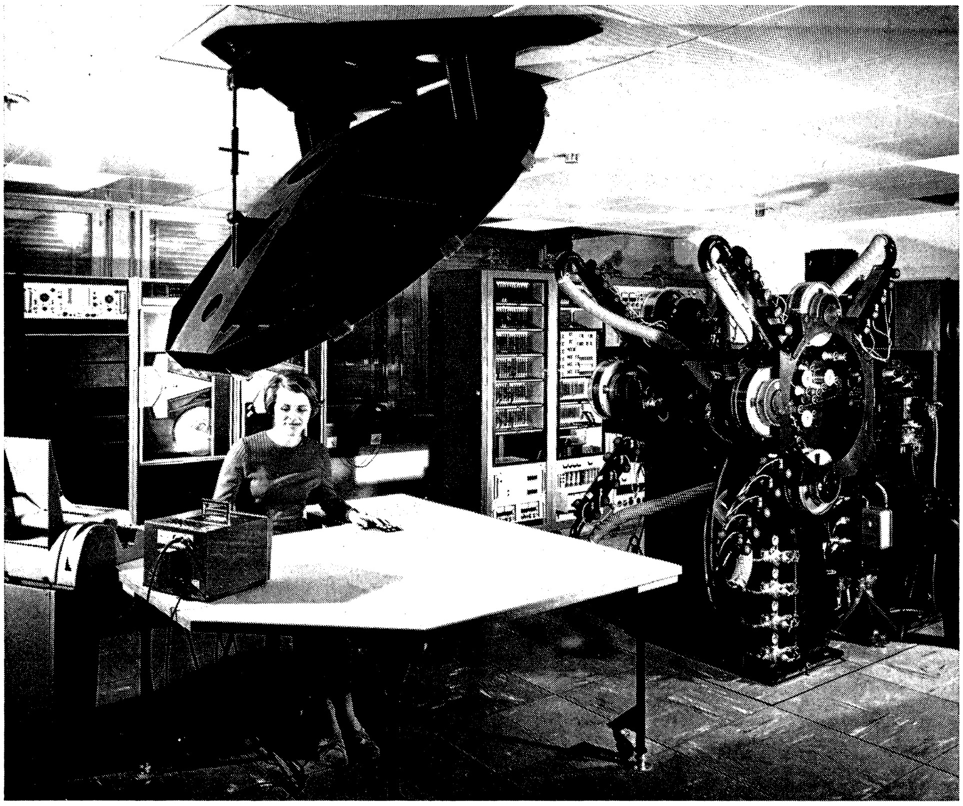
The LSD system differs from the

A view of an LSD (Spiral Reader) automatic measuring machine which is used mainly for the measurement of film taken with the 2 m hydrogen bubble chamber. With the LSD there is some operator guidance during the measurement process. A PDP-9 computer is used on-line.

above in various ways : it assigns to the on-line computer only the simple control and data acquisition functions, thus keeping the required computer size rather small ; it provides human guidance not only in the scanning, but also in the measuring process, thus simplifying the scanning operation and avoiding complicated programs (but still achieving acceptable speed and percentage of successful events); its measurement data are not at all reduced on-line but kept to a reasonable volume by using a vertex-centered slit as filter. The role of computers in the LSD system is as follows: A PDP-11 serves as control computer for six scanning tables and its function is to record operator generated information such as photo number, event type and very crude vertex positions in one view. After on-line checking and formatting, this information is recorded on magnetic tape and transmitted to the control computer of the measuring machine — a PDP-9 for each of the two LSDs operating.

Control functions of the PDP-9 program include the film transport and positioning, the automatic measuring of fiducials, and the steering of the measuring spiral after the operator's precise centering on the vertex. Many different checking functions assure smooth operation of the machine and a correct sequence of operator actions. The operator can also add hand-measured points in confused regions or ask for special programs in which displays or calibration measurements are possible and help in performance checking and failure diagnosis.

Data are finally recorded on magnetic tape and transmitted to off-line analysis programs. Due to the fact that the LSD measures the three views at the same time, the final output of the off-line analysis can be obtained by the physicist within a few days.



CERN 271.1.69

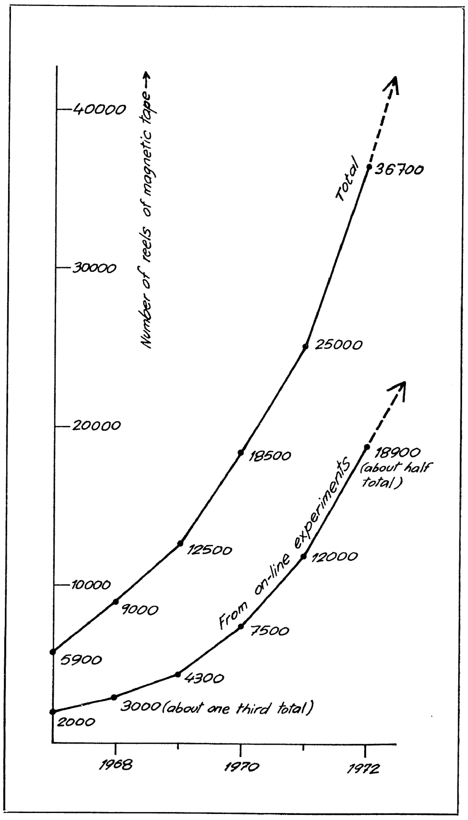
The existing LSD Mark I, since it began operation early in 1970, has measured 280 000 events (355 000 vertices) on film from the CERN 2 m hydrogen bubble chamber, at an average speed of 60 events per hour. A failure rate of 15 to 20 % is experienced due to the lack of on-line analysis and, as with the HPDs, there has to be re-measurement or a special recovery cycle.

RAMSES is designed as a system of lower speed, which is appropriate for the often very complicated events recorded on film from heavy liquid bubble chambers. Although slower than HPDs on LSDs by at least an order of magnitude, this system includes all the desirable features to avoid event recycling : The scanning and measuring phases are combined and entirely dominated by the operator, and the ratio of available computer capacity to data volume is large, permitting an on-line event analysis in three dimensions by full geometrical reconstruction. Thus failures are detected immediately and partial re-measurements or any other operator interventions are possible.

The computer used, serving six measurement tables, is a CDC 3100 system with two central processors, 48 K words of memory, floating point hardware and disks. In the measuring phase, in addition to control and checking functions, it guides the operator through a alphameric display to improve speed and avoid mistakes. In the reconstruction phase, it takes the role of a 'large' computer and communicates the success or failures to the operator after completion, and then waits for his next action.

A system is now being built up at CERN to carry this philosophy further, combining on-line analysis with automatic and high speed measurement. It is described in the separate article on ERASME.

Data storage



The growth of the CERN library of magnetic tapes over the past six years. There is no sign that the demand for data storage will ease off in coming years and alternative methods of storage are being studied.

E. McIntosh

The workload of the CERN central computer system is dominated, in terms of number of jobs, by short jobs submitted from terminals and remote batch stations. The arrival of the CDC 7600, which will be even more easily accessible and will give the user his results more quickly, is likely to accentuate this domination. Nevertheless, more than 80 % of the system's capacity (whether measured in terms of computation, input/output, or memory utilization) is devoted to the processing of the much smaller number of jobs which constitute the production work of the central system.

This production work consists mainly of the processing and analysis of experimental data by the performance of geometric, kinematic and statistical calculations. It involves extensive computation and considerable input/output from/to magnetic tape and it must be performed regularly, and reliably, to meet the requirements of the CERN physicists.

Recent developments in computer technology, as exemplified in the 7600, should give a significant improvement in the handling of this work. The 7600 is expected to compute about five times faster than its predecessor, the 6600 ; the new large core memory and fast disks, together with improved operating system techniques, should largely resolve the problem of memory utilization. However, even the fastest magnetic tape units of the 7600 system will be not more than twice as fast as those of the 6600. In addition, the amount of input/output which can be performed by a magnetic tape storage system is limited as much by the speed with which a reel of tape can be retrieved from the tape library and mounted, as by the speed of the data transfer itself.

The increased capacity and reduced access times of the 7600 system disks will be used to try to ease this problem but the capacity of even the largest disk amounts to no more than the equivalent of a few tens of reels of magnetic tape. This would not satisfy the needs of even individual groups from the many users.

The growing volume of data

The principal source of the data handled at CERN is of course the physics programme at the proton synchrotron, intersecting storage rings and synchro-cyclotron. If we look into the near future in bubble chamber physics — by 1974, when the 3.7 m chamber BEBC and the associated measuring system ERASME are in operation, it should be possible to process over 10^6 events/year. The data collected in this way (raw measurements from LSD, filtered measurements from HPD, or geometry output from ERASME and RAMSES) will then be submitted to the central system for further analysis.

These 10^6 events/year will produce some 5×10^{10} bits of data each year (500 tapes - one 800 bpi 7-track tape holding about 10^8 bits) and this data may need to be retained for up to three years. The analysis of this data at the central system to produce data summary tapes (DSTs) is expected to give at least another 5×10^{10} bits, which must be retained for periods of up to six years for subsequent statistical analysis.

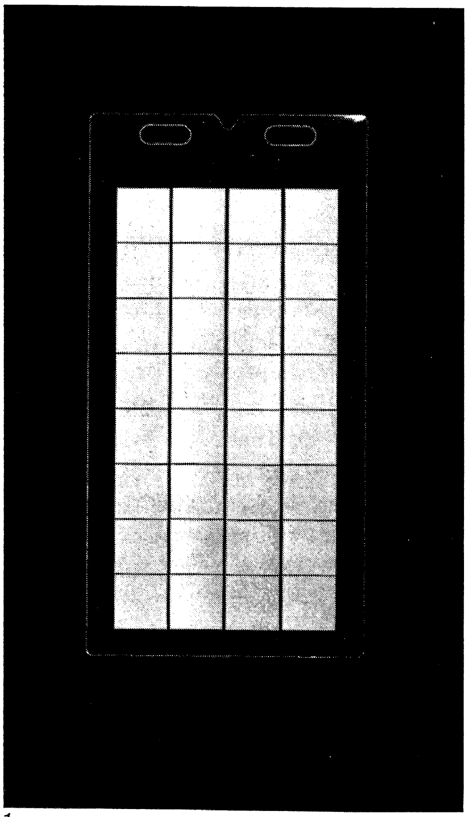
Electronics experiments, in general, generate less data about each event but collect many more events. It is estimated that last year some fifteen experiments yielded 5×10^{11} bits (5000 tapes) of raw data for subsequent analysis. The move towards higher statistics experiments, the availability of beams of higher intensity, and of faster detectors and on-line computers (coupled with the growth in the number of experiments now that the ISR is coming fully into use) imply that these numbers may be expected to increase considerably this year. It is already possible to envisage experiments measuring events at rates of several hundred per second and producing thousands of magnetic tapes.

As with bubble chamber data, this data will be analysed at the central computing system to produce DSTs, though in this case, thankfully, they should in general have a volume of less than 25 % of the input data. Again, it is usual to keep some or all of the data for lengthy periods of time. Confronted with these figures, perhaps all groups should be compelled to make a vow
'Yea, from the table of my memory, I'll wipe away all trivial fond records.' (' Hamlet ' Act I Scene V, as quoted by D. Knuth in his book ' The Art of Computer Programming '.)

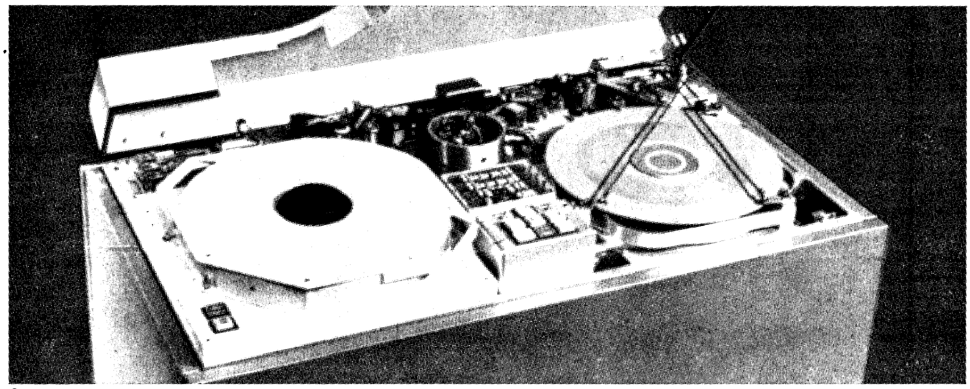
1. Photograph (full-scale) of a film chip as used in the IBM 1360 Photo-Digital Storage System. It can contain about 5 × 10^6 bits (1/20 of a magnetic tape — five copies of Hamlet). The chips are automatically developed after recording and placed in the chipstore. From a maximum capacity chipstore (about 2 × 10^{12} bits) any chip may be retrieved entirely automatically within a few seconds.

2. Other data storage systems use video tape (an IVC-1000 unit is shown). A reel of video tape can contain between 5 × 10^{10} and 10 × 10^{10} bits (500 to 1000 magnetic tapes). The reel may be automatically positioned by a very high speed search to any desired point in an average time of from 10 to 100 seconds depending on the length of the tape.

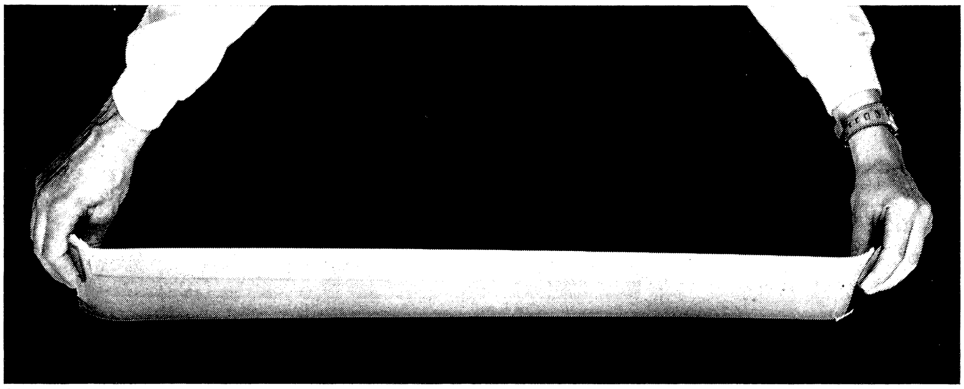
3. A film strip as used in the UNICON 690-212 laser mass memory system. The strip when fully written by a laser can hold 2.5 × 10^9 bits (25 magnetic tapes). Any strip from a maximum store of 10^{12} bits may be retrieved in a maximum of 10 seconds.



1.



2.



3.

The limitations of magnetic tape

Magnetic tape handling is probably the worst single source of concern to computer users. Problems may arise with reliability, compatibility of tape units on different computers and transfer of tapes written in the format of one system to a different system. Magnetic tapes are also far from ideal as archives of data ; they must be exercised (unwound and rewound) or even copied at regular intervals. However, they remain the cheapest and most convenient medium for recording large volumes of data and for transfers between experiments and computer systems both inside and outside CERN.

Just how popular and cheap it is may be judged from the graph which shows how the tape library at CERN has grown to over 35 000 tapes and is increasing at a rate of over 10 000 a year. At the central system it is becoming increasingly difficult to retrieve and mount magnetic tapes fast enough to satisfy the system demands and, as stated earlier, there will be a widening gap between the speed at which information can be processed by the 7600 and the speed at which it can be supplied from tape.

The growth, or at least the rate of growth, of the tape library and of tape handling must be limited in some way.

New storage systems

Nuclear physics research is not the only source of large volumes of data. NASA is currently receiving 10^{13} bits (100 000 tapes) of data each year from satellites in orbit ; the NASA tape library contains approximately 750 000 tapes. The National Archives and Records Service of the Federal Government of the USA archives approximately 10^{12} bits (10 000 tapes) of new data each year. In this cast fast access is not considered essential !

Many large computer installations (both scientific and commercial) are looking for increased capacity storage systems to replace or complement large disk or tape based storage facilities. The American Government, which is buying about one million tapes each year, is implementing a centralised storage system which will supply archive storage facilities, fast access to a large volume of data, and a convenient means of data communication, to several separate large computer systems.

The first device, based on photo-digital recording on film chip, to be capable of storing on-line 10^{12} bits (10 000 tapes worth) was announced by IBM in 1966. Today there are several devices (including using video recording techniques on magnetic tape or laser recording techniques on film strips) which offer access within

Interactive computing

seconds to on-line stores of 10^{12} bits or more and offer the capability of moving data between the device and an off-line library of reels or strips. Research into the use of holographic techniques has started and could eventually offer much faster access to even larger volumes of data.

CERN is investigating such devices and their connection to its computers; at the same time a data communication network, to make it possible to link the many computers on the CERN site to the central computing and storage systems, is being studied. In this way it is hoped to supply cheap and convenient access to the large volumes of data produced by the experimental programme.

When the first 10^{12} bits store was announced, J.-J. Servan-Schreiber wrote in ' Le Défi Américain '... ' It is estimated that the entire store of information in the world's libraries amounts to 10^{15} (one quadrillion, or one million billion) bits. This information is stored in the form of books and other printed documents, and is doubling every 15 to 20 years........... There appears the possibility that by 1980 a small number of computers will replace *all the written documentation* existing in the world, and that they will work in ' real time ' — replying to questions with information at the speed of human conversation. '

Perhaps we can imagine the day when a physicist, from a computer terminal in his own country will have access to any information stored at CERN whether it be experimental results, physics papers or books.

During the past few years a new phrase, 'man-machine interaction', has become fashionable in computer literature. The phrase may be new but the concept it describes is not. Even the simplest computing devices, from the old abacus to modern desk calculators, are essentially interactive computing systems. (Interactive : reciprocally active ; active upon or influencing each other - Oxford English Dictionary). They are interactive in the sense that man is providing the data and specifying the procedure to be followed, and the machine is providing the results while the dialogue between the man and the machine is continuous.

However, with the advent of the electronic computer the pace became faster and the scope more extensive. Particularly when batch processing techniques were introduced, the user became remote from the computer. He precodes his procedures, submits them with the related data and has no possibility of following or interfering with the subsequent process. Only when he bicycles across to pick up his results does he see manœuvres the computer could have done to get closer to the desired output.

This is not necessarily a bad thing. Overall it can save computer time — it gives long intervals for thought before asking the computer to come into action again. But, sometimes, close and immediate interaction is desirable and several methods of bringing this about are being tried. In particular, there has recently been development of several on-line (also called time-sharing) computing systems, often with graphical output terminals, where the user has a window into the computer and can see it at work directly.

Interactive systems (like relativity theories)) can be divided into two kinds — special and general. Special purpose systems are those where only a limited class of problems can be treated by the user. More precisely, the user is not able to define a procedure when interacting with the computer, he simply responds to more or less complicated questions from the computer, which has been programmed in advance for solving a special problem. General purpose systems are those where the user is also able to define his own procedure on-line, thus widening the class of problems which can be treated.

This second class of systems can be further subdivided depending on the degree of interaction allowed. Semi-interactive systems are those where the user is able to define a procedure, provide data, manipulate information, and send this to the computer for execution. The user is then not able to interact with the subsequent execution. Fully interactive systems are those in which this latter capability is also present ; the user can, if he wishes, follow the execution step by step, observe intermediate results, change procedures depending on the feed-back, and restart the execution at the point where he interrupted it.

It might seem, at first sight, that a fully interactive general purpose system would be the best solution for any kind of problem. This is not necessarily true because generality will usually be much more expensive than speciality and the degree of interaction should be tied to the needs and, obviously, to the available budget. In the following three sections on interactive computing at CERN we will cover a general purpose system (GAMMA), a file-handling system (FOCUS) with a network of terminals some of which are available for semi-interactive computing, and two special purpose programs where interactive computing (on an ARGUS at the central computers or using FOCUS) has been a great help.

a) GAMMA (Graphically Aided Mathematical MAchine)

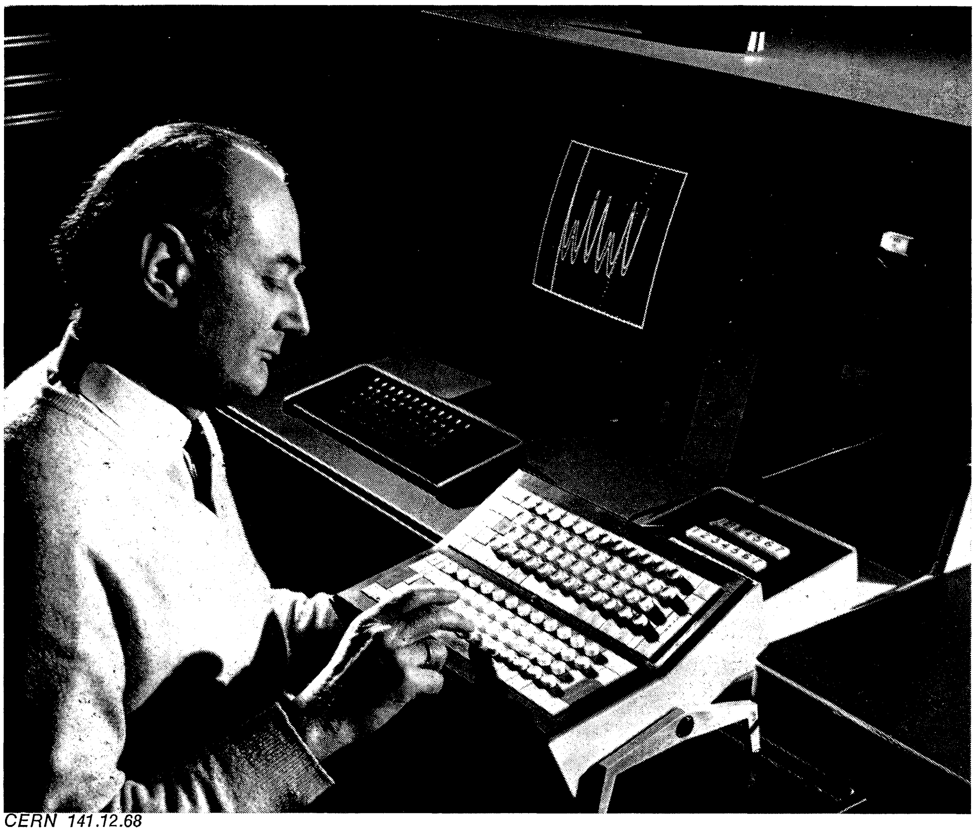
C. E. Vandoni

GAMMA is a fully interactive, general purpose system allowing the user to define, manipulate, and execute his own algorithms on-line in continuous dialogue with the computer. In the field of applied mathematics this kind of interaction is of great interest, in particular for research problems where the user wants to experiment with different formulations and different methods of numerical analysis, and where the feedback of the results determines the algorithms (problems where not only the answer is unknown but also the question and the method of solution are difficult to formulate).

GAMMA was implemented experimentally at CERN in 1968 on a CDC 3100 computer using a CDC 250 display and was moved in 1970 onto the more powerful CDC 3200 computer using a Tektronix T4002 storage tube console as user terminal.

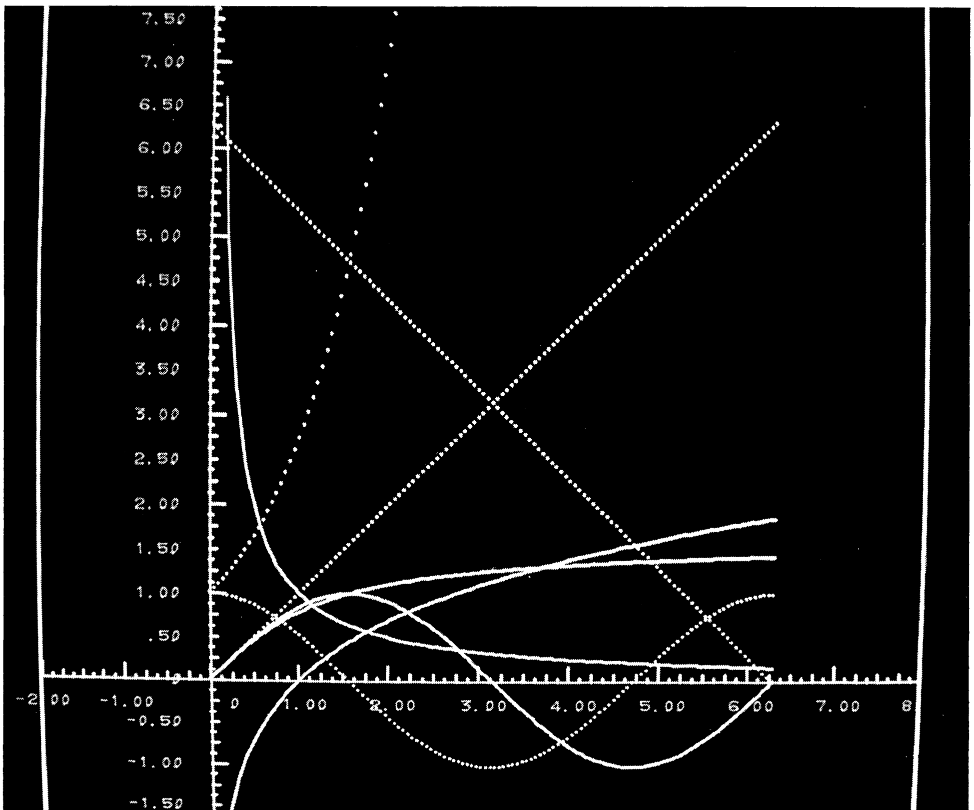
The language of the present system is a mixture of desk calculator language, normal mathematical notation, and the computer's programming language. For instance, it borrows from desk calculators the structure of accumulators, of temporary storage and of operators (which can be called by a single keypush on a specialized keyboard). On the other hand, as with normal programming languages, the user is able to define his own set of programs and to call for their execution. Basic entities upon which the language is able to operate are not only single variables — as is normal in programming languages such as FORTRAN — but also larger items such as vectors implicitly or explicitly defined. The graphical display is obviously an essential part of the system, allowing the user to display procedures and results (the latter in either graphical or numerical form).

The computer obeys the user's command as soon as it is typed in, without any noticeable delay since



CERN 141.12.68

A physicist using the GAMMA system for interactive computing.



CERN 39.9.68

Some of the basic functions which are directly available on GAMMA computed in the interval from 0 to 2π. The functions are sine, cosine, exponent, log, etc.

the time needed to obey a single command is of the same order of magnitude as the human response time. However, the execution time for user written programs depends on the complexity of the problem that the computer is asked to solve, but the user is always able to control the process.

The abilities of the system are picked out in comments from users : 'The two characteristic features of the GAMMA system, namely that it is intrinsically a calculator of functions and that it offers on-line programming and on-line graphical display of calculated results, make it an attractive tool for numerical exploration of mathematical problems. Depending on the problem, the system rapidly provides either sufficient numerical insight to proceed with a further stage of algebraic work, or sufficient numerical insight to decide on how to program for extensive and/or more accurate computation off-line, or sufficient numerical information to regard the problem as solved.'

The following types of problems have been frequently treated on the GAMMA system :

I) Examination of convergence properties of successive approximation schemes and comparison between different schemes
II) Examination of the shapes of complicated curves and their dependence on parameters
III) Function inversion — elimination of a parameter in a parametric representation, for example, given F(x) and G(x) find F(G)
IV) Search for simple functional approximations to given data or curves
V) Qualitative study of parameter fitting to given data or curves
VI) Selection and detailed preparation of figures for scientific reports and publications.

Such problems were studied in both real and complex variables. The complex calculus implemented on GAMMA and the corresponding displays in the complex plane have proved very useful. Another important asset is the on-line production of hard copy of the display.

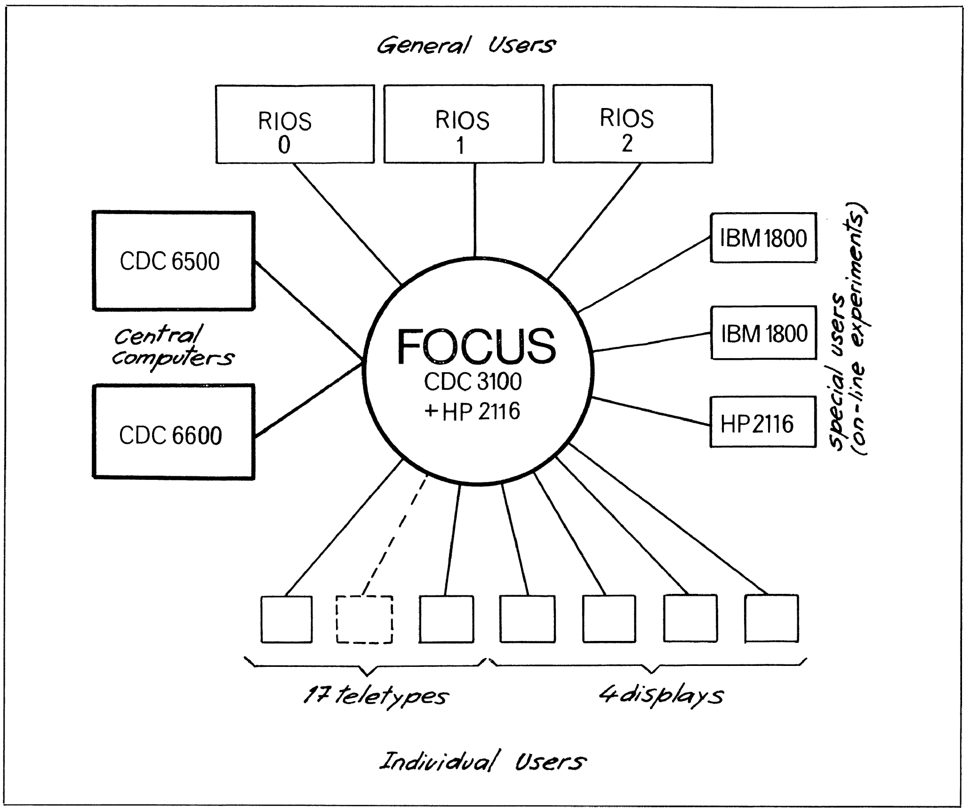
The GAMMA system has been used regularly over the past three years for an average of about twelve hours a week which has yielded considerable experience with this kind of interactive system. This was very helpful in designing an improved version which is now being implemented on the CDC 6000 computers at CERN. The language adopted has gone back to the algebraic formulation of normal programming languages, while many other basic features of GAMMA have been retained and extended. The new system will be operational on a small scale in a few months' time and the present GAMMA system on the CDC 3200 computer will then close down.

b) The FOCUS system

H. Grote

FOCUS is, basically, a complex file-handling system which was developed at CERN during the years 1967 to 1971. It does the file-handling job for users of the central computers and its tentacles reach out to all corners of the CERN site so that many users, for a variety of purposes, can be linked to the central computers.

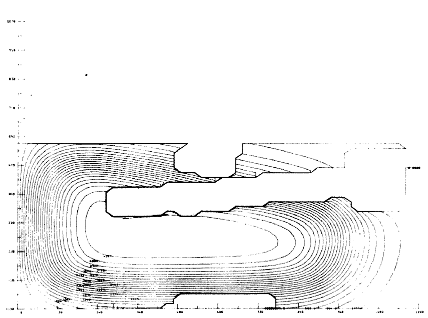
The heart of the system is a medium size computer, a CDC 3100, aided by a Hewlett Packard 2116 which serves to concentrate the incoming and outgoing communications. The 3100 is linked to various other computers and terminals and it is from them that it receives data files and to which it sends data files. These input and output files contain different types of data, depending on the terminal. Thus FOCUS receives files from on-line experiments, from remote input/output stations or RIOS and, last but not least, from seventeen teletypes and four Tektronix 4002 displays that are



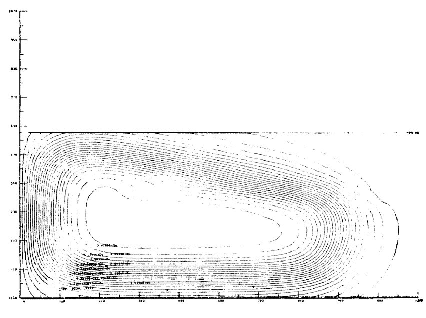
Below left : Representation of the FOCUS system illustrating the various links and terminals through which data can flow in both directions.

1., 2. Two display pictures taken during 'semi-interactive' use of FOCUS. The one on the left, is a field plot taken in the fifth-scale model of the Split Field Magnet with blank areas where obstructions prevented the field being measured. Successive 'fits' eventually yielded the plot on the right.

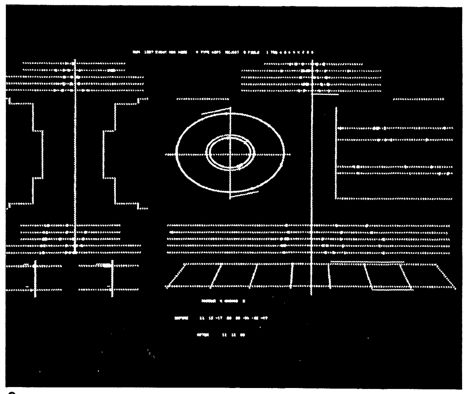
3. Another example where the detection system of an electronics experiment is represented in the display picture. The signals that had occurred were also recorded on the screen and the operator could then help in the processing of the event.



1.



2.



3.

available to individual users. In the opposite direction, of course, it receives program output from the central computers — the CDC 6600 and 6500.

FOCUS assembles files into jobs ready for execution by the 6600 and 6500 and then passes them for processing to the big computers. The output is sent back to the RIOS or terminals where it can be printed out or projected on the displays. For a RIOS user there is almost no sign that FOCUS is at work. He reads his deck of cards into a small computer (for example, the IBM 1130 in the ISR building) and his output is printed out at the same station. Behind the scenes the IBM 1130 has passed the problem to the CDC 3100 (via the HP 2116) which has prepared it for the CDC 6600 and the results have travelled back through the same channels.

If we consider an individual FOCUS user sitting in front of a teletype or display screen the sequence of events would be as follows : The user first tells the system, via a special command, that he is there and wishes to make use of its services. After a few minutes the system will reply that all his files have now been read off tape and copied onto disk. This procedure is necessary because of the very limited disk space available — there is only sufficient for the files of about twenty users simultaneously and not for the files of all the inscribed users of FOCUS (now numbering about 200).

Once the user has his files available on disk (the files typically consist of several card images of FORTRAN programs, data card files, binary program files, and binary display files), he can change them, delete or copy them, send them to other users, assemble them into jobs and send them to the CDC 6500 or 6600 for execution, print them at any of the RIOS, or display them on his teletype. All this is made possible by the file handling programs resident on the CDC 3100 disk. If the user has been lucky enough to get hold of one of the Tektronix 4002 displays, he can, in addition, display pictures which have to be generated in the central computers using the GD3 plotting package.

Let us now take a look at two specific examples of 'semi-interactive' use of FOCUS in which the graphical display of results has been essential (of course, there are numerous others). The first example concerns the magnetic field plot of the ISR Split Field Magnet. The two Figures above show the contour plot of the main field component in one half of the magnet. The first Figure has areas free of field contour lines where, in the fifth-scale model of the magnet, the field could not be measured due to physical obstacles such as pillars and water supply tubes, shims, and compensators. The aim of the semi-interactive computing exercise was to fill in these areas with values of the field as it might look inside the obstacles if they were all made of non-magnetic material.

The simulation programs tracking particles through the fields were told to follow a particle into an unplotted region. Thus fairly reasonable field values in the empty parts, (values good enough to allow a rather precise tracking in these regions) were invented. This was done by interpolation between the existing values in an interactive way : in some twenty runs, using different numbers of points and different degrees of polynomials, this converged, via too low order fits and too high order fits, towards an adequate result (Figure 2) as judged from the smoothness of the curves.

The second example is illustrated in Figure 3. For an experiment of the CERN-Orsay-Vienna collaboration, it was necessary to study rejected events from a detection system consisting of cylindrical and plane wire chambers. The rather complicated layout of the detectors was displayed together with the signals that had occurred, and the information on the tracks which had been found. In a semi-interactive procedure certain parameters were varied in the track association program and the same events were reprocessed several times with only short delays.

c) Interactive design of beams and optics

R. Miller

As further examples of interactive computing there are two special purpose programs being developed at CERN. The first (known as BETON, BEam Transport ON-line) is for the design of beam transport systems which is, by now, a well established application. The second is for the design of the optical system for Cherenkov counters which is a new application.

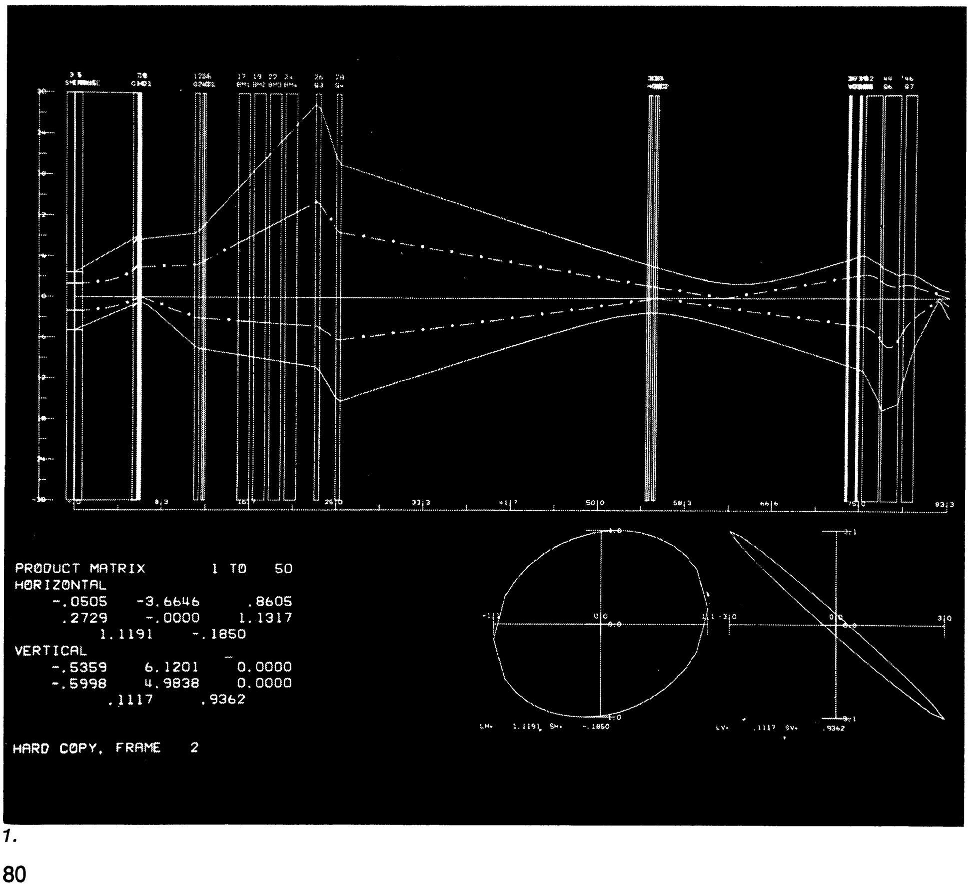
The BETON program is written in FORTRAN and runs on the CDC 6000 computers using a Ferranti ARGUS computer and display for the interactive processes. The user presents data for a beam transport system (either on punched cards or by typing it in at the display keyboard) which describes the beam-line components — field free regions, quadrupole magnets and bending magnets — and which also feeds in the characteristics of the beam as it enters the beam transport system. With BETON the user then proceeds to modify the parameters of the beam-line components so that he can take the beam through the system and have it emerge with desired characteristics.

Once the input data has been read and verified by the user, a graphical representation of the transport system is displayed on the screen. It is possible to obtain a graphical trace of individual rays through any part of the system by typing in the parameters of the incoming particle and by specifying the region of the beam-line to be investigated. The envelope of the beam through the system can be traced and a plot of the phase space ellipse at any point can be obtained.

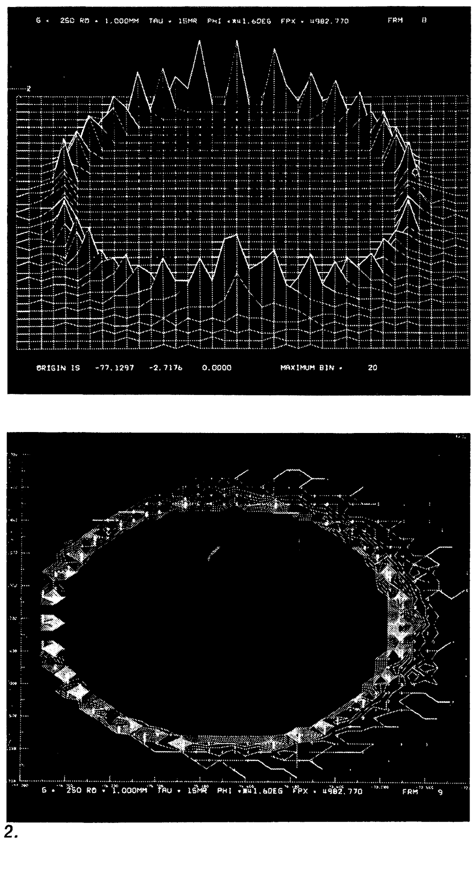
There are two types of facility available for modifying the characteristics of the transport system. On the one hand there are automatic matching facilities, available in traditional off-line programs, for phase-space ellipse matching and trajectory matching. On the other hand there are a series of options for manual editing of the data by the user. These make it possible to alter the data, change the parameters of some components, delete components from the system, and introduce new components. When the editing or matching is completed, the user can immediately see the effect on the properties of the transport system by using the ray tracing facilities.

The user automatically obtains a record of his actions on the line printer and, in addition, he can obtain a hard copy of the information on the display screen either on a plotter or on microfilm. At the end of a session at the display, he can save the data concerning the state to which he has manoeuvred the beam transport system and can feed it in again when he re-uses the program.

The great advantage of interactive



1.



2.

1. A display of information obtained using the BETON interactive program for the design of beam transport systems. Each vertical block is a beam-line component whose position along the beam-line is indicated along the x-axis. The parameters of these components can be changed in an interactive manner.
The lines drawn through the system represent the beam envelope (solid line) and a ray trace (dotted line). Below are the product matrix and phase space ellipses.
2. Examples of output from the interactive program on Cherenkov counter optics. The picture top right is a perspective view of a three-dimensional surface ; below is a contour plot of the same surface.

computing of this type is that the designer can interrupt at certain stages of the process and, from the graphical display, can decide whether to continue or to modify the convergence conditions demanded. This greatly speeds the design and can result in more sophisticated design. With a little experience the work of five or six runs using a conventional off-line batch process program can be performed in an hour at the display.

BETON is still being developed and a number of additional facilities are in preparation. The program has already been applied in the design of the fast ejected proton beam-line used in the neutrino experiments, for the p10 and m12 beam-lines, and in a study of an improved ejected proton beam-line for the next series of neutrino experiments. It was also used in modifying the parameters of the 70 GeV fast ejected beam at Serpukhov, taking into account the final installation details. The results of this work were transmitted to the Soviet Union only hours before they were successfully used for the first beam ejection at the beginning of February. Secondary beams for Gargamelle, with and without r.f. separation, are also being studied using the BETON interactive program.

A second interactive program with graphical output is at present under development for studying the optical system of a Cherenkov counter. The Cherenkov light emitted by different particles along their trajectory in the counter is simulated for different values of velocity, and for different directions and distances of emission of the particle from the optical axis.

The data for display consists of the point of intersection of a ray with the focal plane for about one thousand different rays from each particle. The points are transformed into a density function by summing the number of rays falling within a certain area, thus producing a function which is then output in the form of a perspective view of a three-dimensional surface.

At present the program is being run in a semi-interactive mode through the FOCUS system with output to a T4002 display and hard copy on microfilm. When more experience of the problems involved has been gained, it is planned to provide an interactive version of the program using the ARGUS display.

Mathematical computing

Several times in the above articles we have run into the use of computers for 'numerical mathematics'. The following two articles cover some typical uses by theoreticians and by accelerator designers.

a) In theoretical studies

B. Lautrup

Theoretical physicists mostly use the computer facilities for numerical evaluation of theories in order to compare theory with experiment (or theory with theory). Usually this only puts moderate demands on the computer and its software. Most programs require only a library of special functions and virtually never use tapes or other 'complicated' peripheral equipment. They are reasonably satisfied with a card reader, for input and a line printer for output. About 80 % of the computing 'jobs' from the CERN Theory Division are of this scale. They would in fact be even better off in an interactive environment with an 'advanced desk calculator'. The GAMMA system described above is, among other things, a sophisticated attempt to cater for these needs.

Some theorists use computers on a grander scale. Numerical integration in many dimensions, phase shift analysis and multiparameter fits to phenomenological models lead to large central processor time consumption and require fast computers. This kind of computation is analogous to the last stage in the analysis of experimental results.

A more exotic use of the computer by theorists is in the field of algebraic manipulations. A theoretical expression may not immediately submit to numerical evaluation but require a certain amount of algebraic simplification before numbers can be extracted. This is for instance the case in the evaluation of Feynman graphs in quantum electrodynamics and related fields. A Feynman graph leads to multi-dimensional integrals, over infinite regions, of complicated products of matrices, vectors and spinors. Not only is the integration region infinite but the integrand has singularities within this region. This prevents a direct numerical attack on the integral and other methods are needed.

First of all the problem is to transform the integration region into a finite domain. This is done in a series of well-defined steps reducing the integral to a standard form. In this process matrices and tensors are multiplied out, new integration variables introduced, vectors multiplied with each other to yield physical scalar quantities, the old integration variables integrated out, etc.

Although this is quite simple to do by hand for uncomplicated graphs, it becomes extremely cumbersome for higher order graphs. The number of terms is so large that it is beyond the ability of the human mind to handle them. As the operations performed on each term are almost identical, the problem is mostly of a book-keeping nature. This is an ideal task for the computer since it is able to do the same operation over and over again without tiring, or making errors.

At CERN a large-scale algebraic manipulation program (SCHOONSCHIP) capable of carrying out the reduction described above is available. It was written by a single person, M. Veltman from Utrecht, in the middle of the 1960's and has been continually expanded and modified since then. The program accepts input in the form of an expression containing gamma-matrices, vectors, scalars and even spinors. It allows for expansion, trace calculation, collection of identical terms, a variety of substitutions, limited factorisation, asymptotic expansion, etc. It has even been possible to perform several-dimensional analytic integration using the substitution facilities.

Another program capable of carrying out the same kind of calculations will eventually become available at CERN. This is the language oriented program REDUCE written by A. Hearn from Salt Lake City. It is more flexible than SCHOONSCHIP but requires much more software. It has been implemented interactively on a PDP-10.

b) In accelerator design

C. Bovet, E. Keil, N. Vogt-Nilsen

The design or modification (optimistically, always called 'improvement') of accelerators, storage rings or sophisticated beam transport systems is, today, unthinkable without the use of computers. The study of particle beam behaviour in relation to the electromagnetic fields it experiences (including the space charge forces generated within the beam itself) is often of a complexity which could not confidently be mastered without extensive computation. We will indicate here the sorts of problems (with a few specific examples) for which accelerator specialists use computers.

There are some 'big' programs, which change little in the course of time and which solve standard problems. Examples are beam optics programs used for the design of beam transport systems, cyclic accelerators and storage rings. The basic arithmetic operations are the same in all three cases — multiplying matrices describing the action of components (drift spaces, quadrupoles and bending magnets) on the particles traversing them. The complicated magnet structures which are now fashionable in large synchrotrons and storage rings, with matched insertions, low beta-sections etc., are a product of the use of computers which have made it comparatively easy to calculate their effect on particle beams.

An example is slow ejection using the resonance technique which has been studied at the CERN proton synchrotron for many years and more recently at the ISR. The magnet ring is represented by linear fields (matrix solution) plus more non-linear lenses. For a given set of field values, which correspond to resonant conditions, all the characteristics of the ejected beam can be predicted by following, in the computation, only a dozen protons from the time they become unstable to the time they are ejected.

Another example at CERN of an extensive computer design study to ensure that good beams could be obtained from an intricate machine configuration was in the improvement programme of the 600 MeV synchrocyclotron. The motions of the protons from capture at the centre, through radio-frequency acceleration and extraction were optimized and the design goals specified. At the design stage, the configuration of the electrodes at the centre was studied by furnishing field data measured in an electrolytic tank to the computer and optimizing their configuration by orbit calculations. Orbit calculations were also used to study the shape of the DEE so that it would not induce unwanted radial oscillations. Similar calculations were done concerning errors in r.f. frequency versus time and r.f. voltage. The extraction system, involving an improved regenerator and a new extraction channel (electromagnetic coil with a current septum followed by an iron channel) was designed in detail using the computer.

There are also magnet programs which calculate the magnetic field in the gap of a magnet with a given steel profile, coil position and magnetic characteristics. These programs have changed magnet design from an art into a science, and have made it possible to design magnets with the field tolerances required for modern accelerators so that they can be built in a reasonable time and at reasonable cost without extensive modelling.

However, the biggest impact of computers on accelerator design comes from the fact that the solution of any problem which can be expressed by a formula, hovewer complicated, can now be readily evaluated on a computer. This has drastically extended the range of problems for which solutions are known, it has reduced the work load on the accelerator physicist because he no longer needs simplified expressions which can be handled on desk computers and, finally, it provides numerical information in nearly unlimited quantity on which to base decisions. This activity (evaluating formulae) actually takes most of the programming time of accelerator specialists, although it subsequently absorbs only a tiny amount of computer time.

On several occasions, complex problems have been solved by the Monte Carlo method, using random numbers generated by the computer, to select values in a multivariate distribution. This was the case when the effect of magnet imperfection or misalignment on the closed orbit was studied, in advance, for the ISR and the PS Booster. Tolerances were thus imposed on the magnet construction and correction devices were developed accordingly.

Other examples are the computation of the effects on a particle beam of multiple scattering when hitting an internal target or septum. It is vital that the ejection efficiency, which can be computed in this way, is known in advance so as to predict the distribution of radiation on components.

Finally there are problems in accelerators which can be solved by simulation. These are typically problems involving space charge effects where every particle is not only subject to external focusing, from guide fields, but also to forces due to all the other particles in the beam (and in the counter-rotating beam in a storage ring). The differential equations describing the motion of individual particles and their individual contributions to the space charge field can be formulated but the solution in closed form cannot. In these cases, the particle motion is simulated on a computer. Used properly, simulation is a powerful tool to stimulate new thinking about beam behaviour under heavy space charge conditions.

Such a simulation was done to study, in advance, the behaviour of multiturn injection into the PS Booster. In this case, only a few hundreds of particles (called macroparticles, because each represents, say, one billion protons !) were tracked together for a dozen revolutions in the machine during which time space charge forces were applied in steps following a numerical solution of Poisson's equation.

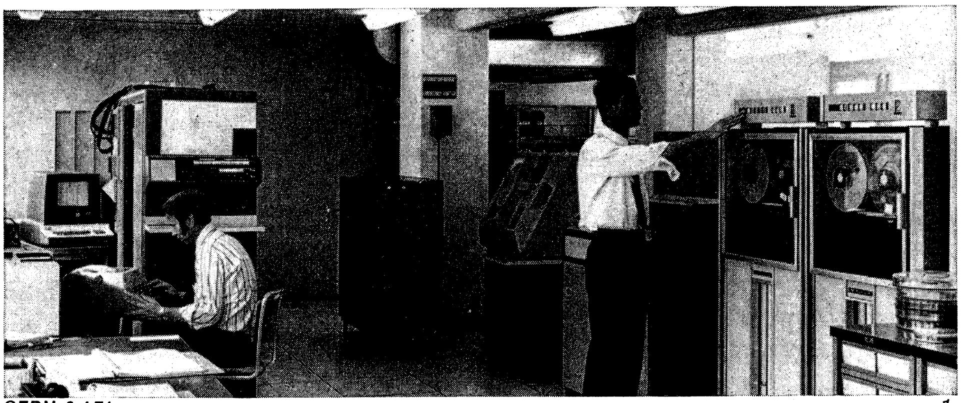
Special applications

a) Omega and SFM computer system

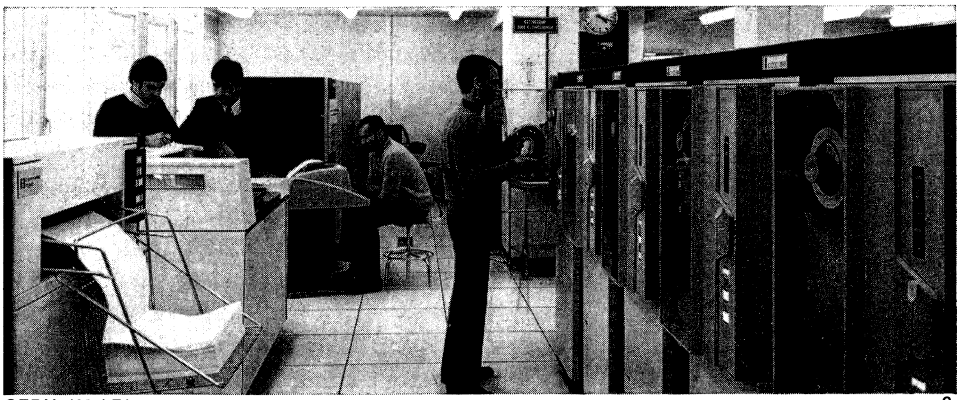
1. *One of the EMR 6130 computers which completed its acceptance tests in 1971 and has already been used on-line in ISR experiments.*

2. *The CII 10070 computer which also completed its acceptance tests in 1971. The first link to an EMR 6130 is now being tested. The full system for Omega and the Split Field Magnet is scheduled to be in operation by the end of this year.*

H. Davies



CERN 9.4.71 1.



CERN 120.1.71 2.

A special computer system is to be used with the Omega and Split Field Magnet projects. It is the most intricate and extensive system ever to be allocated specifically to experiments using electronic detectors and merits description both for itself and as an example of a way of using computers which will probably become more prevalent in high energy physics laboratories in years to come.

First a brief mention of what the Omega and SFM projects are. The Omega spectrometer now being built in the West Hall has a superconducting magnet providing a 1.8 T field over a very large useful volume (14 m^3). Within the volume various systems of electronic detectors can be set up (initially an array of optical spark chambers viewed by Plumbicon cameras will be installed). Many experiments can use the spectrometer simultaneously and data taking rates can be very high. The SFM is to be built at Intersection 4 of the ISR. Its 'split' field will affect secondary particles produced in collisions between protons at the intersection, so that their properties can be measured, while not, overall, disturbing the stored proton beams which are orbiting the two rings. Multiwire proportional chambers will be installed in the magnet aperture and, again, several experiments can use the same detectors and data taking rates can be very high.

Some of the features of these projects which have influenced the design of their computer system are :
— They are 'universal' detectors similar to bubble chambers. This means that they are fixed in position and can accommodate a wide variety of experiments with comparatively little modification. They can be used for many experiments at the same time. They can result in floods of data. They represent high capital investment and should be used to the maximum possible. Data, to a higher extent than before in electronic experiments, will be taken back to research centres in the Member States for analysis (as with bubble chamber film). The following description of the computer system indicates how these features have been catered for.

The heart of the computer system is a CII 10070 computer (a French-built Sigma 7) which has 80 K words of 32-bit memory and 4.5 M words of disk storage and which is provided with a multi-programming operating system. Later this year, it will also be equipped with five 1600 bpi tape units, replacing lower performance units which are connected at present.

The next largest machines in the system are two EMR 6130 computers, one used by Omega and one by SFM. They have almost identical configurations which include 24 K words of 16-bit memory, a 1 M work disk and high speed input/output channels. System software includes a simple but efficient operating system, with full FORTRAN IV capability and an overlay loader. Three small PDP-11 computers (8 K words of 16-bit memory, paper tape equipment) are used by the Omega project and a fourth PDP-11 is used for the control of two Tektronix T4002A display terminals equipped with tracker balls for interactive work.

All the small computers in the system will be connected to the CII 10070 via CERN-built data links. Data transmission is in serial form using Phase Code Modulation and a standardized data format so that, in principle, any computer can be linked to any other one once it has a link controller. Special buffering techniques allow data transfers at different speeds and the transmission rate can go up to 7 Mbits/s depending on the quality of the cable and the distance between the two computers involved.

The principle function of the system is for on-line data acquisition and checking. It will be used both during the development and testing of the experimental hardware (wire chambers, counters, read-out systems and so on) and during the production phase of the experiments when data from large numbers of events has to be read, checked and stored on tape for further processing (either on the CERN central computers or in the home research centres of visiting groups).

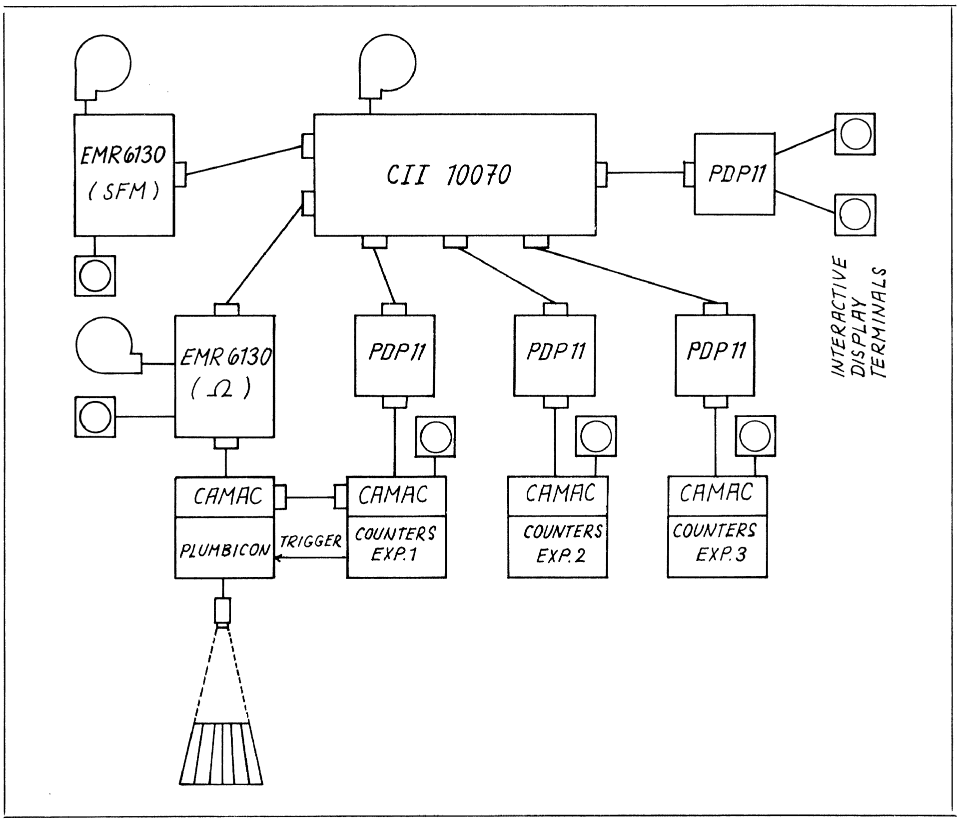
At the SFM, all the experimental equipment is connected directly to its EMR 6130 and a data acquisition program is provided to read data after each trigger, buffer it in the computer memory and then write it onto magnetic tape. The same program allows a sample of the data to be passed to a second program running in the machine which can check that the experimental hardware is functioning correctly and that the quality of the data is good. Samples of data can also be sent along the data link to the CII 10070 for more extensive analysis. Periodically, the results of these calculations can be sent back to the physicists at the EMR 6130 giving fuller information on the progress of the experiment.

At Omega, the system works in the same way but only the Plumbicon camera read-out system and counters common to all experiments (for example, the beam counters) are connected directly to its EMR 6130. Since several groups can be working simultaneously with Omega (for example, two setting-up new experiments and a third actually taking data) each group is being provided with a PDP-11 computer for setting-up and testing individual systems. The PDP-11 being used by the group which is taking data is connected to the EMR 6130 via a one-way link between two CAMAC systems developed in the Nuclear Physics Division. The EMR 6130 then reads the counter data from its CAMAC system almost as though the counters were connected directly. The software and operation of the machine is therefore very similar to that for the SFM.

The Omega groups who are checking their systems can send data along the link from their PDP-11 and thus supplement the limited computing capacity of their on-line machines by making use of the CII 10070. The difficulty of programming very small machines has been overcome by providing a high-level assembler language called PL-11. Later this year, a user sitting at a PDP-11 teletype will be able to modify his program which has been stored on the CII 10070 disk, have it compiled on the 10070 and then load it into his PDP-11. This is a very powerful tool to help in the complex procedures needed in setting up a new experiment and can be used without interfering with an experiment in progress.

A second important function of the system is to provide development facilities for the off-line analysis programs for Omega and SFM experiments. These off-line programs cover a wide variety of applications — simulation of events in Omega, pattern recognition and geometrical reconstruction of Omega events (a system called ROMEO), pattern recognition in three dimensions for SFM events and studies of detector arrangements to optimize event detection in SFM.

Two interactive display terminals are being provided to help the pattern recognition work and for applications such as the correction of errors made in automatic event recognition and analysis. The use of storage tubes makes it possible to provide cheap terminals. To the user, they appear as peripherals of the CII 10070 but



Schematic representation of the computer system for the Omega spectrometer and the ISR Split Field Magnet detectors. Top left is the EMR 6130 which will be used on-line to experiments in the SFM. Below is the EMR 6130 which will be used on-line to the experiment actually taking data in Omega. Other Omega experiments will use PDP-11s for setting up and can call on the large CII 10070 if necessary. The CII 10070 will also be used for final processing.

in fact a PDP-11 intervenes to control them making it easier to connect two terminals simultaneously (the number can be increased later) and to provide fast response to user actions such as indications of position on the display screen using a tracker ball. The graphics display system GD-3, already used on the CERN central computers, has also been made available on the CII 10070. The two EMR 6130 computers are equipped with T4002 terminals and each on-line PDP-11 has a Tektronix 611 storage tube connected through its CAMAC system. Extensive use is thus made of display techniques and care has been taken to ensure maximum compatibility in the programming of the various machines so that data generated on one can emerge in more or less the same form on any of the others.

The system is now at an advanced stage of implementation. Each component computer is working and the first versions of the off-line programs are being used. The SFM EMR 6130 has been in action for two experiments at intersection I-4 of the ISR. The first link between the CII 10070 and an EMR 6130 is tested ; the first link between the CII 10070 and the display PDP-11 will be ready shortly and the display system will then be made available. When these two links are completely debugged, the remaining links will be added one by one.

All the basic facilities will be available by the time the first Omega data is produced in June of this year and, by the time the two large projects are completed in January 1973, a complete array of hardware and software systems will be ready to help in carrying out a new generation of electronic experiments.

b) ERASME computer system

D. Lord

ERASME is a system designed particularly for the scanning and measurement of film to be taken with the large hydrogen bubble chamber, BEBC, which will be operated this year at CERN. As mentioned earlier in this issue, it carries the philosophy of operator intervention, in both the scanning and the measurement stages, further than many other systems and, in this, is probably typical of the new generation of this type of device.

The operators of ERASME units will be able to search for particle events (scan the film) using optical projection facilities and then to request the measurement of these events by means of precision CRT digitizers incorporated in the units. Each unit will also contain displays whereby the operator can correct or aid the measuring process and the subsequent analysis of the resultant data.

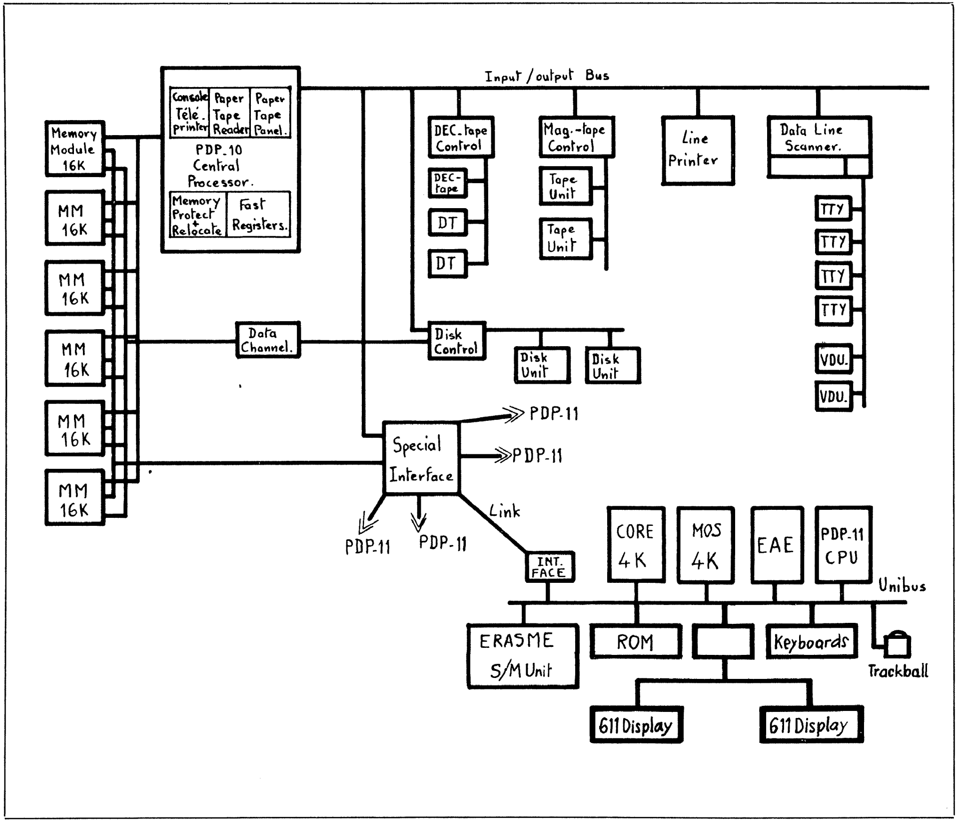
Many of the experiments that will be carried out in BEBC will be 'high statistics' experiments (involving several hundred thousand events) and will be studying types of event that occur frequently (once or more per expansion of the chamber). This has been one of the major factors influencing the design of the ERASME system. Another has been the need for flexibility, since ERASME can be in use processing film from more than one experiment at a time. It is therefore desirable to be able to operate units in more or less automatic modes and also to be able to mix production work and development of the system freely. These considerations have lead to a system in which many of the processes (scanning and measurement), which in other systems are carried out on separate pieces of equipment, are combined into a series of operations on a single machine. It has also lead to a system in which the measurements of each event will be subjected to a rigorous three dimensional geometric test before they are allowed through to the output.

It is obvious that, with these additional tasks to perform, ERASME has need of a computer system more extensive and versatile than other devices of this kind. Besides the Scanning and Measuring Units (S/M units), ERASME has an impressive complex of computers. The focal point of this complex is a PDP-10 computer with 96 K words of 36-bit core store and 10 M words of disk store ; it is furnished with a powerful operating system that provides time-sharing, multi-programming, batch processing and real-time facilities. Each S/M unit is equipped with its own PDP-11 computer. Each PDP-11 has an Extended Arithmetic Element, 8 K words of 16-bit memory (eventually to be made up of core store and MOS-memory modules) and a 256 word Read-only-Memory (built at CERN).

Each PDP-11 is linked to the PDP-10 in two ways - by a slow serial link, that allows free communication between the operator of an S/M unit and the PDP-10 operating system, compilers and utility programs, and by a fast parallel link. This parallel link has several unusual features that essentially allow a zone to be defined for each PDP-11 in the PDP-10 core store. These zones then serve as extensions of the PDP-11 memories — in other words, each PDP-11 central processor can directly execute programs or access operands in these zones. As the zones can be located more or less anywhere in the PDP-10 memory by merely changing the contents of relocation registers, this parallel interface allows considerable extension of the memory available to each PDP-11 without the use of overlaying techniques. The parallel link also provides the means whereby the PDP-10 and a PDP-11 can interrupt one another and test status.

The computers in the ERASME

Schematic representation of the ERASME computer system. At the special interface (indicated at the centre of the diagram) the PDP-11s, each associated with a scanning and measuring unit, are brought in. In the bottom right-hand corner is indicated an S/M unit, its computer and controls.



system have many roles - control of the measuring operation; pattern recognition, filtering and correction of data; geometric tests; calibration calculations; services.

Measuring, pattern recognition and filtering are essentially operations that are carried out together and the main parts of these programs run in the PDP-10. During, for example, the measurement of a track, the measurement program will send a command to the appropriate PDP-11 for measurements to be made in a small area of the picture (typically 0.5 x 1 mm^2); the PDP-11 in its turn will translate this command into a set of control words that instruct the 'Scan Control' and 'Digitizing' logic of the S/M unit to sweep the CRT spot over this area and to generate position measurements every time it encounters an 'object' in this area. These measurements are then transmitted directly into the memory of the PDP-11 where a preliminary filtering operation, that of histogramming them with respect to an edge of the area, is carried out. The results are then returned to the PDP-10 where the filtering operation is completed and the control program decides which area should be examined next.

Other operations carried out by the measurement, pattern recognition, and filter programs in the PDP-10, with the same kind of collaboration with the PDP-11 during the measurement of an event, are — read-out of coded data from the Data Box; fiducial location and measurement; vertex location; track selection at a vertex. During these processes the operator, who can follow what is happening on display screens, can intervene to correct or aid as required.

Once the measurement of an event has been completed and corrected for the distortions in the CRT measuring system, and as an S/M unit permits all of the views of an event to be measured one after another, the event data can be processed in the PDP-10 by part or all of the geometric reconstruction program, LBCG, that has been developed for the new generation of large bubble chambers. This program, written in the form of highly modular HYDRA processors, described earlier in this issue, can perform all the necessary tests for on-line detection of faults in event data, even to the extent of doing rough kinematic tests. If the reconstruction of tracks in an event fails, the operator is called on to supply subsidiary information, to correct the data or to initiate a re-measurement of all or part of the event. The data of satisfactorily reconstructed events is written into a disk file for subsequent 'spooling' to magnetic tape or transmission over a data link to the central computers, where the kinematical and statistical analyses are carried out.

As the CRT measuring systems can experience drifts and distortions they have to be calibrated from time to time by measuring a standard grid, under the control of programs in the PDP-10. The programs do fits to the completed measurements and compute the necessary coefficients to be applied to the measurements of the bubble chamber film to correct them.

The services controlled by each PDP-11 are — overall servo-control of the various moving stages and the film transport of the S/M unit; read-out of the positions of these stages and the operator interface. The operator interface is envisaged at present as consisting of — two Storage Tube Displays (type 611) on which the PDP-11 can write displays of digitizings from its S/M unit or the contents of display files received from the PDP-10; a track ball by which the operator can indicate desired displacements of either the cursor in the Storage Displays or of stages to move the projected optical image; a functional keyboard, for the selection of alternative program action, and an alpha-numeric keyboard. As the stage motions are digitized the operator can, by using the track ball, align some feature of the optical image with a reference mark. The stage coordinates then give an indication of that feature, allowing the operator to 'point' to it in a way that is analogous to what can be done in the Storage Displays with the cursor.

To achieve the desired flexibility, each S/M unit with its PDP-11 should be able to use the facilities of the PDP-10 independently. This will be accomplished by a combination of the HYDRA system and standard features of the PDP-10 monitor system, which will enable a number of separate, but interdependent, time-sharing tasks to run together in the PDP-10. These tasks can be swapped on and off the disks as required.

One of the main services to be

provided by the PDP-10 is that of aiding program development. To this end the PDP-10 is equipped with a communications multiplexor and six terminals (teletypes and CRTs). From these terminals programmers can enter and edit program texts, control compiling loading and execution, manipulate files and do on-line debugging. In fact the PDP-10 has no card reader, program source files being kept on disk or magnetic tape.

The PDP-10 was installed at CERN last summer and is now linked to the PDP-11's of the first two S/M units. The construction of the first S/M unit is almost complete and test runs on small samples of events are expected to start in April or May of this year. The construction of the second and third units has started and they are scheduled to be completed by the beginning of 1973 ready to receive film from BEBC.

c) Computer control of accelerators

J.M.B. Madsen, R. Keyser, J.T. Hyman

Not many years ago there was still debate as to whether the use of computers in the control of accelerators was desirable. Now there is no doubt about the important role that computers can play in the operation of accelerators and the debate is only about the extent and the mechanisms of computer control. All new machines are built with computers as an integral part of their design. All old machine are struggling to adapt themselves to the maximum to computers which have been grafted on. We cover here the use of control computers at CERN in the operation of the 28 GeV proton synchrotron, the Intersecting Storage Rings and the coming proton synchrotron of several hundred GeV energy at Laboratory II.

At the PS

The control of the PS is a mixture of a purely manual system and a computer system. This has come about because computer control was unheard of in the days when the PS was built and it was only in 1967 that an IBM 1800 was introduced. (Recently constructed equipment, however, such as for the PS Booster, is computer compatible and all their controls are handled through the computer.)

Adapting the already existing data acquisition and remote controls to the computer required a general rebuilding of the hardware which has been a costly and time consuming business. A range of standard interface equipment and a computer-driven digital addressing and data transmission system (called STAR) were built to help these transformations. So far, most progress has been in the data acquisition field.

The computer control system is based on an IBM 1800 whose major features are given in the table. During PS operation it is connected to the process all the time. As there are other tasks (such as developing and testing of new programs) besides the execution of process jobs, some restrictions are imposed on the way the computer can be used. For example, a specific real-time job (the generation of 48 time-varying analogue voltages) was diverted to a small computer, a VARIAN 620/i, which is connected to the IBM 1800. Also, the number of routine tasks performed per cycle has been kept low. The central computer is able to perform its multiple tasks using the software system provided by IBM, the Multiprogramming Operating Executive Systems (MPX). With the MPX, there is a permanent 4 K space in the IBM memory for application programs for each of the Linac, the Booster and the PS, and there is an 8 K variable core at general disposition.

Two small computers (SIEMENS 301) are assigned to the power supplies of beam transport elements in the

Characteristics of the PS control computers

IBM 1800	Core Storage	40 K	16 + 2 bits	2.25 μs
	Data Channels	7		
	Digital Output	8	16 bits	500 K words/s
	Digital Input	8	16 bits	100 K words/s
	Process Interrupts	3	16 bits	10 μs
	Disk Unit	3	512 K words	36 K words/s
	Line Printer	1		150 lines/m
	Card Reader/Punch	1		300 cards/m
				80 columns/s
	Printers	4		15 ch/s
VARIAN 620/i	Core Storage	4 K	16 bits	1.8 μs
		1	16 bits	202 K words/s
	Digital Input	1	16 bits	202 K words/s
	Process Interrupt	56		1 μs
	Teletype	1		ASR-33

experimental areas - one of them takes care of the data logging of the elements in the East Area, while the other will later this year form the central part of a power supply control system for the West Area.

Applications of the IBM 1800 are :

I. Complex measurements which may include control functions (beam emittances, energy spread of Linac beam, closed orbits etc...
II. Data acquisition, handling and display
III. Watchdog functions (implemented on a few systems such as the slow ejection)
IV. Book-keeping
V. Optimizations (not used on-line, but good experimental results have been obtained on PS injection).

Great importance is attached to operator-computer communication and multiple control and observation points are provided in the Main Control Room (MCR). There are three alpha-numerical displays with vector mode and keyboards (the system operates via the IMLAC PDS1 4 K mini-computers linked to the IBM 1800) ; three midi-consoles (used for the Booster) to select parameters via push-buttons and to set and record these parameters (the consoles are directly linked to the IBM 1800) ; thirty Nixie displays served by the IBM 1800 each having a ten parameter selection panel.

The operator can call standard programs via a push-button panel and can specify options via a conversation carried out on the PDS1 displays. To enlarge the interaction possibilities an interpretive language is being built up which is already in use for elementary control operations.

Maximum benefit from computer control of a system comes when computerization has been applied from A to Z. This is the case with the Booster where there are 410 controls and 760 data acquisitions. However to complete the computerization of the Linac and PS would drown the IBM 1800 and other solutions need to be found. An expansion based on the introduction of more mini-computers for specific tasks (such as close monitoring of ejection systems, beam measurements and Linac control) is being developed. These mini-computers will become satellites of the central computer. The final control system should automate the setting-up of the machine, ensure close monitoring of performance and high level communication with the operator, and be capable of optimizing certain processes. The operator, ultimately, will remain in command as he has always been.

At the ISR

It was decided early in the ISR project to include a computer in the control system and this meant that 'computerization' was applied throughout in the design of machine components. A Ferranti ARGUS was installed in the ISR Control Room towards the end of 1969. It is a 24 bit machine capable of 300 000 instructions per second and has a disk of 600 000 words and a display system. At present there are 28 K words of core store, card reader, etc. The system is capable of reading over 3000 variables such as magnet currents and positions, and also of setting such variables to prescribed values. Together with these analog values the computer can read some 8000 digital values, such as whether a switch is on or off, and can set such values.

From the start of running-in of the beam transfer system in 1970 the computer proved a very useful tool for the operators and the following description of some of the major applications will illustrate the advantages of computer control. Setting the power supplies in the beam transfer system to predetermined values is a standard procedure before each ISR run - the computer is many times faster than an operator and more reliable. The same is true in the setting up of the power supplies of the magnets in the two rings and here there is an added need that as many as 24 supplies may need to be varied in harmony to ensure a stored beam is not lost.

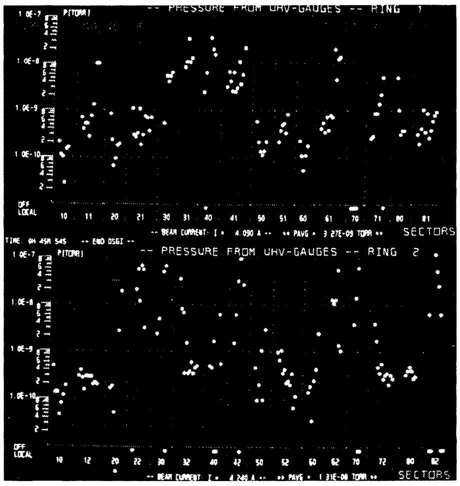
The computer is used to calculate and display the beam orbit and the vacuum pressure around the ring. These sorts of jobs are characterized by large amounts of raw data needing to be processed and converted into values that the operator can quickly absorb. The readings of instruments themselves are drifting, under the influence of temperature and other uncontrollable factors, and they need frequent calibration. The computer stores the calibration constants on its disk for future use.

The computer also periodically checks equipment for mal-functions or breakdowns relieving the operator of a tedious but essential task. This checking is useful not only for signalling faults before they cause trouble but also for informing the operator of the particular reason that could have caused the breakdown.

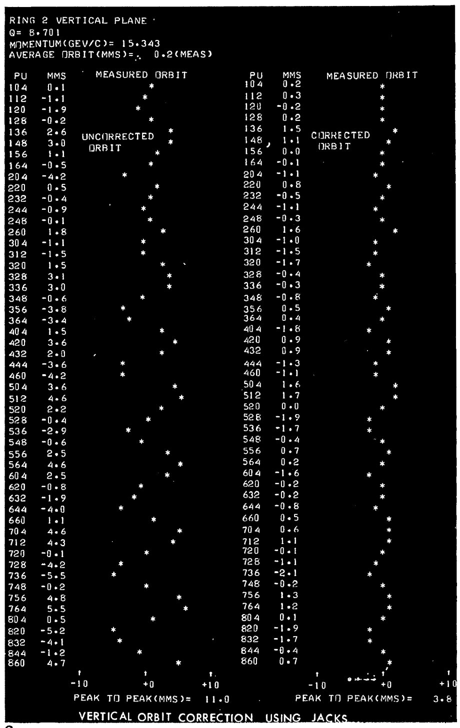
The interface between the instrumentation and the computer can cause problems but they are usually much more easily resolved than the problems involved in the computer-operator interface. At the ISR the operator can communicate with the computer by means of several keyboards or by buttons. Though the computer can reply on one of a number of printers, the display of a graph or picture on the CRT is often much more desirable and convenient. A powerful display system, involving four screens capable of graphic output as well as text, is attached to the ARGUS for this purpose.

The reliability of the ISR computer

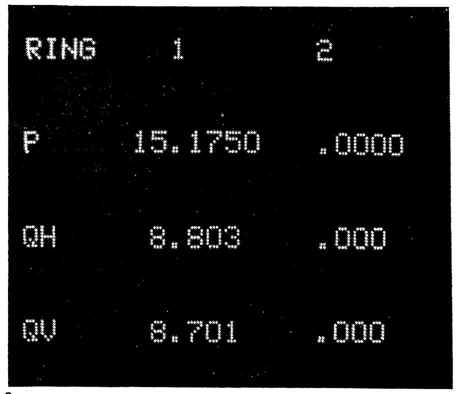
Information emerging on display screens from the ISR control computer.
1. A map of the vacuum pressure collected from gauges distributed around both rings.
2. Closed orbit data from 53 electrostatic pick-up stations in a single ring.
3. Machine parameters related to the magnet settings — the proton momentum (p) and the horizontal and vertical oscillation frequencies (Q_H, Q_V).
4. Magnetic field variation displayed as an index related to the initial field setting.



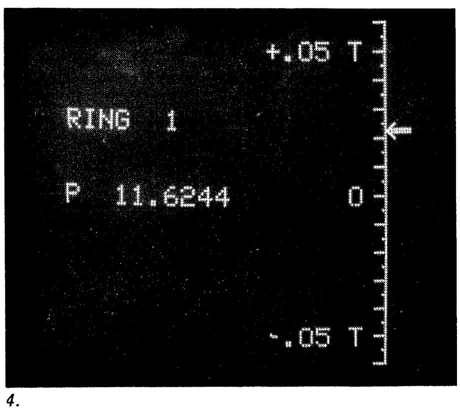
1.



2.



3.



4.

system is extremely high despite the fact that it has no scheduled maintenance. When the ARGUS system was bought, the purchase included a second computer (though with many fewer peripherals). This was mainly to ensure a 'back-up' in case of trouble but it has rarely been called on to perform a back-up task for the on-line machine. It has, however, proved invaluable for the development of equipment and programs while the on-line computer was occupied with its control functions.

Linked to the ARGUS system via a data-link, but in fact autonomous, is a Hewlett Packard 2144A computer which is involved in field measurements of the reference magnet units. It feeds the forecast beam parameters in the two rings, drawn from these measurements, through to the ISR control room.

A full and varied development program of the ARGUS system is under way. Existing facilities such as logging and monitoring will be expanded. The r.f. accelerating system will be brought under computer control. A large effort will be devoted to the exploitation of a data-link network with experimenters' computers around the ring. Data that the ARGUS has in its store, or can obtain, is often required by the experimenters ; on the other hand, to improve machine conditions, the operators may require data that the experimenters' computers can furnish (they being the arbitrator that conditions have improved).

Other data-links are also under consideration : one in particular will connect the two ARGUS computers to a PDP-11 that is on order. The main purpose of this new computer is for the attachment of new peripherals as part of the effort to improve the communication between man and machine. CAMAC is beginning to be used widely in the ISR control system, especially for interfacing equipment with the ARGUS. Due to its generality and computer independence, it has been chosen as the basis for the data-links to experimenters' computers.

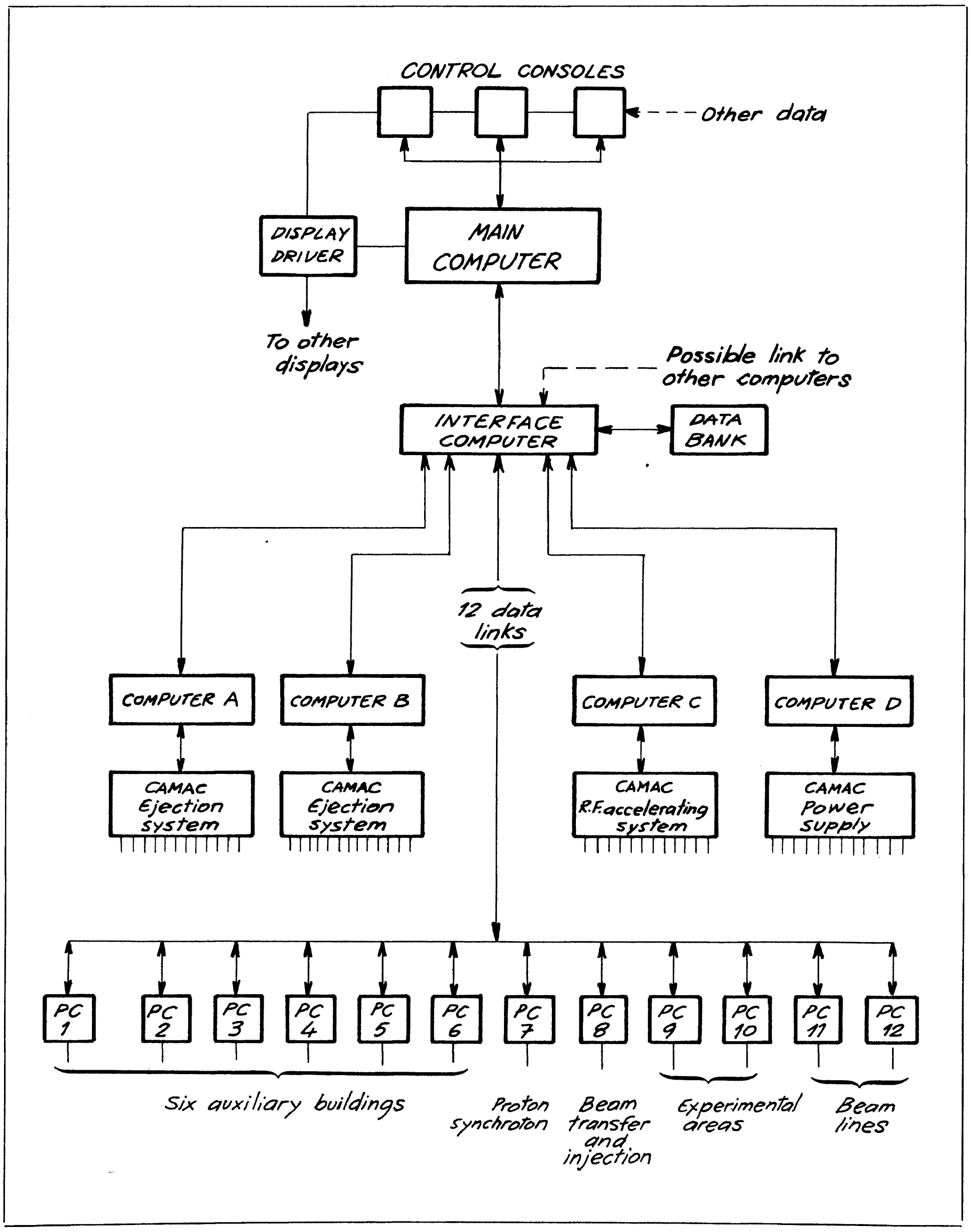
For the SPS

From the start it was clear that a computer based control system would be essential to handle the large amounts of process data and central commands needed in the operation of a machine providing energies of hundreds of GeV. The outline of the computer control philosophy is already clear.

A highly modular system is envisaged for the SPS. At the lowest level, up to twelve process controllers (mini-computers with simple configurations) will collect data and transmit commands to general equipment (for example, vacuum pumps, pressure gauges, etc.) via CAMAC interfaces. Larger computers, probably of the same type as the minis but with more core store, with disk systems and capable of 'stand-alone' operation will be used for the major sub-systems (for example magnet power supplies, r.f. accelerating system, etc.). Information will pass from the mini-computer level to a central computer (or computers) and vice versa, via an interface or message switching computer. This will also control the passage of information to and from a disk-based data bank.

The function of the central computer(s) will be to provide facilities for the control consoles and displays, to break down operator requests into the constituent parts for transmission to the appropriate mini-computers and also to provide computational facilities for complex control functions. In this latter task it may be assisted by a link to a central CERN computer.

In addition to simple on/off and raise/lower commands, complex control functions employing linked



Schematic diagram of the control system envisaged for the SPS. Computers A to D will be small computers with disk-based systems. Process controllers (PCs), numbered 1 to 12, will be mini-computers.

controls will be used. Displays of processed, rather than raw, data give the operator a better understanding of the results of his actions — for example, a single 'orbit bump' control and graphical display are easier to manage than the three constituent magnet controls each with their own current meter.

One of the major problems of applying computer control to a large accelerator is that of software. Particular flexibility is required since the system is never 'finished', in the way that it is for a chemical plant or steel mill, but is always evolving to improve the abilities of the accelerator. For the SPS, the software, as well as the hardware, will be modular and will contain control and monitoring procedures. These will be linked together or called directly either by the operator or by program control. The key to this method will be the use of an 'Interpreter' working directly on high-level source code (probably a specially extended version of the BASIC language). By the adoption of a unified data structure and language syntax at all levels, stand-alone operation of parts of the system will be possible for parallel development and commissioning. A careful choice of the level of interpretation and the use of assembled or compiled code for real-time procedures and functions will enable an adequate speed of response to be achieved.

Many of the ideas, to be incorporated in the SPS control system will be tested in a small computer system being built as part of the magnet measurement programme. This will help in fixing the parameters of the final system.

d) Administrative Data Processing

G. Minder

The use of computers in administrative systems is very widespread, both in scale and in application, ranging from multi-purpose records in large computer networks of government departments to small-scale book-keeping in individual factories. CERN studied the application of a computer to its own administrative needs in 1965-66 and purchased an IBM 360/30 in 1967. It is known as the ADP computer (Administrative Data Processing) and its role can be summarized as to take over administrative tasks so as to absorb the increasing workload in the growing Laboratory without recourse to more staff, and also to provide required information more efficiently and faster.

For those who wish to go over the early days of the ADP in more detail there were articles in CERN COURIER vol. 6, page 157 (concerning the reasons for launching the project) and in vol. 10, page 352 (concerning the completion of ' Phase 1 ' of the project during which the major administrative tasks which can be handled by a computer had been transferred to the available computers). We will concentrate here on the current developments ('Phase II') and on some possibilities for the future.

Phase II aims to achieve a substantially integrated system on the 360/30 in the course of 1972. ' Integrated ' here means that the wide variety of tasks to which the computer can be applied will be as interrelated as possible in their use of the computer. The applications are now linked in the IBM 360/30 into a set which is schematically represented in the diagram. For example, the same records stored in the computer can be drawn on for budgeting purposes, or in forward planning, and they include information relevant to claims (overtime, etc.), insurance scheme calculations and so on. Thus the data that the computer holds with regard to

A schematic representation of how data in the ADP computer are 'integrated'. Information in one category may be accessible for applications in others.

salaries do not exist in an isolated program, responding only to the 'salaries' button, but are available for, and are supplied by, many administrative tasks.

The IBM 360/30 configuration used for the integrated part of the ADP system now consists of a 96 k bytes central processor, an IBM 2314 direct access-storage facility with eight disks (plus one reserve) an IBM 2415 tape unit, a slow printer and a card reader.

In addition, the CDC 6000 series computers are being used for a number of applications which would not benefit much from being integrated into the ADP system. These are mainly: network-based project planning (PERT), health physics and medical files, machine tool and electronic instrument inventories. These administrative tasks can all be handled by the individual services responsible and each stands on its own feet without being inter-related with the data in the ADP system. The CDC 6600 computer is also being used for planning purposes by individual Departments, according to their varying needs. The NCR 390 machine, which has been used mainly for the 'Salaries' application since 1964, is to be phased out.

When the decision was taken at the beginning of last year to establish Laboratory II alongside the existing Laboratory, it was understood that both Laboratories would share, as far as possible, the administrative infrastructure which had already been built up. This obviously included the use of the ADP system and Laboratory II has used ADP programs from the beginning of 1971. The new work load which this represents could therefore be dealt with by the staff already in post. On a smaller scale the same has applied to the collaboration between CERN and the European Southern Observatory. The work on the ESO 3.6 m telescope, which is being designed at CERN, also uses the administrative systems of CERN Laboratory I such as the existing ADP computerized applications for Personnel Records, Accounting, Stores, etc.

In looking to the future, it is certain that the present outputs can be further improved — information for all levels of management can be made faster, more detailed or more aggregated, with better presentation etc. Obviously, a limit is imposed by the cost of implementing improvements and also by the desire not to change codes, forms, etc., too frequently. Upgrading the ADP computer itself is unlikely to come about under foreseeable future budgets but, nevertheless, some improvements are being investigated with a view to implementation possibly over the period 1973-76.

Software: The ADP system could make use of COBOL and DBMS facilities which will be available on the CDC 7600/6000 configuration. At present, most ADP programs are written in COBOL — (ANS) or consist of IBM utilities which are often not appropriate when one wants to retrieve selected data quickly.

Hardware: The ADP system could also make use of terminals in the network planned for scientific computing. An IBM 2260 terminal was tested in 1969 but hardware and software restrictions made it an unattractive solution at that time. An Olivetti DE 523 cassette recorder has been purchased recently and there are various advantages in using this device, which lies somewhere between the card punch and the on-line terminal.

Output: Microfiches could replace hard copies in some cases. Here also, the ADP system could benefit from recent developments if they can be shared with scientific computing effort.

These three possible areas of development indicate how administrative and scientific computing interests, which were quite different when ADP was launched five years ago, have moved closer to each other (mainly because large permanent data banks, which are found in most administrative applications, are now also being used in the physics).

The next five years could see significant progress with the ADP system at relatively low cost. But experience has shown that progress is rarely as fast as one hopes. There has been delay in implementing the applications foreseen for the ADP computer. Nevertheless, the ADP project has been carried out within the figures set in 1967 both for the budget (3.5 million Swiss francs for equipment costs — purchasing, conversion and rental — over the five year period 1967-71) and for staff ceilings (having the ADP system has resulted in some fifty administrative posts less than the number which would otherwise have been required by 1971).

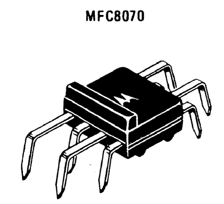
MOTOROLA

Omni Ray
INFORMATION

Le nouveau déclencheur Motorola à tension de zéro est arrivé!

Grâce au MFC 8070, vous vous épargnez de l'argent et des difficultés en éliminant les sources de parasites dans les circuits utilisant des thyristors et des triacs.

- Comme le MFC 8070 déclenche à la transition par le zéro, le SCR ou le triac ne produit aucune perturbation de charge.
- Les SCR et les triacs sont mieux utilisés par l'emploi du MFC 8070. Il est possible d'admettre une plus petite valeur de la raideur di/dt du courant d'enclenchement. Le MFC 8070 est livrable du stock! – Le MFC 8070 est équivalent au GEL 300 FL (PA 424).



Petit boîtier
Case 644A

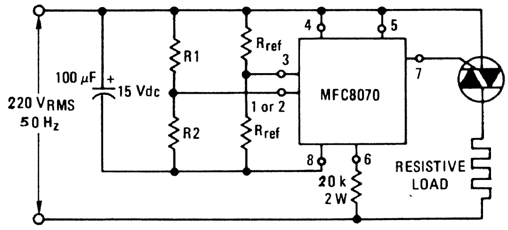
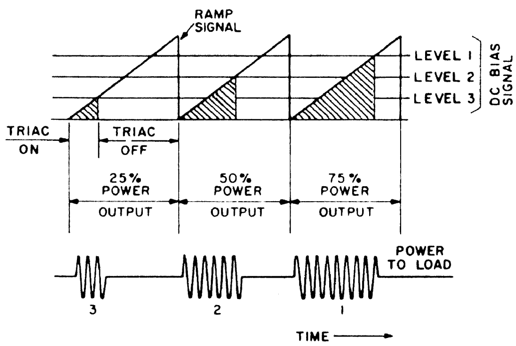
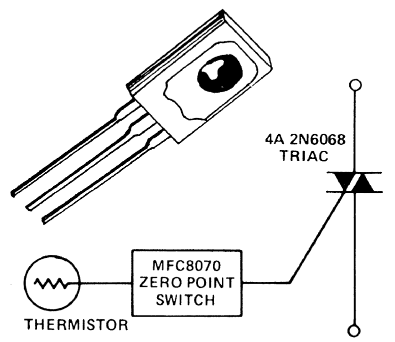


Schéma typique d'une commande à triac

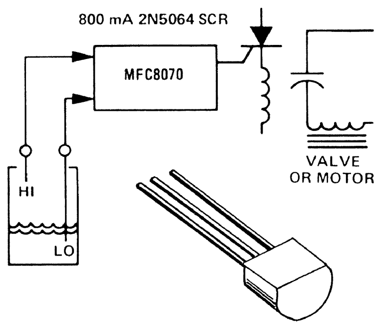


Mode de fonctionnement d'une commande à tension de zéro

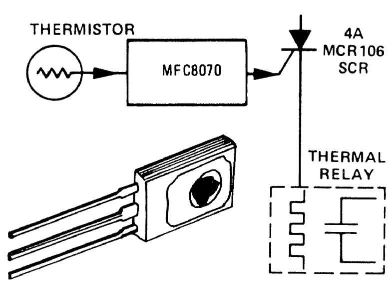
Quelques exemples où le MFC 8070 est particulièrement bien adapté:



Commutateur synchrone de plaque chauffante, de moulin à café, de chauffage électrique, de bouilloir, de toaster, etc.



Contrôle du niveau des liquides dans les machines à laver la vaisselle ou le linge, dans les humidificateurs, etc.



Contrôle de température des séchoirs à cheveux, des fours, des chauffages, etc.

Nous sommes prêts à vous faire parvenir une documentation complète, avec liste de prix, concernant notre grand éventail de thyristors et de triacs, sur simple demande de votre part.

OMNI RAY AG, Dufourstrasse 56, 8008 Zürich Abt. Halbleiter ✆ 01 34 07 66 Telex 57198
Conseils techniques en Suisse romande: tél. 021 25 24 55 télex 25450

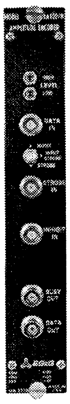
Three new NIM modules: top performance, bottom dollar.

Why *try* to save money at the expense of performance when you *can* save money by getting performance?

EG&G modules generally represent state-of-the-art technical achievement. And their specs are unfailingly truthful. Which is why many laboratories specify EG&G and don't mind paying the extra buck it sometimes takes to get performance instead of specmanship.

Here are three modules that provide the performance you want, and beat other manufacturers' prices, to boot.

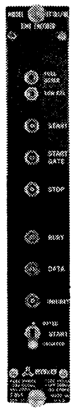
EA100/N AMPLITUDE ENCODER $510



Interfaces to most CAMAC scalers. An economical solution to nuclear ADC requirements.

- Upper and lower level discriminator
- Coincidence or anti-coincidence operation
- Differential linearity typically better than 1%
- Stability better than 0.1 channel/°C
- Noise < 0.2 channel rms
- 2mV resolution (optionally < 1mV)
- Equivalent to 10-bit ADC

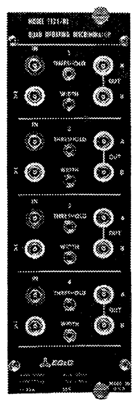
ET101/NL TIME ENCODER $450



Improved encoder incorporated new features not found on previous ET100/N model.

- Dynamic range 20 to > 130nsec
- Gating input for start
- 200psec resolution (optionally < 100psec)
- Differential linearity typically better than 1%
- Stability better than 40psec/°C
- Interfaces to all CAMAC scalers

T121/N QUAD UPDATING DISCRIMINATOR $695 (only $173.75 per channel)



Low cost per channel in applications requiring several discriminators. Front panel threshold adjust from −50 to −300mV.

- Updating timer
- Up to 24 discriminators per bin
- Pulse width continuously adjustable (< 5 to > 600nsec)
- 8nsec pulse-pair resolution

NIM . . . CAMAC . . . EG&G . . .
Three names to keep together in your mind

EG&G NIM modules are designed to work across the interfaces of computer-based NIM-CAMAC systems. We make CAMAC modules and NIM-CAMAC hardware, too.

For data sheets on the products described in this ad, or for an authoritative response to your interest in any phase of computer-based NIM-CAMAC systems, write or call today. EG&G Inc., Nuclear Instrumentation Division, 500 Midland Road, Oak Ridge, Tenn. 37830. (615) 482-4429.

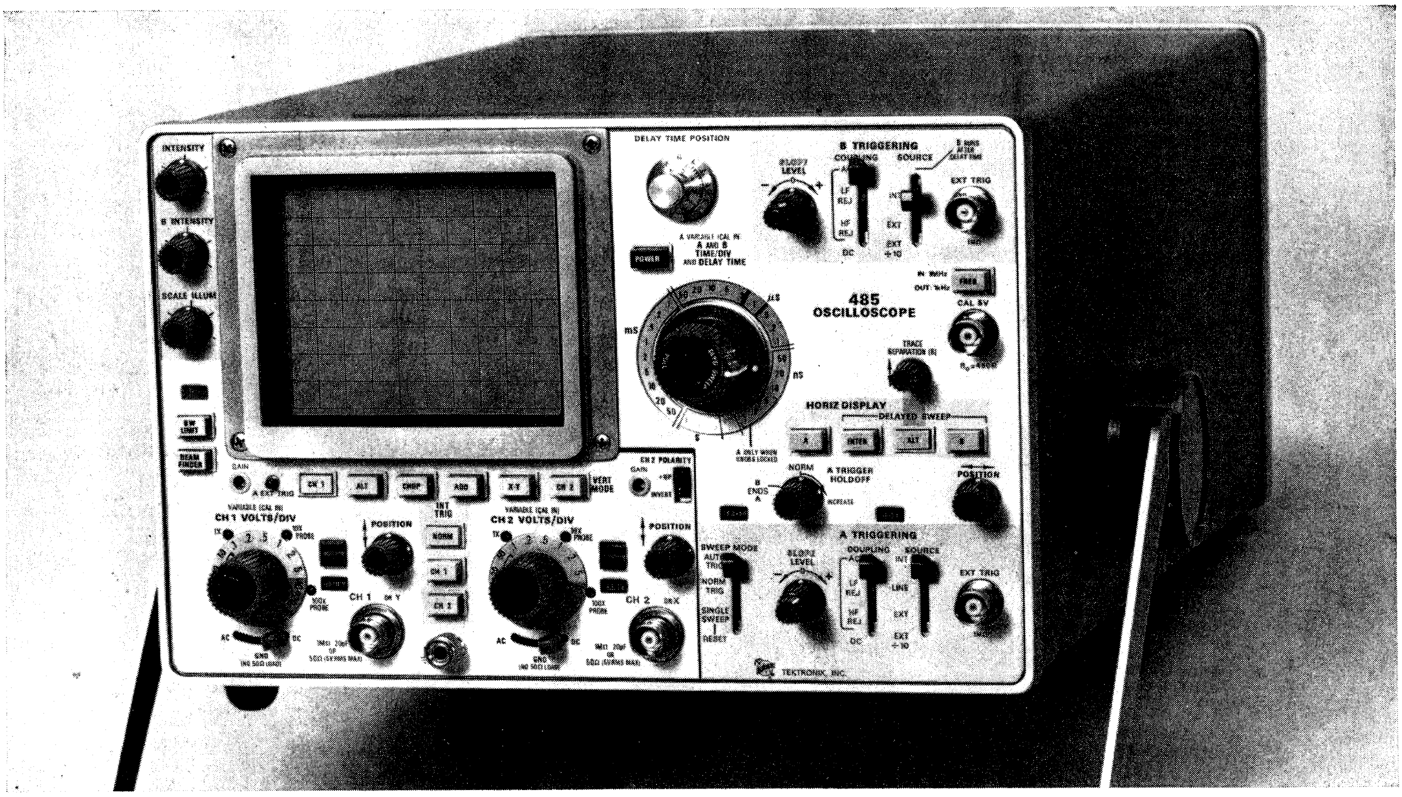
EG&G

NUCLEAR INSTRUMENTATION DIVISION

350 MHz

REAL-TIME

PORTABLE



The NEW 485 is a portable 350-MHz*5mV/Div dual trace oscilloscope with a host of new features like:

- **5mV/Div Sensitivity at full Bandwidth**
- **1ns Sweep Rate. No Magnifier.**
- **Selectable Input Impedances: 50 Ohms and 1 Megohm**
- **Alternate Delayed Sweep**
- **Vertical Scale Factor Readout**
- **External Trigger Display**
- **X - Y Operation (3° phase shift at 5 MHz)**
- **Reduced Weight, only 10 kg**

Price: from Fr. 17 330.— to 18 900.—

We shall be glad to send you complete information. Please call 042/21 91 92

*** at 50 Ohms, 250 MHz at 1 Megohm**

TEKTRONIX®
committed to technical excellence

TEKTRONIX INTERNATIONAL AG
POSTFACH 57 6301 ZUG/SCHWEIZ

FIVES LILLE-CAIL

Groupe Babcock Fives

- Mécanique et chaudronnerie lourdes
- Masses polaires en acier moulé
- Tuyauteries en aciers alliés et inox
- Portes, dalles et bouchons
- Compresseurs d'air et de gaz
- Turbines, groupes turbo-alternateurs
- Traitement des minerais d'uranium (broyeurs, centrifuges de filtration, etc)
- Appareils de levage et manutention, ponts roulants
- Pièces sur plans

- Heavy mechanical engineering and platework
- Cast steel magnets
- Alloy and stainless steel tubing
- Air tight doors, plugs
- Air and gas compressors
- Turbines, turbo-generators
- Uranium ore processing (grinding mills, centrifuges, etc)
- Hoisting and handling equipment, overhead travelling cranes
- Job-engineered parts

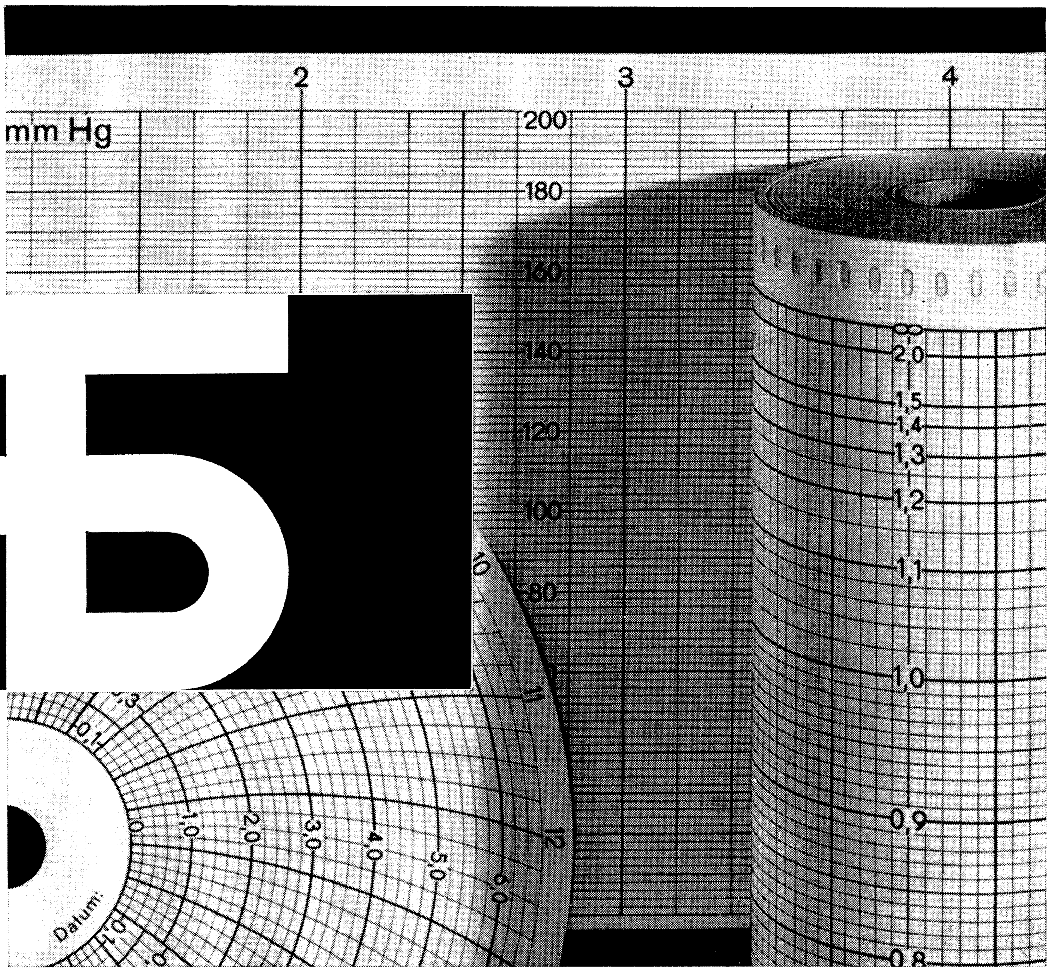
7, rue Montalivet - PARIS 8e
Tél.: 742.21.19 - 265.22.01 – Télex: FIVCAIL 65 328

SAGAL Publicité - 558

Spezialfabrik für

Registrierpapiere
Registriertinten
Wachsschichtpapiere

zu allen schreibenden Instrumenten



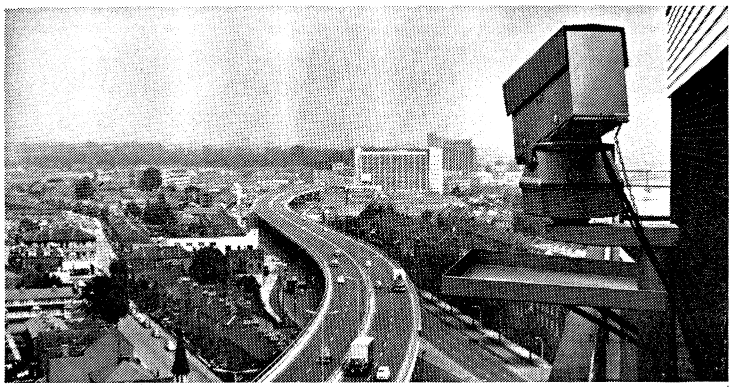
DIAGRAMMA

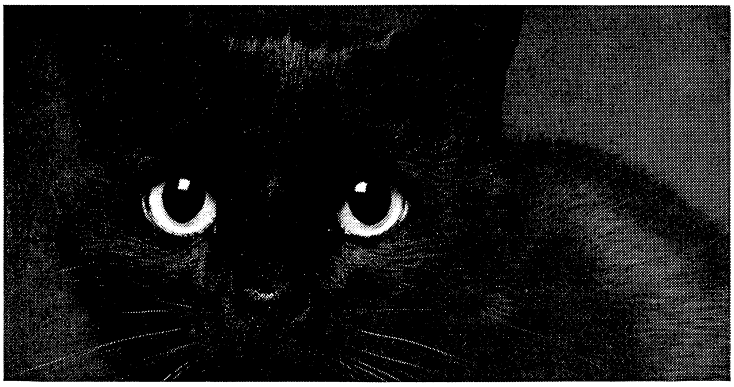
Oskar Treyer

Zürcherstrasse 152
CH - 8953 Dietikon

Tel. (01) 88 84 83

EEV know how helps you see





Some people still have the idea that TV cameras need good lighting conditions before they can work effectively. There is, of course, a wide range of vidicons for tungsten or daylight conditions, but until you know about our low light level tubes you haven't really seen anything.

You can, for example, see a black cat in a dark room, clearly, sharply, continuously – with light levels as low as 10^{-5} foot candles. To do this a high-sensitivity 3-inch image isocon is used fibre-optically coupled to a compact image intensifier which amplifies light 150 times.
Sensitive though this unit is, it can't be put out of action by bright lights. Applications include night observation, astronomy, microscopy and nuclear physics.

CRC 28

André Besson

Ingénieur E.P.F.L.

Transformateurs spéciaux et normaux

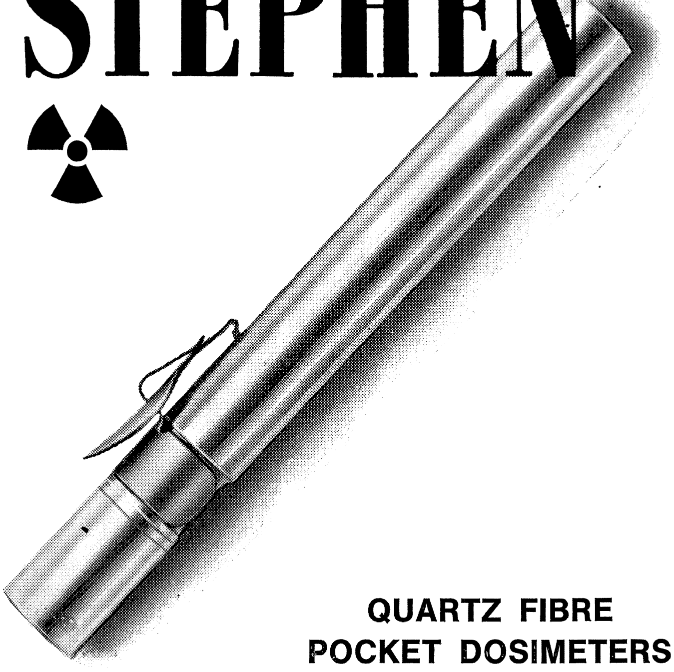
Automatismes, **électronique** :

études, montage de prototypes
et de moyennes séries

1260 NYON (Suisse)

1bis, rue d'Oulteret
Télex : 27 328 bin ch
Tél. (022) 61 35 06
Boîte postale 61

STEPHEN



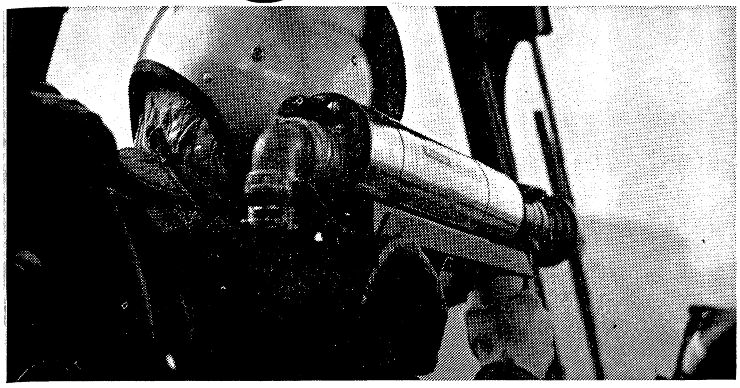
QUARTZ FIBRE
POCKET DOSIMETERS

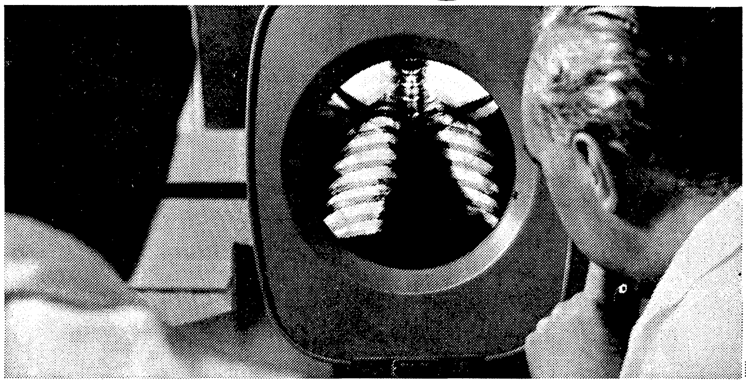
Ask for literature giving details of full range and charging unit

R. A. STEPHEN & CO. LTD.

MILES ROAD — MITCHAM — ENGLAND CR 4 3 YP

things in a different light.



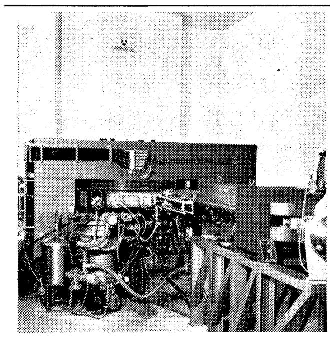


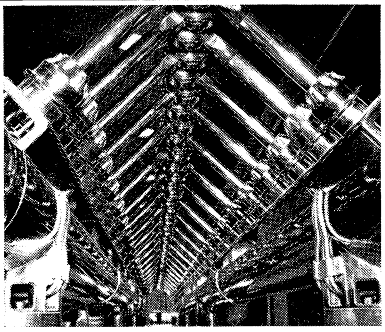
Certain scientific work, or surveillance applications, might demand tubes that are sensitive to infra-red or ultra-violet light. EEV vidicons are available with special photosurfaces to satisfy these requirements. They're also available as short-lag types for high light levels or long-lag types for integrating light over ⅛ to ½ second, the latter for viewing repetitive light of low levels, such as radar screens emit.

In the EEV image isocon range there's a tube that can give radiologists a bright, moving X-ray picture in daylight – without exposing a patient to high X-ray dosage. In fact dose rates as low as 5 micro-Rontgens per second can be used, so enabling prolonged diagnostic study.
Ask for details of these or any other EEV camera tubes for industrial and specialist applications.

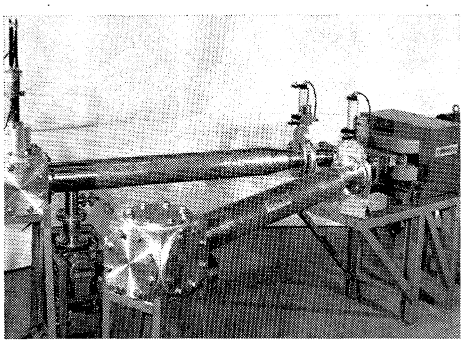
EEV know how.

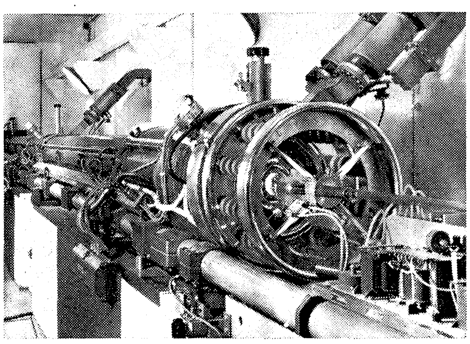
ENGLISH ELECTRIC VALVE CO LTD, Chelmsford, Essex, England, CM1 2QU. Tel: 0245 61777. Telex: 99103. Grams: Enelectico Chelmsford.
A member of THE GEC ELECTRONIC TUBE CO LTD, a management company which unites the activities of English Electric Valve Co Ltd and The M-O Valve Co Ltd

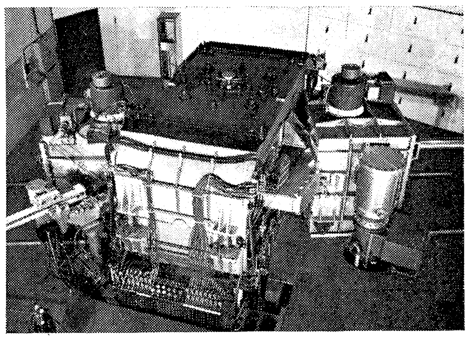


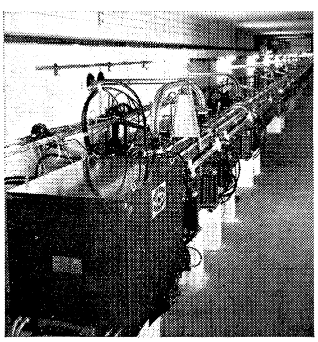


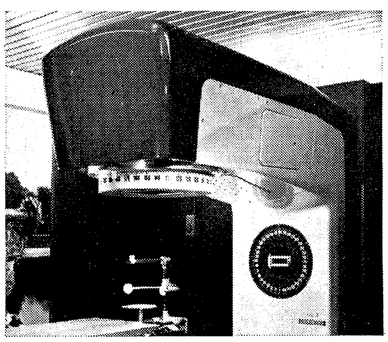
from components to complete facilities all accelerators for all particles energies and power









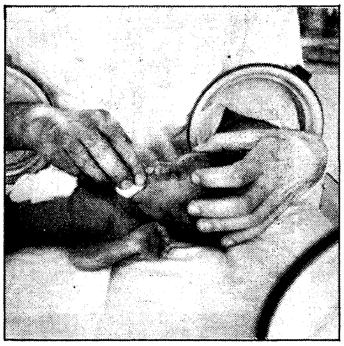


THOMSON-CSF

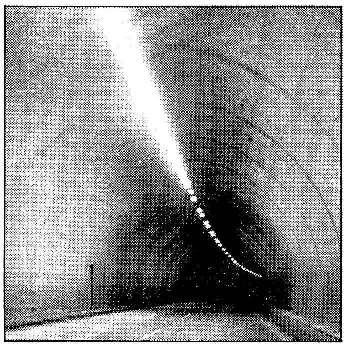
DÉPARTEMENT ACCÉLÉRATEURS
DOMAINE DE CORBEVILLE
B.P.10 / 91 ORSAY / FRANCE / TÉL. 907.77.33
FOR INFORMATION IN THE U.S.A., THOMSON-CSF INC
445, PARK AVENUE / NEW YORK / N. Y. 10022 / TEL. 212.753.5046

TH-CSF/DRP 1484_

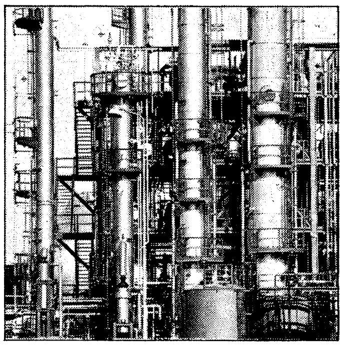
Où tout dépend d'un infime apport de courant:



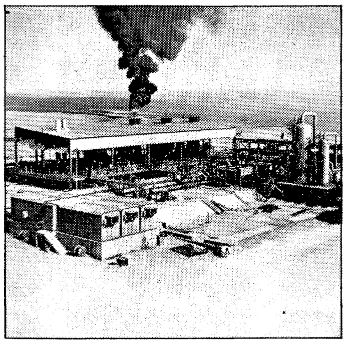
Afin qu'il vive!
L'alimentation ininterrompue en courant est garantie par une unité électrogène statique de secours GUTOR.



Pour vous préserver des conséquences d'un obscurcissement intempestif!
Les pannes de courant de courte durée sont surmontées automatiquement et infailliblement grâce à une unité électrogène statique de secours GUTOR.



Eviter des millions de dommages!
Dans maintes raffineries du monde entier, l'alimentation en courant des commandes électroniques est doublement assurée grâce aux unités électrogènes statiques de GUTOR.



Dans des régions isolées, les réparations représentent des frais élevés!
Cette usine de liquéfaction de gaz dans le désert de Lybie à Sarir est équipée d'onduleurs de haute fiabilité GUTOR, qui constituent un élément important de l'alimentation des commandes électroniques.

Des groupes électrogènes statiques pour courant continu ou alternatif, des convertisseurs statiques, des stabilisateurs de tension GUTOR assurent une alimentation ininterrompue et réglée de courant à maints points critiques dans le monde entier: dans la circulation, les hôpitaux, les commandes électroniques, les départements d'ordinateurs, les centrales téléphoniques et radio-télégraphiques.

Demandez notre offre, si vous avez des problèmes d'alimentation en courant électrique!

GUTOR

GUTOR SA
CH-5430 Wettingen Téléphone 056 6 25 25
Electronique industrielle Produits normalisés en acier Transformateurs

Choose a LEAK DETECTOR -to suit your application and price range from the CENTRONIC SERIES

FROM **£540**

1 FULLY AUTOMATIC CENTRONIC LD800 Automatic Pumping Sequence, Fail-Safe Vacuum Protection, Quick Change Pre-Aligned Filaments, Ease of Maintenance, Demountable Detector and Control, Built-in Sampling System, Versatile (Helium 4, Helium 3/Helium 4), Leak detection down to 10^{-11} At. cc/sec in components up to 100 litres capacity. Equally at home in both the Laboratory and on the production line and can detect a very wide range of leak rates.

2 CENTRONIC LD400 with High Performance and Low Cost. Dual Purpose Pumping System, Built-in test leak, Fail-Safe Vacuum Protection, Quick Change Pre-Aligned Filaments, Single Lever Vacuum Control, Leak rates down to 10^{-11} At. cc/sec.

3 CENTRONIC DEMOUNTABLE DETECTOR AND CONTROL For in-situ testing or multiple checkpoint use. Specifically designed for vacuum systems repeatedly opened to atmosphere for the introduction of equipment or materials, e.g. Environmental testing chambers, linear accelerators, vacuum furnaces. Allows rapid and frequent testing at any point.

SEND THIS COUPON TODAY!

Please send me full details of your Centronic Series of Leak Detectors.

Name ______ Position ______

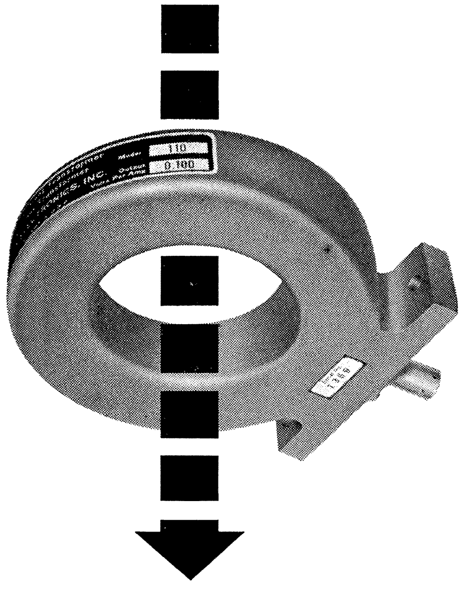
Company ______

Address ______

______ Telephone No. ______

CENTRONIC **20th CENTURY ELECTRONICS LTD.**

Centronic Works, King Henry's Drive, New Addington, Croydon CR9 OBG England Telex 896474



Wide Band, Precision

CURRENT MONITOR

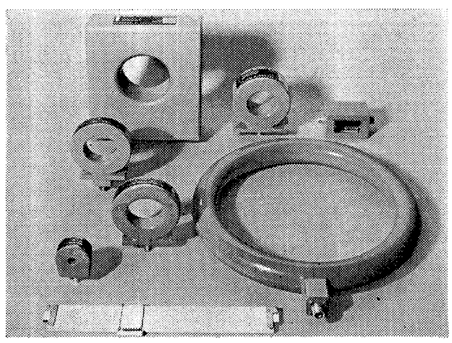
With a Pearson current monitor and an oscilloscope, you can measure pulse or ac currents from milliamperes to kiloamperes, in any conductor or beam of charged particles, at any voltage level up to a million volts, at frequencies up to 35 MHz or down to 1 Hz.

The monitor is physically isolated from the circuit. It is a current transformer capable of highly precise measurement of pulse amplitude and waveshape. The one shown above, for example, offers pulse-amplitude accuracy of +1%, −0% (typical of all Pearson current monitors), 20 nanosecond rise time, and droop of only 0.5% per millisecond. Three db bandwidth is 1 Hz to 35 MHz.

Whether you wish to measure current in a conductor, a klystron, or a particle accelerator, it's likely that one of our off-the-shelf models (ranging from ½" to 10¾" ID) will do the job. Contact us and we will send you engineering data.

PEARSON ELECTRONICS INC

4007 Transport St., Palo Alto, California 94303
Telephone (415) 326-7285

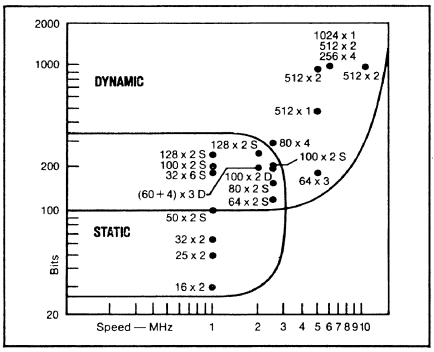


TEXAS INSTRUMENTS

MOS/LSI-Integrierte Schaltungen

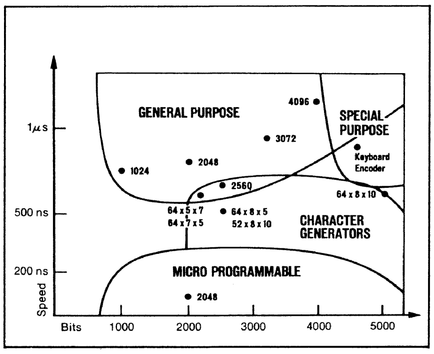
MOS-Katalogprodukte:

Schieberegister



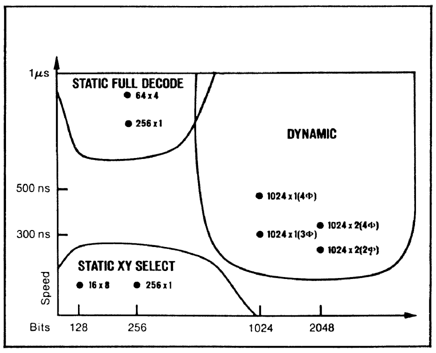
TMS 3000 LR Dual 25-Bit Static
TMS 3001 LR Dual 32-Bit Static
TMS 3002 LR Dual 50-Bit Static
TMS 3003 LR Dual 100-Bit Static
TMS 3012 JR/NC Dual 128-Bit Static
TMS 3016 LR Dual 16-Bit Static
TMS 3028 LR Dual 128-Bit Static
TMS 3101 LC/NC Dual 100-Bit Static
TMS 3102 LC/NC Dual 80-Bit Static
TMS 3103 LC/NC Dual 64-Bit Static
TMS 3112 JC/NC Hex 32-Bit Static
TMS 3113 JC/NC Dual 133-Bit Static
TMS 3114 JC/NC Dual 128-Bit Static
TMS 3304 LR Triple 66-Bit Dynamic
TMS 3305 LR Triple 64-Bit Dynamic
TMS 3309 JC/NC Dual 512-Bit Dynamic
TMS 3314 JC/NC Triple 60 + 4-Bit Dynamic
TMS 3401 LC/NC Single 512-Bit Dynamic
TMS 3402 LC/NC Single 500-Bit Dynamic
TMS 3406 LR/NC Dual 100-Bit Dynamic
TMS 3409 JC/NC Quad 80-Bit Dynamic
TMS 3412 JC/NC Quad 256-Bit Dynamic
TMS 3413 LC/NC Dual 512-Bit Dynamic
TMS 3414 LC/NC Single 1024-Bit Dynamic
TMS 3417 JC/NC Quad 64-Bit Dynamic
TMS 3419 JC/NC 9 x 128-Bit Dynamic

Festwertspeicher



TMS 2403 JC/NC 5 x 7 Char. Gen. USASCII
TMS 2404 JC/NC 5 x 7 Char. Gen. EBCDIC
TMS 2601 JC/NC 2048-Bit ROM/ sample
TMS 2602 JC/NC Code Conv. USASCII to Select.
TMS 2603 JC/NC Code Conv. EBCDIC to USASCII
TMS 2604 JC/NC Code Conv. USASCII to EBCDIC
TMS 2605 JC/NC Code Gen. USASCII, BAUDOT, Select., EBCDIC
TMS 2801 JC/NC Priority Encoder
TMS 4103 JC/NC 64 x 35-Bit Char. Gen. USASCII
TMS 4177 JC/NC 7 x 10 Char. Gen. USASCII
TMS 4178 JC/NC 7 x 10 Char. Gen. USASCII
TMS 4179 JC/NC 5 x 7 Char. Gen. EBCDIC
TMS 4401 JC/NC 4096-Bit ROM 1024 x 4-Bit
TMS 4405 NC 512-Words Sin. Gen.
TMS 4886 JC/NC Char. Gen. 5 x 5 USASCII
TMS 2301 JC/NC 2560-Bit Dyn. ROM, sample
TMS 2501 JC/NC Char. Gen. 64 Char. 40-Bit
TMS 2701 JC/NC Code Conv. USASCII to Selec.

Aktivspeicher



TMS 4003 JC/NC 256-Bit Static
TMS 4006 JC/NC Dig. Stor. Buff. 13 x 6-Bit
TMS 4062 NC 1024-Bit Dynamic
TMS 1103 NC 1024-Bit Dynamic
TMS 4000 JC/NC 128-Bit Con. Addr. Mem.
TMS 4024 JC/NC Dig. Stor. Buff. 64 x 9-Bit
TMS 4028 NC 2048-Bit Dynamic

Mehr-Kanal-Schalter

TMS 6002 JC/NC 6-Channel
TMS 6005 JC/NC 6-Channel
TMS 6009 JC/NC 6-Channel

Arithmetische Einheiten

TMS 1802 NC 8-Digit, 4-Operations Calculator
TMS 0201/TMS 0301 2-Chip 12-Digit Calculator
TMS 5700 JC/NC Dig. Diff. Analyser

Programmierbare MOS-Festwertspeicher nach Kundenkodierung:

TMS 2400 JC/NC 2240-Bit Char. Gene. 5 x 7
TMS 2600 JC/NC 2048-Bit ROM 256 x 8-Bit
TMS 2800 JC/NC 1024-Bit ROM 256 x 4-Bit
TMS 4100 JC/NC 2240-Bit Char. Gen. 35-Bit 5 x 7
TMS 4400 JC/NC 4096-Bit ROM 512 x 8-Bit
TMS 4880 JC/NC 2736-Bit Char. Gen. 5 x 7 or 5 x 6
TMS 2300 JC/NC 2560-Bit Dynamic ROM
TMS 2500 JC/NC 2560-Bit Char. Gen. (5 x 8)
TMS 2700 JC/NC 3072-Bit ROM

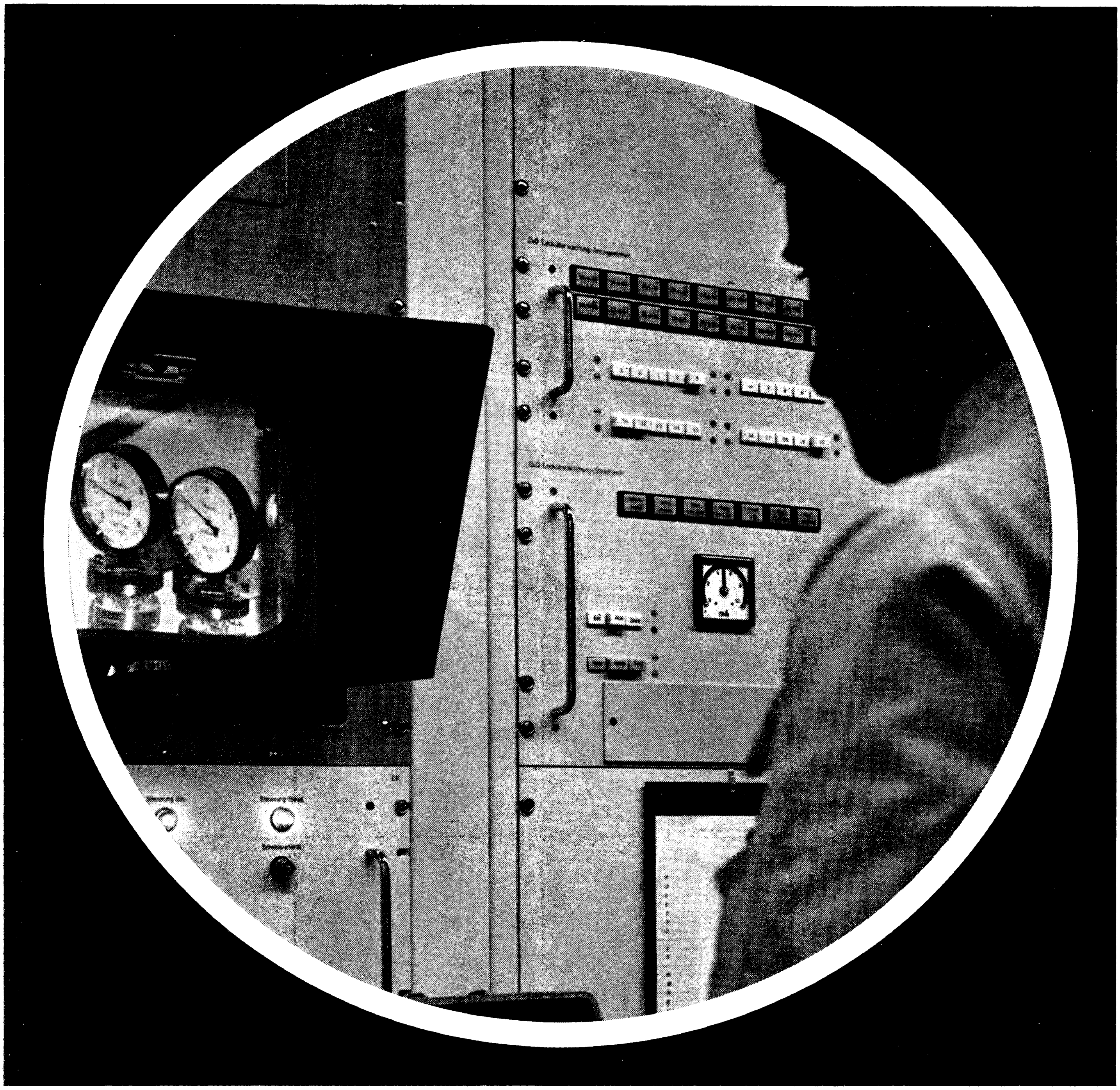
Kunden-Spezial-MOS-Schaltkreise

angefertigt nach Kundenspezifikationen ● hohe Komplexität ● kleine Abmessungen ● niedriger Stromverbrauch ● TTL-kompatibel ● hohe Zuverlässigkeit ● Preisreduktion des Systems

Verlangen Sie technische Beratung und Dokumentation

FABRIMEX

Fabrimex AG
8032 Zürich
Kirchenweg 5
Telefon 01/47 06 70



Quand un câble de télévision est-il parfait ?
Lorsque vous oubliez qu'il existe !

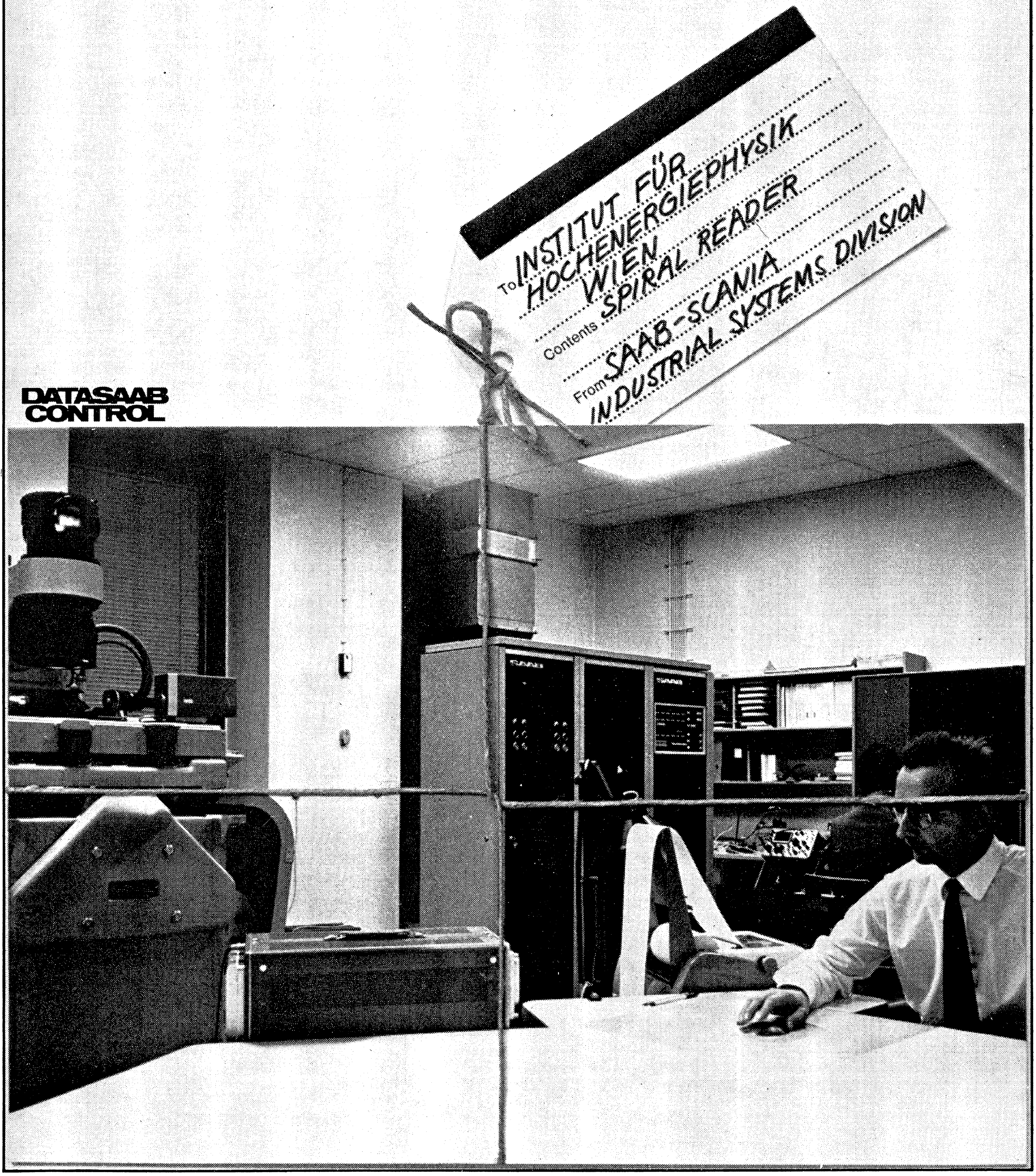
Les câbles de télévision Dätwyler garantissent une transmission parfaitement fidèle des signaux de télévision, de la caméra à l'émetteur, et de l'antenne au récepteur. Dans le domaine de la télévision industrielle, le nombre des possibilités et applications des câbles à haute fréquence Dätwyler est impressionnant. Le problème de la surveillance des endroits éloignés ou inaccessibles est ainsi facilement résolu. Selon l'utilisation, les câbles peuvent être combinés avec un nombre quelconque de fils de commande et de signalisation, de telle sorte qu'un seul câble d'un encombrement réduit, vient à bout de nombreuses missions. Sur demande, tous les câbles coaxiaux et de télévision industrielle Dätwyler sont livrables en exécution « Isoport » ; la corde d'acier insérée dans la gaine donne à ce câble la qualité d'autoporteur. Nos techniciens sont prêts à tout moment pour résoudre avec vous vos problèmes de câbles, s'il s'agit d'exécution spéciale de câbles à hautes fréquences ou à fréquences audibles, radar, radio, télévision, électronique, recherche et application médicales, industrielles ou nucléaires !

Câbles pour hautes fréquences et fréquences audibles

Dätwyler

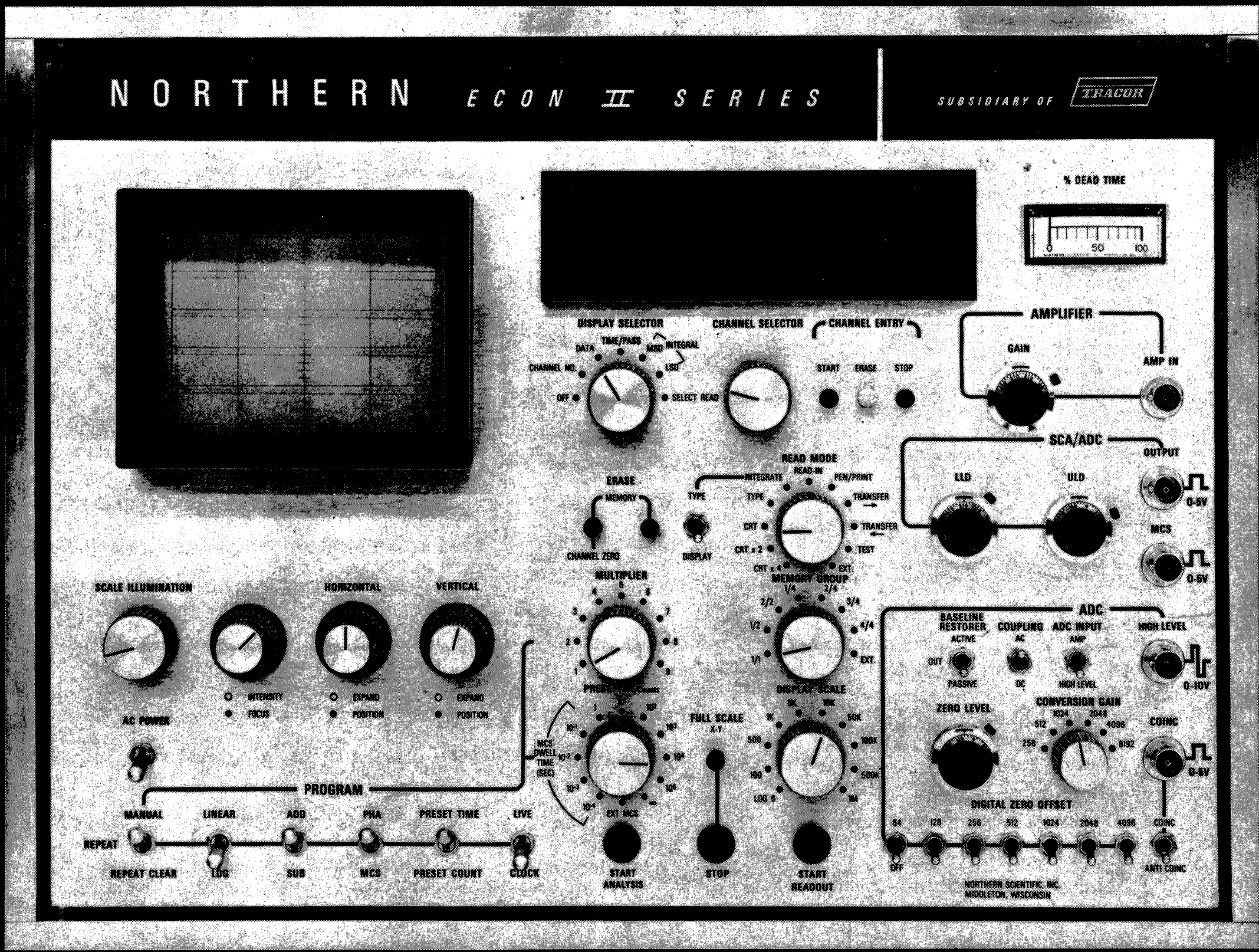
Dätwyler SA, Manufacture Suisse de Câbles, Caoutchouc et Plastique Industriels, Altdorf-Uri

Spiral Reader Saab, serial No. 2 in the agreeable Vienna! This powerful semi-automatic measuring system helps Them to produce scientific results in a short time.
Ask dr H Jeram at Institut für Hochenergiephysik about it and then contact us: Saab-Scania, Industrial Systems Division, Fack, S-550 02 Jönköping 2, Sweden

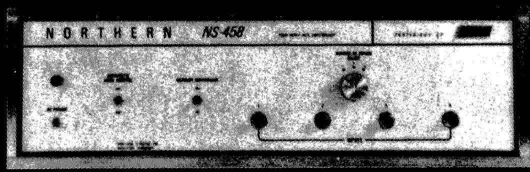


DATASAAB CONTROL

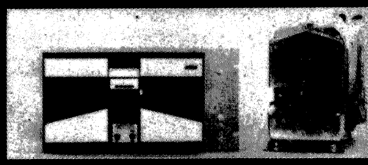
PERIPHERALS? Anything goes with the NS-700 PULSE HEIGHT ANALYZER



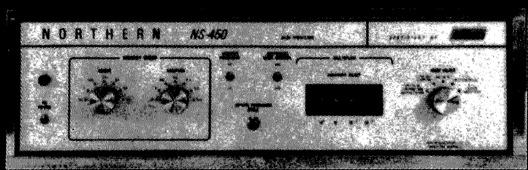
NS-110 Cassette Tape Unit



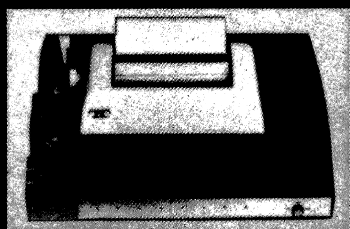
NS-458 Four Input Multiscaler



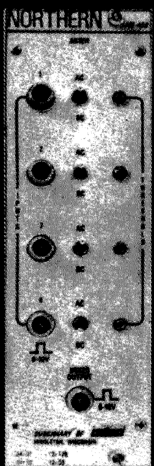
High Speed Paper Tape Punch and Reader



NS-450 Data Processor (Spectrum Stripper)



Model 33-ASR Teletype



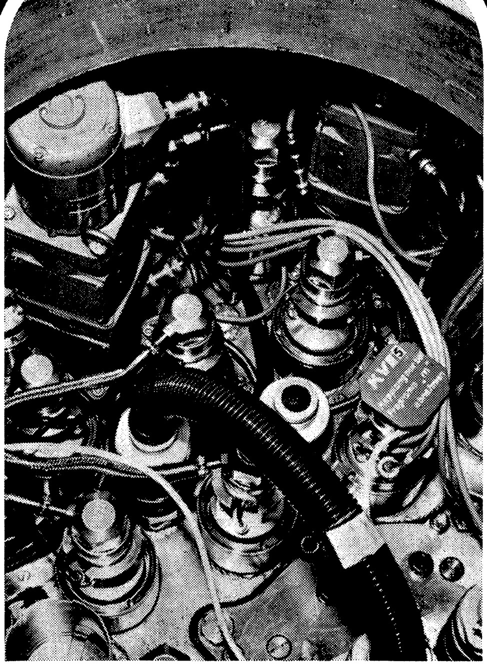
NS-459 Mixer/Router

Wang Magnetic Tape System with NS-406M Magnetic Tape Controller

In addition to the peripherals shown here, many others — including X-Y Recorders, Parallel Printers and Computer Interfaces to Nova, PDP-8 and PDP 11/15 Systems — are available with the NS-700.

TRACOR®

TRACOR EUROPA, N. V.
SCHIPHOL AIRPORT / AMSTERDAM
BUILDING 112A / THE NETHERLANDS
TELEPHONE 020-151602/TELEX 13695

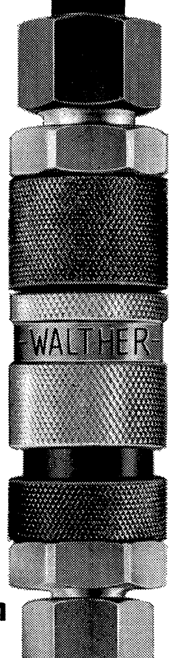


walther präzision

channels media

with
Walther Quick Connect
Couplings

for all piped media ☐
in nuclear research
and technique ☐
for all other applications
and pressure ranges ☐
Standard Programme ☐
Purpose Designed Couplings.



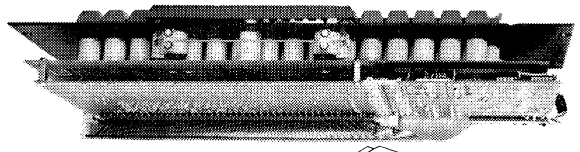
walther präzision

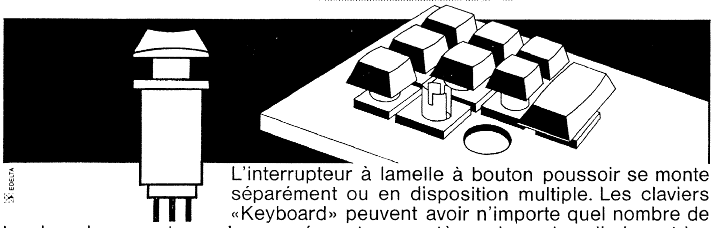
Carl Kurt Walther GmbH & Co. KG
D-56 Wuppertal 11, Postfach 110377
Bahnstraße 43-51 Tel. 783023
Telex 8591611

Generalvertretung für die Schweiz:
Wieland + Oertli AG
Postfach
CH-8308 Illnau
Tel. 052-441488
Telex 76450 wilor ch

Contact parfait en 1 milliseconde

interrupteur à lamelle à bouton poussoir pushbutton reed switch





L'interrupteur à lamelle à bouton poussoir se monte séparément ou en disposition multiple. Les claviers «Keyboard» peuvent avoir n'importe quel nombre de touches. Les montages incorporés ont un système de code «diode-matrix» avec circuit intégré qui donne la suite logique de deux touches, «strobe», etc. Existe en version «CHANGE OVER» réf 2 RB1. Les types 1 RB1 et 2 RB1 sont livrables avec voyant lumineux.

TVI-TELEVISION INDUSTRIELLE SA

TV en circuit fermé
Electronique industrielle
Informatique

Etude, réalisation, vente, location
78, avenue des Communes-Réunies
1212 GRAND-LANCY - Tél. 437140

Demande de documentation Tél.: ____________

Société: ____________ Adresse: ____________

Secteur d'activité: ____________ Nom du destinataire: ____________

HÉLIUM — HYDROGÈNE — AZOTE — OXYGÈNE — ARGON

■

Pour toutes les applications des très basses températures

■

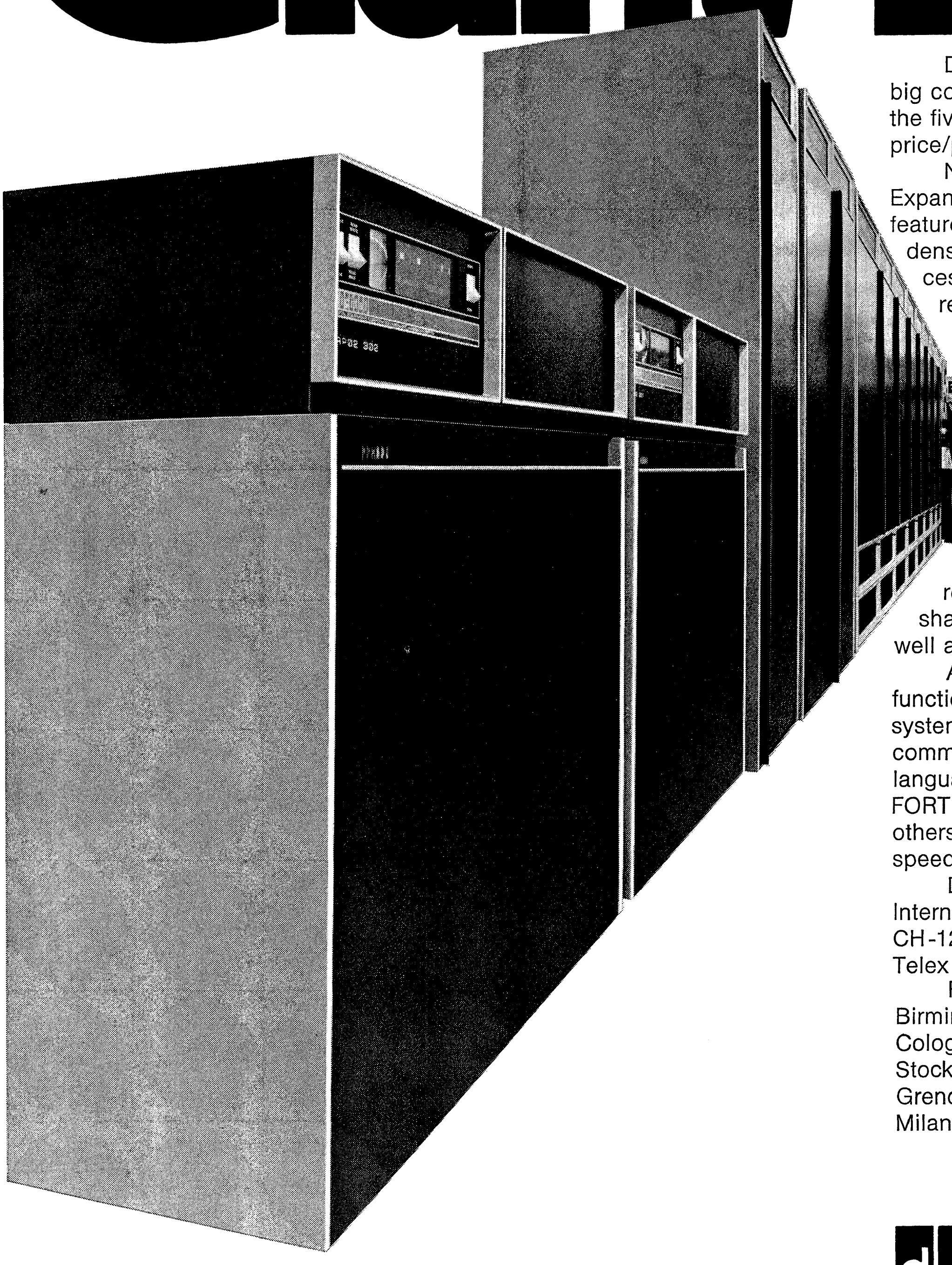
- **CONTAINERS BIOLOGIQUES DE CONSERVATION**
- **VASES DEWARS**
- **CONTAINERS DE STOCKAGE N²**
- **RÉSERVOIRS He**
- **CRYOSTATS**
- **LIGNE DE TRANSFERT**
- **RÉGULATION DE NIVEAU**
- **RÉGULATION DE TEMPÉRATURE**

■

CRYO DIFFUSION

28, rue Bayard — **PARIS VIII^e** — Téléph. 225-53-69

The Giant Ten



Digital Equipment's new family of big computers, DECsystem-10. Each of the five systems (2nd shown) is a price/performance giant.

New faster, bigger processor. Expanded core memories. More COBOL features. New high performance dual density disk packs. Super multiprocessor systems. Improved card readers. New magtapes. And more.

DECsystem-10 runs four functions: batch processing, multi-access conversational timesharing, remote job entry (batch and timesharing), and real-time equally well and simultaneously.

All five systems run all four functions using the same operating system with the same job control commands. All are serviced by the same language processors COBOL, ALGOL, FORTRAN, BASIC, MACRO, and many others. The only thing that changes is speed and capacity.

Digital Equipment Corporation International-Europe, 81, Route de l'Aire, CH-1211 Geneva 26. Tel. 022/42 79 50, Telex 22683.

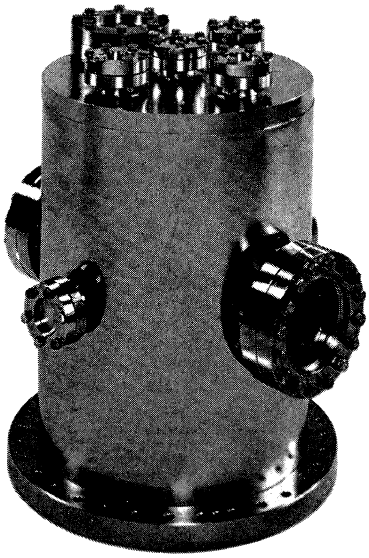
Reading, London, Manchester, Birmingham, Edinburgh, Munich, Cologne, Hannover, Frankfurt, Vienna, Stockholm, Oslo, Copenhagen, Paris, Grenoble, The Hague, Brussels, Zurich, Milan.

digital

VACUUM PRODUCTS
Hositrad/Holland N.V.

Hositrad / Holland N.V. is a company, specialised in the custom made High- and Ultra High Vacuum field.

We have polishing facilities (chemical) and can handle any shape or object.



This is one of the custom made products, made for one of our customers in the U.H.V. field.

The sales representative for Veeco in Holland and Denmark.

Amersfoort — Holland. Phone : 03490 - 10080.

Entreprise de peinture bâtiment industrie

J. Prézioso & Fils S.A.

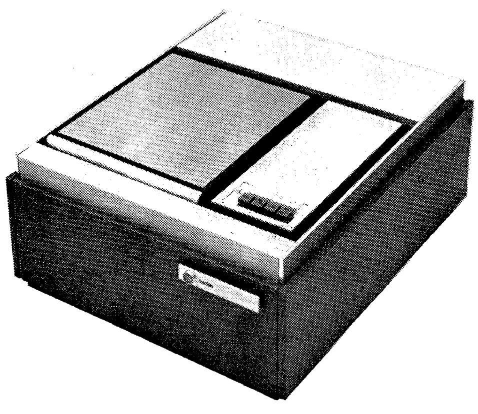
C.E.R.N. - GENÈVE

Siège social :

Boîte postale N° 2
38 - SAINT-CLAIR DU RHÔNE
Tél. (74) 85 53 07
85 52 28
Télex : 30 516-PREZIOSO SCLAR

varian

STATOS 21®



The revolution in the computermarket

- The fastest printer / plotter
- 6000 characters per second
- Compatible with all computers
- Software and interfaces for most computers existing
- Electrostatic writing technique

Please ask for more information or a demonstration

(7003 EE)

Industrievertretungen
Junkholz 333 – CH-8968 Mutschellen

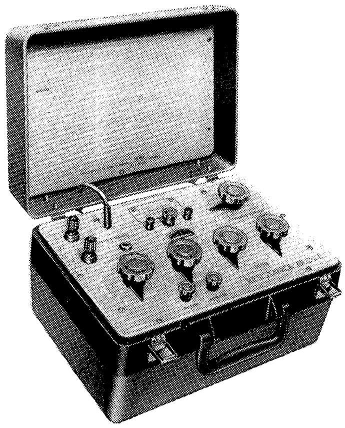
STOLZ AG

Tel. 057 5 46 55

DURTAL

DELÉMONT
74, route de Porrentruy
Téléphone 066/22 39 44

- Outils coupants de haute précision selon dessin.
- Pièces d'usure, pièces spéciales, recherches en nouveaux procédés d'usinage.



OHM-mètres de précision

- Instruments portatifs pour mesurer des résistances selon le principe d'un ohm-mètre en pont de Kelvin ou Wheatstone
- Type KB1 : Echelle 0,000050 à 105 Ω
- Type KB2 : Echelle 0,000500 à 1050 Ω
- Type PW3/E : Echelle 0,01 à 10 MΩ
- Exactitude : types KB1 et KB2 ± 0,2 %, type PW3/E ± 0,1 %

ETHER LIMITED BERNE,

Case postale 41 - 3000 Berne 26 - Tél. (031) 24 11 55

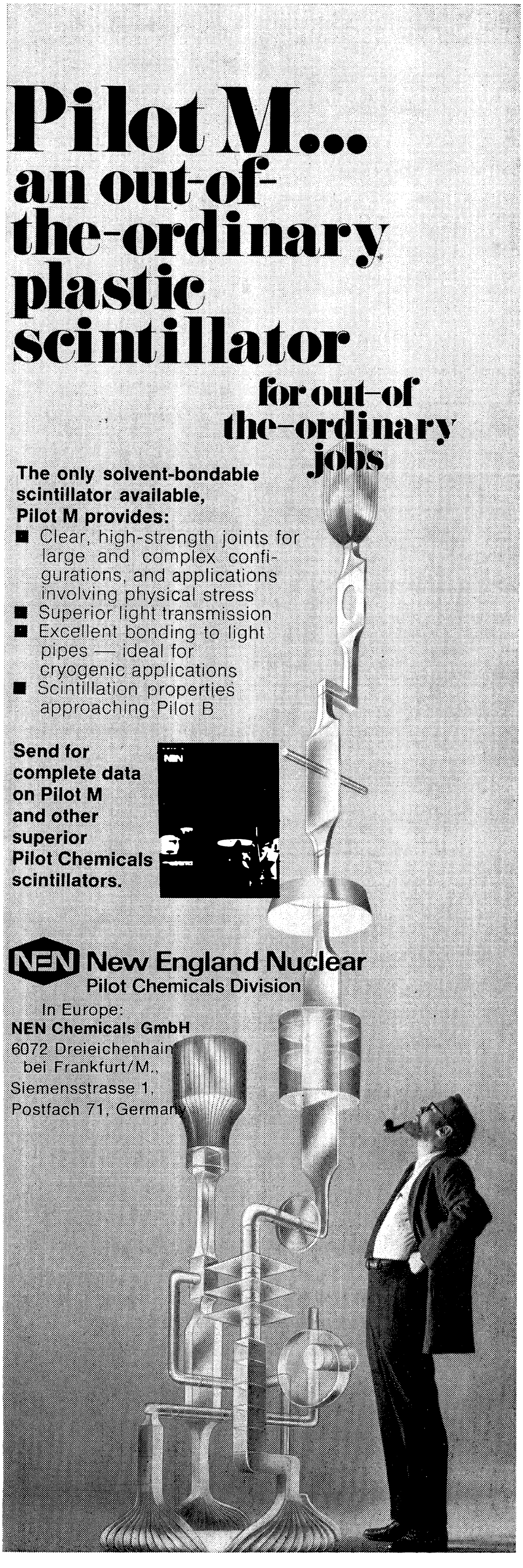
TRANSFORMATEURS < 250 kVA
SELFS, TRANSDUCTEURS
TRANSFORMATEURS DE
HAUTE TENSION ET COURANT
ALIMENTATIONS ET DIVERS
ÉQUIPEMENTS ÉLECTRONIQUES

EAB

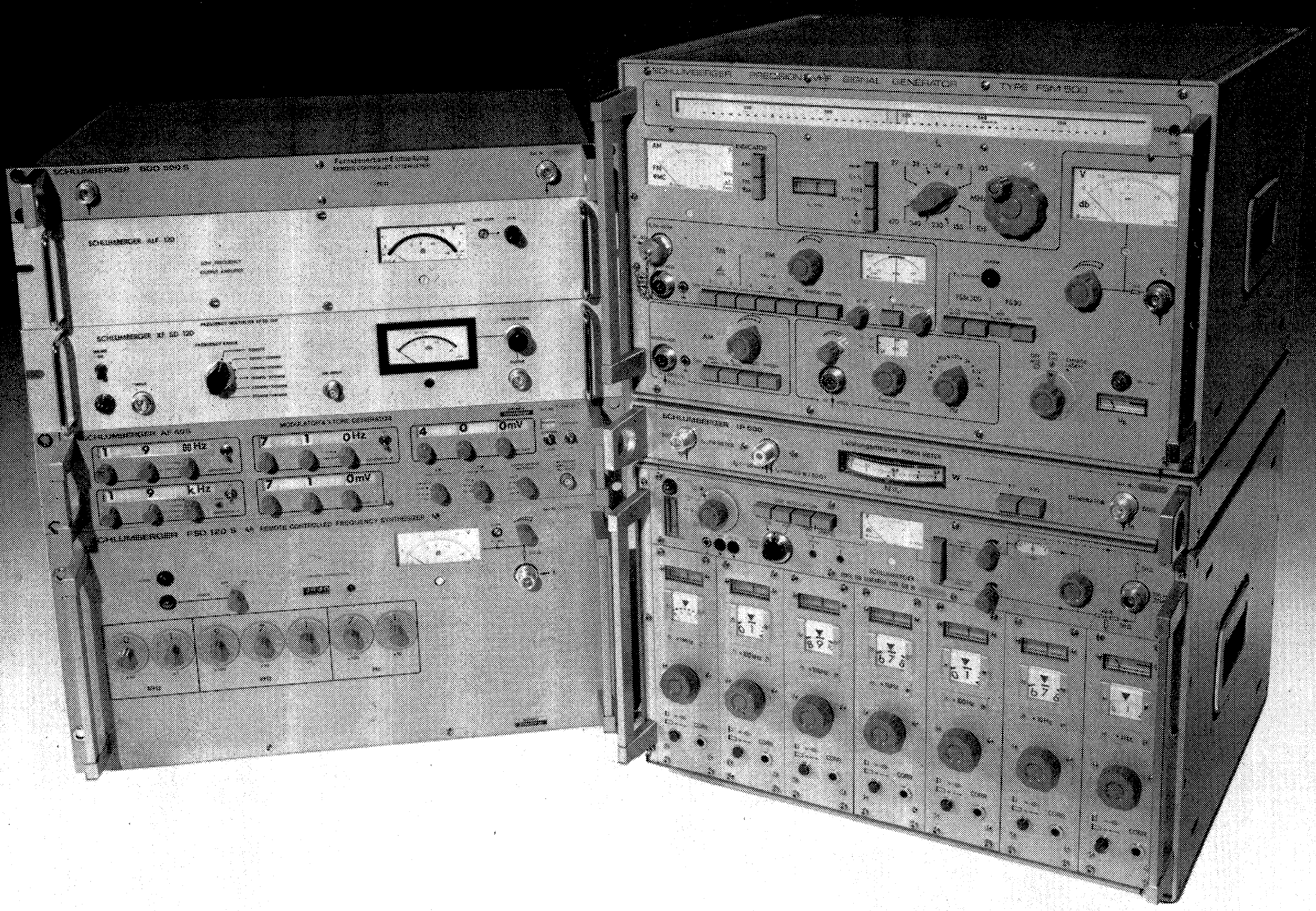
La maison de confiance depuis 1936 renommée pour ses produits de haute qualité et ses ingénieurs-conseillers qui se tiennent à votre entière disposition.

Téléphone (039) 44 12 55
Télex eab 35 3 65

EAB Fabrique d'Appareils électriques S. A.
2608 COURTELARY



Set it and forget it!



Solartron's synthesizer signal generator eliminates those three operator headaches: keeping the signal generator within the bandwidth of the RX that's being checked; having to reset output levels with each modulation change; and having to readjust controls with every frequency change.

Just look at these advantages:

- *crystal accuracy and stability*-3 parts in 10^9 over 24 hours. We guarantee that the frequency you set today will be there tomorrow. Or the day after that!
- *digital decade frequency setting*-down to 10Hz resolution. Setting times a few seconds manually, or a few milliseconds by electrical programming.
- *complete modulation facilities*-AM, FM, SSB or Pulse.

Solartron-Schlumberger are Europe's proven leaders in synthesizer signal generators.

Tell us about your Laboratory or ATE requirement. We'll be pleased to meet it. Precisely.

15, rue du Jeu-de-l'Arc
1207 Genève — Tél. (022) 35 99 50

Schlumberger

SEN CAMAC

CAMAC — Fast Electronics

INTERACTION

Fast Electronics is used both for signal conditioning and for setting-up decision networks. Why don't you put these decision nets under computer control? SEN has the necessary CAMAC Modules. (These modules are especially designed to accept and to deliver fast logic signals: —16 m A across 50 ohms).

Strobed Input Registers 16 P 2007 S I R 2026

Commonly referred to as "Pattern Units", they convert any event pattern into a digital word. The S I R 2026 is also especially well suited as an "L-Request Module".

Output Register OR 2027

A general purpose 12 bit register, which can provide fast electronics with control variables. Typical applications include signal routing for test or calibration purpose. This module can be instructed to deliver levels as well as pulses.

Controlled Gate 6 CG 2017

A module made from MECL IC's for direct handling of fast signals or pulses. Three major functions:
— Controlling the flow of 6 fast signals.
— Signal multiplexing, input selection by Dataway command.
— Signal demultiplexing, output selection by Dataway command.

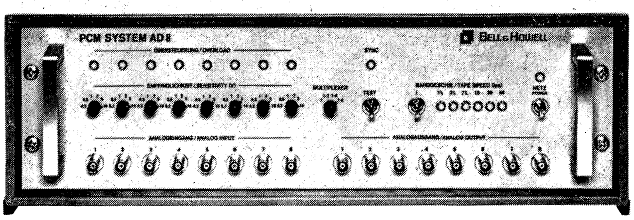
These modules are stock items. Many other modules in the CAMAC program are designed to deliver fast signal levels. Ask for detailled literature.

SEN ELECTRONIQUE

1211 GENÈVE 13 - SUISSE/SWITZERLAND - 31, av. Ernest-Pictet - Tél.(022) 44 29 40 - Télex 23359

BELL & HOWELL

AD-8 PCM-System



For all analog tape recorders

- Up to 8 signals on each tape track
- 60 db SNR peak to peak at all tape speeds
- output data available in analog or digital form
- The digital output is suitable for computer analysis
- Useable as an A/D converter
- No adjustment — easy to operate
- Linearity error max. 0.2 %

Please ask for detailled documentation or a demonstration.

(7002 EE)

Industrievertretungen
Junkholz 333 – CH-8968 Mutschellen
STOLZ AG
Tel. 057 5 46 55

EUROVAN

SAUVIN, SCHMIDT S.A.

Déménagements (membre EUROVAN)
Service fret avion
Camionnage officiel CFF

GENÈVE
Gare de La Praille — Tél. (022) 43 80 00

SATEM

Tous les produits du pétrole

●

Huiles de chauffage

Carburants

Lubrifiants

●

SATEM

14, place Cornavin

Genève

Téléphone (022) 32 71 30

Télex N° 22 336

CERN Stores

For sale :

1 Impulphysik ruby laser, triggered by a Kerr cell, complete with power supply.
Repetition rate : up to 1 pulse per second.
Peak power : 50 Megawatts.
Pulse width : 30 n/sec., divergence 1 mrad.
Ruby diameter : 9.5 mm.
Un-Q-switched mode energy : 5 joules.
Ancillary equipment : calorimeter, biplanar photo-diode, auto-collimator, prims, lenses, flash tubes.

Those interested should contact the Stores-Salvage for further information at the following address :

CERN - 1211 Geneva 23 (Ext. 2180)

CERN

FAST LOGIC MODULES

Borer industrialized versions of CERN's wide range of types are :

- Power saving (= more modules per standard NIM-Bin)
- Cooler running
- Favourably priced
- Delivered with a full industrial warranty

Standard CERN versions are also readily available upon request

CERN Type	BORER Equiv	Description
Discriminators / Triggers		
N2620	**300**	Shaper, cable timed
N2625	**302**	Dual limiter
N6009	**303**	Updating discriminator
—	**350**	12-bit pattern unit
Coincidences and OR's		
N6234	**310**	5-fold coincidence
N6237	**312**	3 × 2-fold overlap
N6235	**313**	3 × 2-fold coincidence
N6236	**314**	5-in strobed coinc.
N4132	**320**	6 input OR gate
N2629	**315**	Mean timer
Active accessories		
N4149	**323**	2 × 6-fold fan-out
N4160	**324**	8 × 4-fold fan-out
N2251	**332**	Timing unit
—	**340**	Quad pre-scaler
—	**955A**	1024-channel ADC
Linear elements		
N2233	**330**	Linear gate
N9053	**361**	Delay line
—	**370**	Attenuator
—	**701**	Remote control delay line

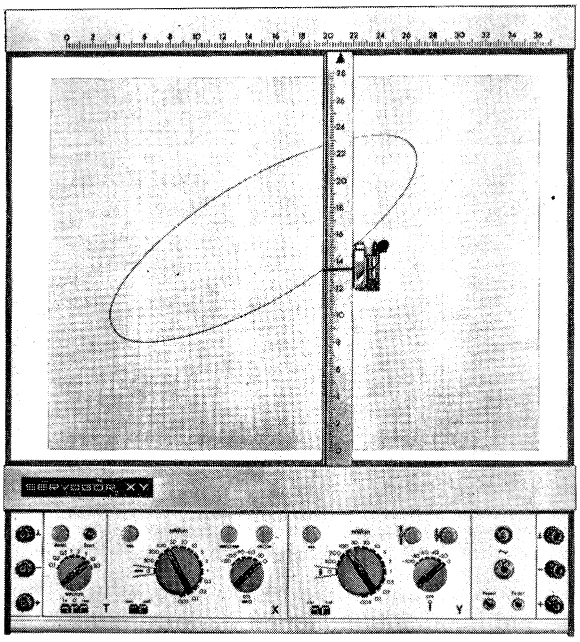
ELECTRONICS

borer + co

4500 Solothurn 2, Switzerland. Tel. 065 4 88 21. Telex 34228

GOERZ ELECTRO

Potentiometrischer Koordinatenschreiber DIN A3 SERVOGOR XY, Type RE 551



Transistorisierter XY-Schreiber mit elektrostatischer Papierniederhaltung
13 Empfindlichkeitsstufen von 0,05 bis 500 mV/cm. Zusätzlich in jedem Bereich kontinuierliche Vergrößerung der Empfindlichkeit bis auf das 2,5fache möglich

Genauigkeit ±0,2% vom Endwert oder ±10 µV
Schreibbreite: X-Achse . . . 37 cm
Y-Achse . . . 28 cm

Schreibgeschwindigkeit 40 cm/sec
Aufzeichnung auf DIN A 3 Blatt mit Tinte

Kalibrierte Nullpunktunterdrückung für die X-Achse in Stufen von 5 x 30 cm, für die Y-Achse in Stufen von 5 x 20 cm

Zeitablenkung (nur für die X-Achse) einmalig oder mit automatischer Wiederholung in 8 Geschwindigkeitsstufen von 0,1 bis 20 s/cm, Amplitude einstellbar von 5 – 37 cm

Netzanschluß: 115 – 220 – 240 V, 50 Hz, ca. 100 VA

GOERZ ELECTRO Ges. m. b. H., A-1101 Wien · Postfach 204 · Telex: 1 31 61

Une saine alimentation : SODILEC à plein régime !

SDPR 03

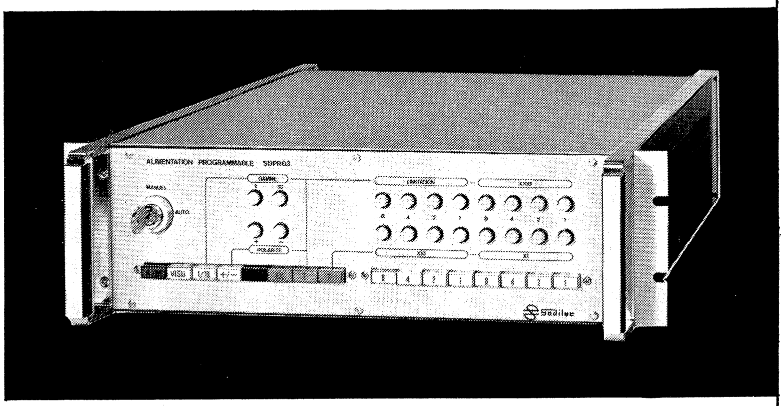
Générateur de tension programmable

directement adaptable aux calculateurs (Interface incorporée)

CARACTÉRISTIQUES D'ENTRÉE :

Secteur : 127 V - 220 V ± 10 % (48 Hz à 60 Hz).

Programmation : 2 mots de 16 bits (Code B CD 1-2-4-8) dont 4 d'adresse.
Soit automatique, couplage avec le registre entrées-sorties d'un calculateur.
Soit manuelle par clavier situé en Face avant.



CARACTÉRISTIQUES DE SORTIE :

Alimentation bipolaire (4 quadrants)

2 gammes de tension :
0 à ± 10 V
0 à ± 60 V

Courant : 1,5 A

Temps d'exécution : 50 µs + 2 µs/V.

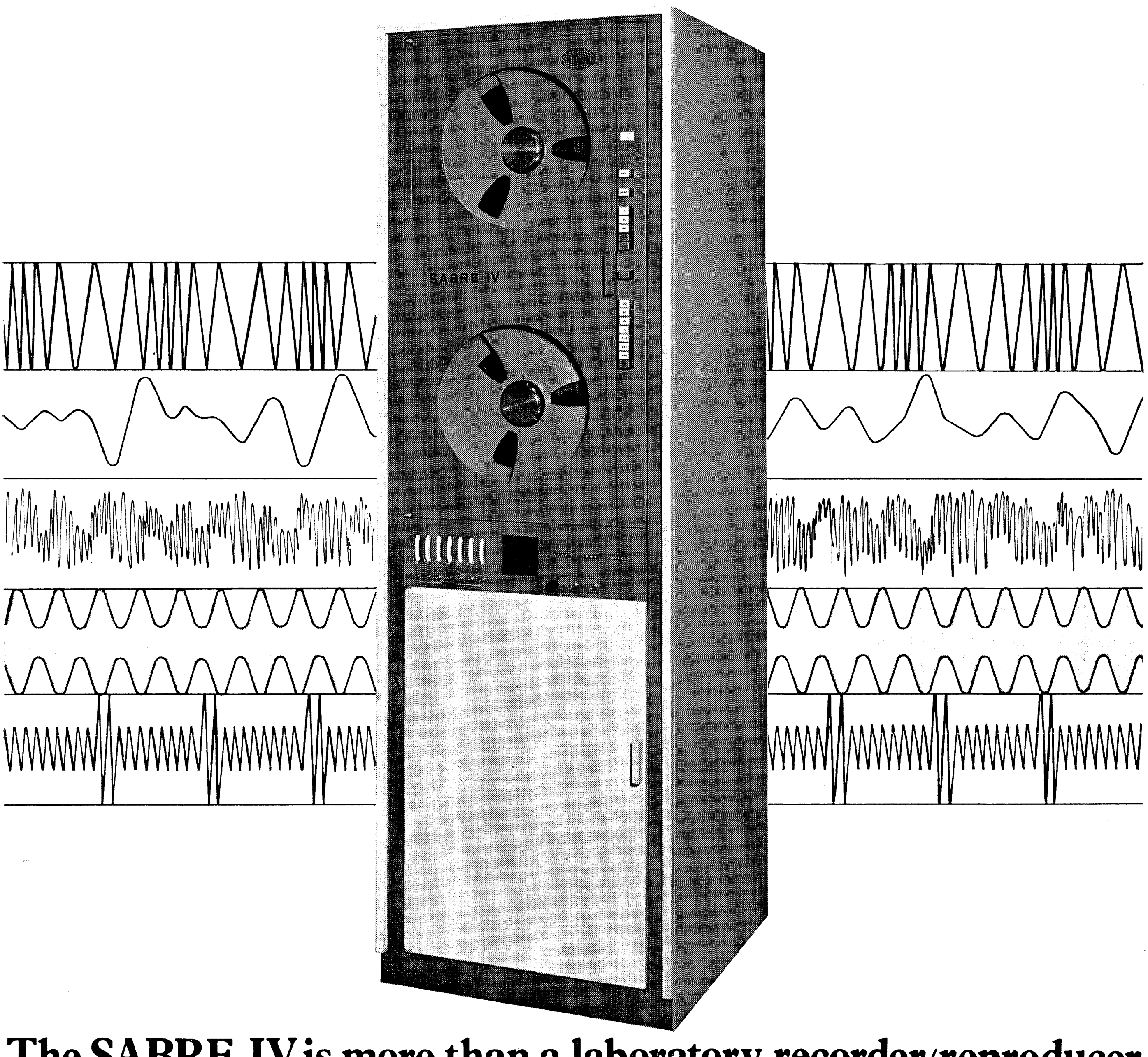
PRÉSENTATION :
Adaptable au rack standard 19" - Hauteur 3 U.

PEMA INDUSTRIE BM 7262

Sodilec

7, avenue Louise - 93 - Neuilly-Plaisance
Téléphone : (1) 927.38.07

The next generation is here now



The SABRE IV is more than a laboratory recorder/reproducer.

It's a complete magnetic tape system that is setting NEW STANDARDS in the accurate recording and recovery of data . . . whether low or high frequency, analog or digital.

A SABRE IV in your laboratory means data reduction performance unmatched by other recorder/ reproducers. The SABRE IV allows you to reduce data up to 2.0 MHz in the direct mode and 500 KHz in the FM mode with unequalled reproduction quality. With eight transport speeds the SABRE IV allows time base expansion and contraction ratios up to 128:1. The Total Bandwidth Convertibility of the SABRE IV provides more capability than previously found in two or more recorder/reproducers.

If you would like to know more about the most advanced magnetic tape systems available today . . . including the best portable system available today . . . write or call:

SANGAMO
Electric Company

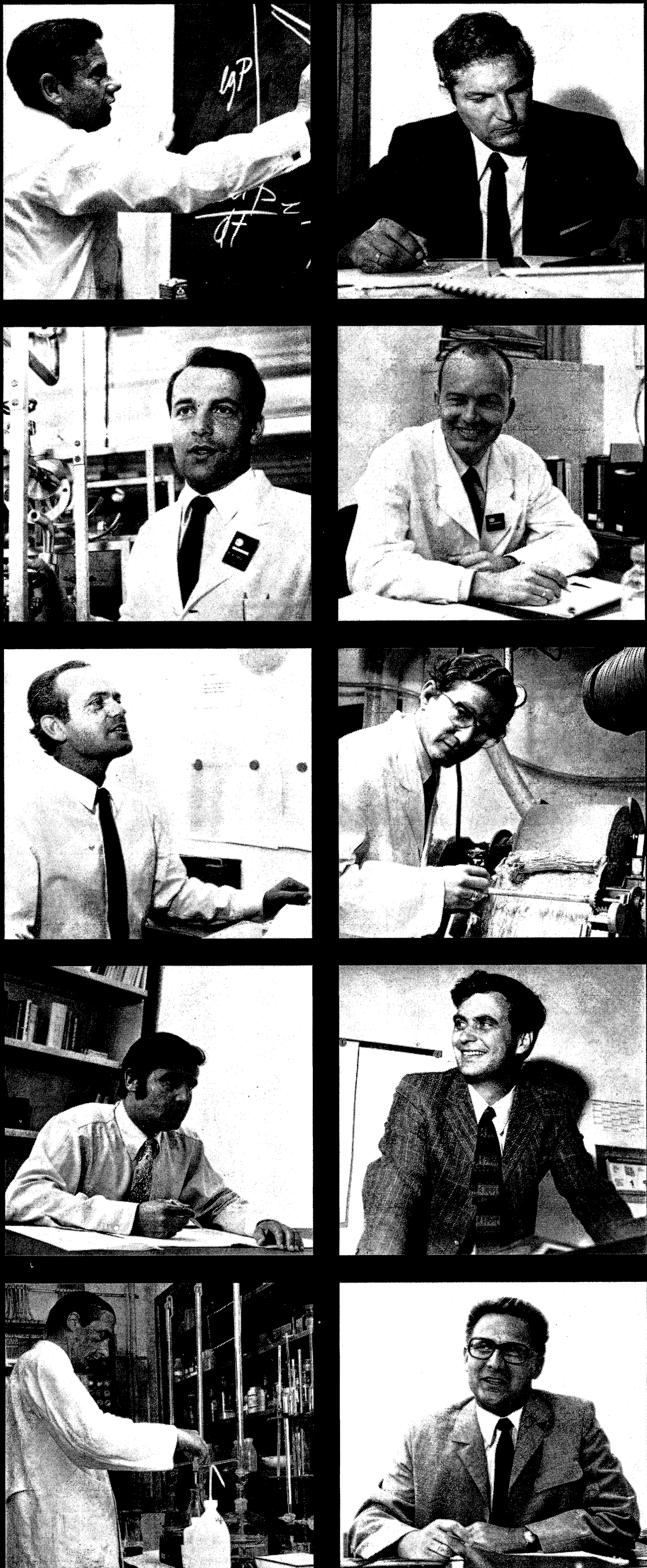
The innovators in Tape Instrumentation
P.O. Box 3347, Springfield, Illinois 62 708 / USA

H.W.TSCHÄPPELER AG

8008 Zürich
Mühlebachstrasse 28
Telefon (01) 34 07 77

1007 Lausanne
7, chemin des Bruyères
Tél. (021) 26 01 14


Tête de mesure ultrasonore de profondeur de gorges.
SOGEME et CERCA
s'entendent pour proposer
TOUS LES CONTRÔLES NON DESTRUCTIFS A FAÇON :
contrôles d'étanchéité
contrôles dimensionnels et métrologiques
contrôles par radiographie
contrôles par ultra-sons
contrôles par courants de Foucault
SOGEME ET CERCA
SOCIÉTÉ GÉNÉRALE ÉTUDES MÉCANIQUES ÉLECTRIQUES
25, rue de Chony
26 - BOURG-LES-VALENCE
Tél. 43-45-40
Télex : 33.741 BRGLV
COMPAGNIE POUR L'ÉTUDE ET LA RÉALISATION DE COMBUSTIBLES ATOMIQUES
41, avenue Montaigne
PARIS VIII^e
Tél. 359-46-00
Télex : 29 - 242 - CERCA - PARIS



Let us solve your engineering problems

Process development, process equipment design and construction, instrumentation, and other technical services in nuclear and chemical engineering.

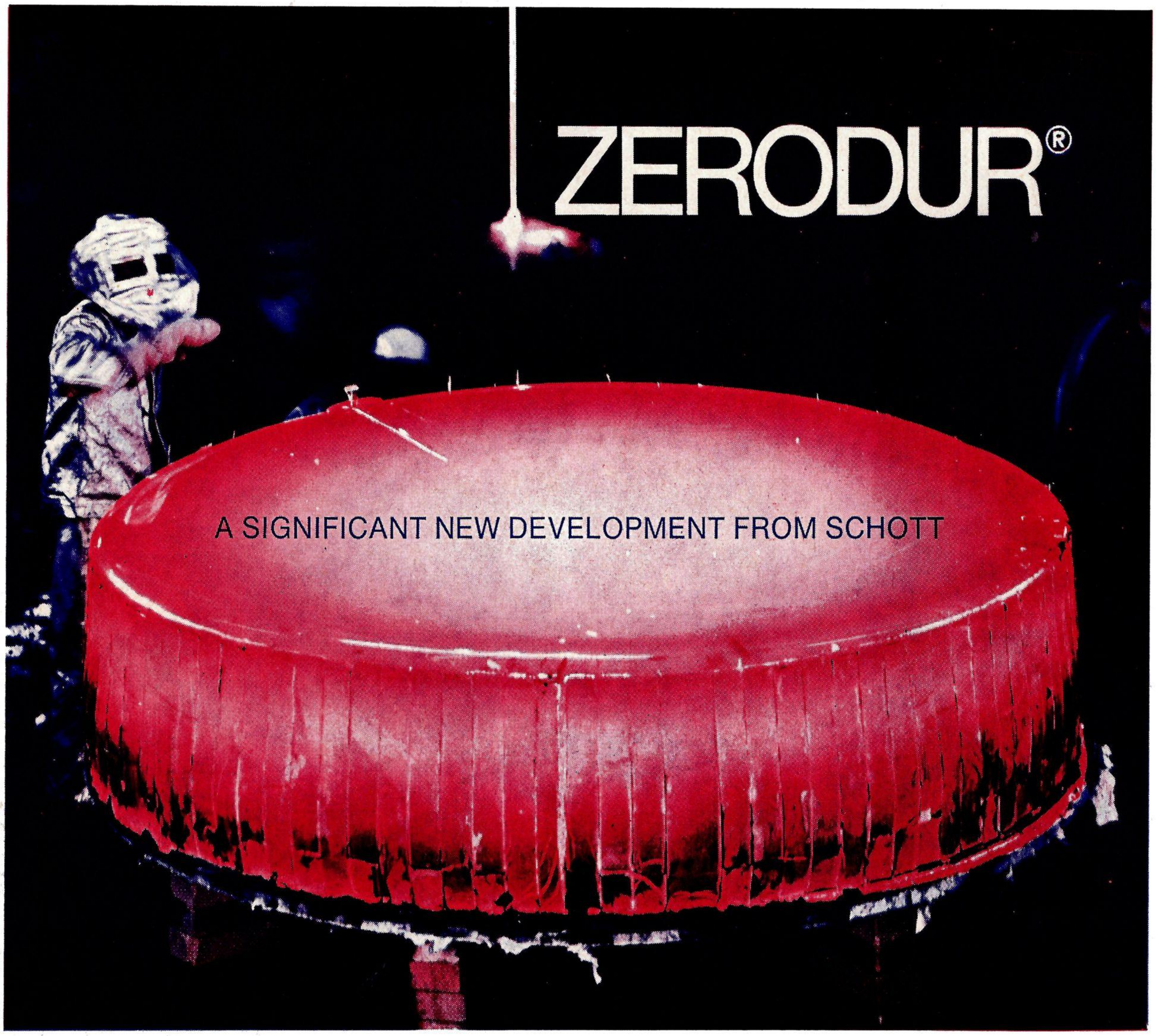
For detailed information contact :

NUKEM

NUKEM GmbH

D-6451
WOLFGANG bei Hanau,
P.O. Box 869,
West Germany.

Telephone : (0 61 81) 500-1
Telex : 4 184 113 nukm d



Opt 27 A

ZERODUR is ideally suited for use in high resolution astronomical telescopes due to exceptional properties inherent to this high-performance material.

ZERODUR is virtually unaffected by temperature variations. It is the zero expansion property of this glassy-crystalline material that permits continuous operation of telescopes and makes thermostats superfluous.

ZERODUR is extremely homogeneous and highly transparent. It offers polishing properties equal to conventional optical glass and is receptive to coatings. Mirror blanks made of this glassceramics are always supplied precision-annealed.

Send for our detailed data sheet and quotation on your specific size requirements.

SCHOTT MAINZ

SCHOTT

JENAER GLASWERK SCHOTT & GEN., MAINZ
(West-Germany)