CERN COURIER

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European Organization for Nuclear Research

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. CERN is one of the world's leading Laboratories in this field.

The experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). At the latter machine, large intersecting storage rings (ISR), for experiments with colliding proton beams, are under construction. 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 their research material from CERN.

The Laboratory is situated at Meyrin near Geneva in Switzerland. The site covers approximately 80 hectares equally divided on either side of the frontier between France and Switzerland. The staff totals about 2950 people and, in addition, there are over 650 Fellows and Visiting Scientists.

Twelve European countries participate in the work of CERN, contributing to the cost of the basic programme, 244.1 million Swiss francs in 1970, in proportion to their net national income. Supplementary programmes cover the construction of the ISR and studies for a proposed 300 GeV proton synchrotron.

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Cover photograph: In the photograph can be seen many of the happy people who thronged the ISR Control Room on the night of Friday 29 October. The centre of attention in the top right hand corner is a monitor, connected to a beam current transformer, which recorded in milliamperes the current circulating in the ISR ring. No-one could reasonably have expected to see any signal that night. In fact it recorded up to 340 mA of stacked beam. The graph of this stack is superimposed (it occurred after midnight, hence the date of 30 October). Time is counted to the left. Thus on the right can be seen the signals (blocks of almost even height) coming from repetitive injection and ejection of twenty bunches from the proton synchrotron. The ejection (beam dump) was stopped and, moving towards the left, the current rises steadily (apart from one or two hiccups) as twenty bunches per pulse are injected and stacked.

Comment

Commissioning storage rings is not quite so clear cut as commissioning an accelerator as regards defining the point at which we say 'it works' and blow a fanfare of trumpets. For an accelerator, the day on which particles are accelerated up to near the design energy is fanfare day; for storage rings it is probably the day on which sufficient particles are stored in each beam with a long lifetime and collided together to give a healthy interaction rate.

The CERN Intersecting Storage Rings project has still a fair way to go — component installation in one of the rings is not yet complete and a great deal of accelerator physics with the two rings remains to be done. But we must sound at least a few trumpets in celebration of the quite remarkable achievements of the night of 29 October when the first injection tests were carried out with the completed ring.

Many months ago the annual shutdown of the 28 GeV proton synchrotron was arranged for the end of the year so that it would be back on the air ready for sending beams to the ISR early in 1971. However, the installation at the ISR had progressed so well that one ring was completed in advance of the shutdown and it was decided to have a few preliminary runs with this ring.

The night of 29 October was the first scheduled run with a few of the PS bunches assigned to the ISR while the rest of the PS beam was in use as usual for the physics programme. The ISR control room was thronged with people, including of course Kjell Johnsen, Director of the ISR Department, and practically all the design and construction team. By some sort of intuition many other CERN people were there also including Bernard Gregory (Director General), John Adams (Director of the 300 GeV project), Kees Zilverschoon (now Director of the PS Department who played an important role in the ISR work until recently), and Hildred Blewett (without whose presence it would be presumptuous to attempt to commission a new machine). Many of them were to relive the excitement of the first operation of the PS eleven years ago. This time the glory goes to the ISR team.

Injection tests with an accelerator usually consist of days or weeks of, first of all, getting the beam to go in properly, and then patiently coaxing it around, correcting and optimizing the magnet fields progressively round the ring. At the ISR it was decided to set up the ring fields and just to see if the beam would get round without going through the coaxing procedure.

Comes the moment, the buttons are pressed, protons are ejected from the proton synchrotron, guided to the ISR, injected into the ring and the very first pulse sails right round and carries on sailing round without any tuning up at all. Probably never before has this happened with a ring of anything like this size (it is about 1 km in circumference second only to the 76 GeV proton synchrotron at Serpukhov) and complexity (the ISR rings, because of the need to store beams circulating for hours, are the most complex ever built). The myriad components in ejection from the PS, in transfer to the ISR, in injection into the ISR, in the magnets and power supplies, in the vacuum system, in the beam monitoring system... were all working from the word go. The design team had proved themselves complete masters of their craft.

Within an hour beam storage tests had been carried out and protons had circulated the ring for over twenty minutes, much longer than had ever been achieved before. Then came the first test of the stacking process when successive pulses from the PS were to be added together in the ISR ring to build up a large stored current. The buttons were pressed and the protons stacked, the current climbing steadily to nearly 60 mA. Protons were stacked for the first time ever at the first attempt.

Did nothing go wrong that night ? Yes. The clock on the control room wall wasn't reliable. It took an hour to find the key to a locked room. These were healthy reminders that human beings were involved. So well did that night go that there was danger of confusion on this point.

We have now brought one ring into action. We are a little ahead of schedule and we are within the budget laid down five years ago. It remains to bring in the other ring and to confront the climb towards a good beamlife, the design beam intensities and design interaction rates. Already intensity dependent effects have been observed and there is a lot of hard work ahead to bring the ISR into operation. In the spring of next year it is hoped to achieve beam collisions. At about the same time the experimenters will start installing their detectors in the intersection regions and in the middle of the year the adventure of the first experiments with high energy colliding proton beams is scheduled to begin.

For our new readers we summarize the main features of the ISR project:

The aim is to achieve virtually head-on collisions between two beams of protons each accelerated to energies of up to 28 GeV by the CERN proton synchrotron. In such collisions all the energy given to the particles can go into the phenomena of interest of the physicist — the transformation of particles and the creation of new particles — and equivalent effects could only be obtained from a conventional accelerator (firing particles onto a stationary target) having an energy approaching 2000 GeV. On the other hand the ISR is limited in the range of phenomena which can be studied and in the rate at which the phenomena occur by comparison with a conventional accelerator.

The way in which the collisions are achieved is to eject protons from the PS, guide them some 500 m along a beam-transfer line and bend them into one or other of two magnet rings 300 m in diameter which are slightly deformed so that they intersect at eight positions. Protons travel in opposite directions in the two rings and the collisions take place at the eight intersection regions.

If only one pulse from the PS (containing about 10^{12} protons) were collided against another similar pulse, the collision rate would be far too low to do useful experiments. It is therefore necessary to 'stack' many pulses from the PS in the rings so that the colliding beams will each contain over 10^{14} protons (the design aim is 4×10^{14} which is a beam current of 20 A in each ring). A radiofrequency system is used to get hold of the protons as they come in and to accelerate them slightly so that they move across the vacuum chamber of the ISR (which has an elliptical cross-section of 16×5 cm^2) to sit alongside the protons which have previously been injected. This is the process known as stacking

When beams of sufficient intensity have been built up, they are kept stored in the rings (orbiting, hopefully, for many hours without their intensity falling too low to be useful for experiments). In addition to such requirements as magnetic fields held constant during the storage time with extreme precision, the vacuum chamber in which the protons circulate must be evacuated to a very low pressure (the design value for the major part of the ISR is 10^{-9} torr) so as to avoid collisions with gas molecules in the chamber resulting in the protons being scattered in the course of many millions of revolutions.

These technical requirements have called for alignment precisions, component manufacturing tolerances, power supply stabilities, vacuum techniques, etc... which are at the very limit of what is now possible.

First beams in the ISR

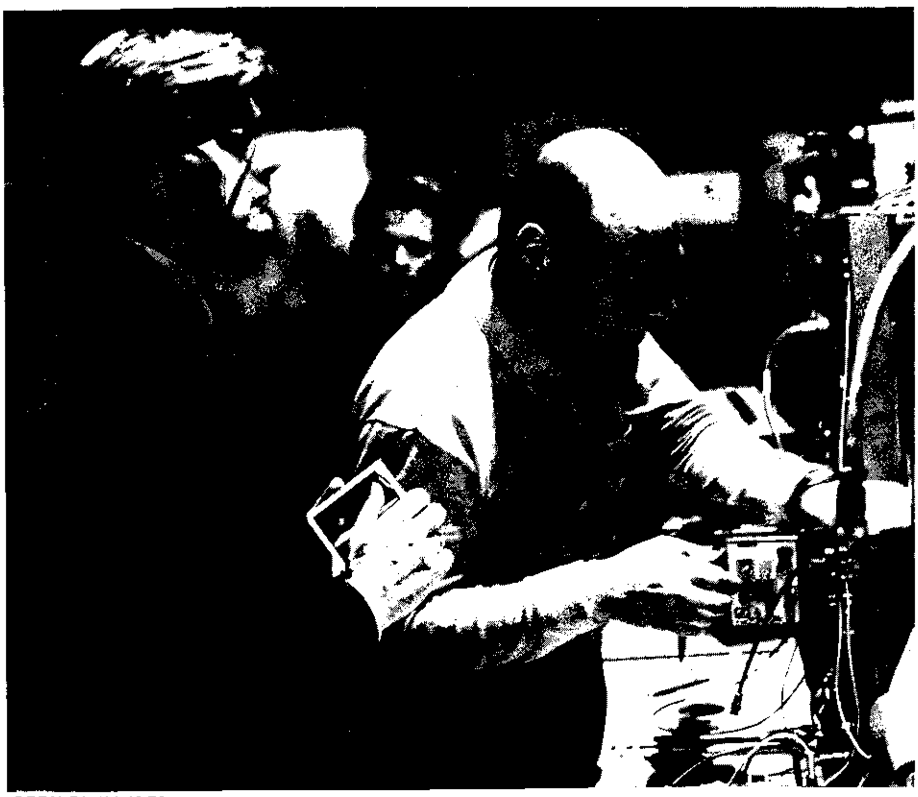
Throughout October, effort at the Intersecting Storage Rings was concentrated on bringing 'Ring 1' into a state where a few tests with beams from the proton synchrotron would be possible before the shutdown of the accelerator in mid-November.

The first run was scheduled for the 29 October and, a few days before, the vacuum system of the ring was completed. About a third of it was 'baked-out' (this involves heating the vacuum chamber to several hundred degrees which effectively de-gasses the inner surface and, given sufficient pumping power, enables very low pressures to be obtained). In the baked-out sections pressures in the region of 10^{-10} torr were being achieved, ten times better than the design figure which itself was regarded as a very ambitious aim a few years ago. The average pressure around the ring was about 3×10^{-9} torr.

For several months tests had been under way on the beam transfer channels to each ring and both were conveying protons ejected from the PS up to the ISR with 100 % efficiency. These tests had also ironed out all problems of liaison between the control rooms of the PS and ISR which was an important thing to have under the belt when the ISR runs started.

The magnets in both rings had been successfully powered in August. Monitoring systems to observe the beam, based on electrostatic detectors (described in detail later in this issue) and beam current transformers were not completed but were in a sufficiently developed state for the initial requirements.

All that was essential for the first runs was ready and working. A series of eight six-hour periods were allocated — during six of them the ISR was a 'parasite' (stealing up to four of the twenty bunches of accelerated protons from the experimental programme in progress at the PS); during two of them the ISR was the 'main user' able to take all twenty bunches at will. It was hoped, at a minimum, to achieve a circulating beam and not much more before the PS shutdown. At a maximum, it was hoped that some beam studies (on such things as closed orbit, Q values, longitudinal instabilities) might begin and,



CERN/PI 521.10.70

Several photographs taken on the night -
1. Kjell Johnsen (left) and Klaus Unser gathering data on beam behaviour.
2. Bas de Raad seemingly caught in the act of announcing the news to the waiting world. Keen eyes may be able to pick out the time, 8.34, on his watch — two minutes after the first circulating beam.
3. 'Not by physics alone doth man live'. The Control Room was a long way from a source of food and drink and was therefore the scene of improvised snacks and clusters of thermos flasks.
4. Crowd scene — many of them rejoicing in the perfect operation of components to which they had given years of work.

at the extreme, it was proposed to attempt some stacking.

The story of the 29 October is perhaps best told in a blow by blow account.

The run was scheduled to start at 20.00 h. The countdown hadn't gone too well. In the afternoon a power cut had slammed all the valves in the vacuum system shut just after they had been opened and inspected. The beam current transformer, an important monitor of the circulating beam was exhibiting stage fright until the late afternoon. When the time came to switch power to the magnets, there was no power. Then came the search for the key (for access to the fault) mentioned in the Comment.

By about 20.30 h all is ready. The PS is alerted to eject protons along transfer channel TT2 to the ISR at an energy of 15 GeV. (Why Channel 2 feeds Ring 1 and Channel 1 feeds Ring 2 is a linguistic nicety we leave to the ISR historians to analyse.) A single bunch per pulse (9×10^{10} protons) is called for. The ISR magnets are set to the theoretically predicted values on the basis of the magnetic field measurements carried out prior to their installation. The beam dump system is set so that if particles go round they can be kicked out safely by the 'dumping magnet' into a cooled block to keep particle loss in the ring and subsequent induced radiation to an absolute minimum.

At 20.32, the injection system is powered. Immediately, to the blank astonishment of everyone, it is obvious that protons are being injected and are circulating the full ring and are continuing to circulate until the beam dump kicks them out, clearing the ring ready for the next bunch from the PS two seconds later. The beam monitors record just over 2 mA circulating, about 60 % of the maximum possible.

20.45. People are beginning to get their breath back. Two bunches per pulse are called for and the circulating current goes up to near 5 mA.

20.58. The first attempt is made to see how well the ring is storing. Two bunches are injected and are allowed to continue circulating — the beam dump is not operated. The monitors record 5 mA falling

CERN/PI 449.10.70

CERN/PI 482.10.70

CERN/PI 492.10.70

5. An animated Wolfgang Schnell (left) tells it like it is to Mervyn Hine and Hildred Blewett.

slowly. The bunches smear out into a ribbon beam which continues to circulate decaying at a rate of less than 1 % per minute. The half-life (the time taken to fall to half the initial intensity) is calculated as 56 minutes.

21.19. The dump system is operated and the monitors click back to zero. Already a world-first has been achieved: a proton beam has been stored for 21.5 minutes, far larger than the 9 minutes previously achieved at the PS during a storage trial several years ago.

More detailed measurements on the beam begin and adjustments of machine settings are carried out. The proportion of the beam from the PS which is successfully injected leaps to about 95 % — the monitors record 8 mA with two bunches injected. Beam parameters such as the closed orbit and the horizontal and vertical Q values are measured, revealing an incredible precision by comparison with the theoretical predictions. The calculated lifetime is in excellent agreement with the value expected at the average pressure prevailing in the vacuum chamber.

The r.f. team disappear from the Control Room into the local control station in the A1 building (the r.f. controls have not yet been connected to the main Control Room) to bring in the acceleration system. When the accelerating cavities are brought on, in very little time, the injected beam is being trapped by the r.f. fields in the ISR and the protons are moved across the vacuum chamber onto wider orbits as they are gently accelerated. The time has now moved beyond midnight. Euphoria prevails and the ISR team decides to really stick its neck out and to try stacking.

30 October, 00.28. Repetitive injection of two bunches from the PS with the beam dump in action. The monitors record 8 mA injected per pulse.

00.29. Repetitive injection continues, the beam dump is switched off, the r.f. system is brought on with a beam acceleration programme which will so accelerate successively injected pulses as to achieve stacking. The monitors record circulating current rising steadily to 57 mA. For the first time protons have been stacked and stored.

CERN/PI 543.10.70

A discussion is held to decide how much current can be allowed. Conditions are arranged to receive a maximum of 500 mA and after consultation with the PS control room the experimental programme at the PS is temporarily halted so that all twenty bunches can be fired into the ISR.

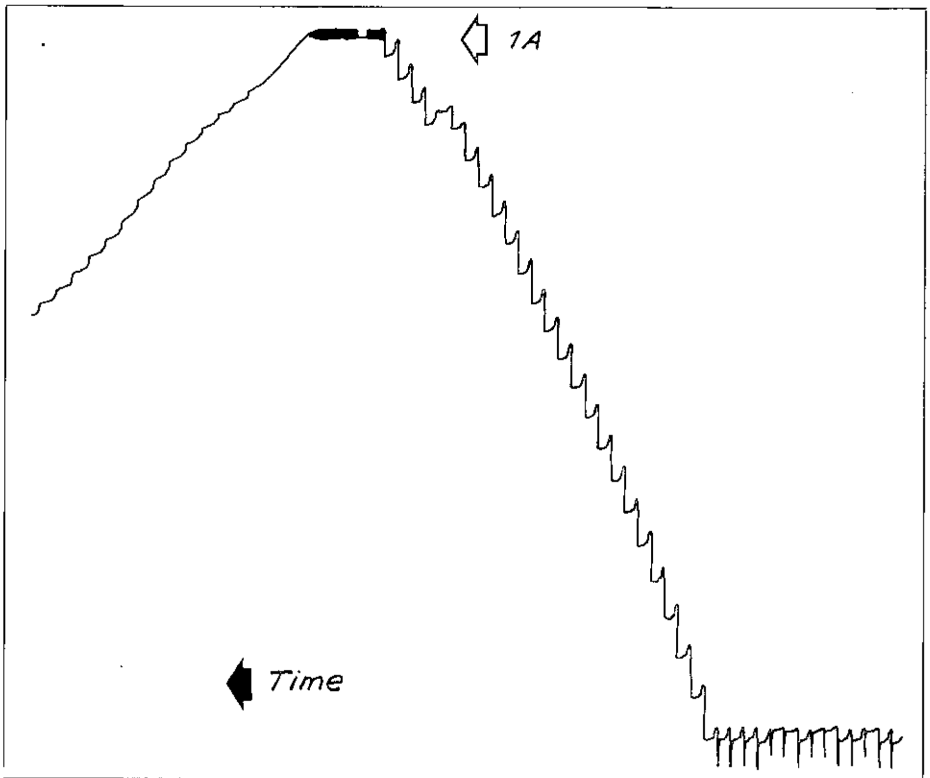
01.13. All twenty bunches are injected and the monitors record 80 mA circulating. The beam dump is in operation. When it has been confirmed that the ring is handling twenty bunches well, it is decided to go for stacking.

01.16. Repetitive injection with the beam dump off. The current climbs to about 340 mA (the graph of this climb is shown on the front cover). Injection is stopped and the beam is watched circulating. The decay rate is faster than with lower beam intensities and the first tremor of apprehension passes through those in the know. They realize that this could spell a lot of work to analyse and master.

01.55. The beam dump is operated and the monitors click back to zero again. Enough for one night's work. Kjell Johnsen records his thanks to the ISR and PS teams for their splendid achievement. One last bunch for good luck is squirted in at 2.00 and kept circulating for quarter of an hour before people retire to bed.

Now we become less chronological in summarizing the results of some of the tests carried out in the remaining runs which ended with two consecutive six hour periods on 13 November. What was astonishing at this early stage was the steady, reliable performance of practically all components which enabled test programmes to be prepared and carried out. In 48 hours of running less than an hour was lost from equipment failures and there was never need to enter the ring for repairs or adjustments.

The peak stacked beam was obtained during the second run. With twenty bunch injection the circulating current climbed to 1.5 A (3×10^{13} protons) which is the most intense proton beam at GeV energies ever achieved. This was not the limit which could be stacked but for several reasons it was decided not to try to climb higher (in fact, apart from this one stack, the current was deliberately kept to 1 A and below for all the tests). The emergency



A copy of the graph produced on 6 November by the pen recorder during one of the beam stacks. Time, as in the graph on the cover, runs to the left. On the right are the signals indicating twenty bunches injected, circulating and dumped. When the beam dump is switched off the current climbs steadily (apart from one hiccup near the peak) to 1 A when further injection is stopped. (The splurge at the top is where the pen was bumping into its full scale ceiling.) On the left can be seen fast decay experienced with the more intense beams accentuated in this case by applying r.f. to the beam for an experiment. Better stacks were achieved, for example, putting in two bunches (8 mA) eighty times yielded 640 mA of stacked beam.

trigger for the beam dump is not yet in operation and if any major component had tripped out there would be no control over where the intense beams were deposited. Also beam scrappers have not yet been installed. One of them protects the moving screen which comes up to shield the stored beam from the field of the injection magnet. The screen was not used when stacking twenty bunches for fear of burning it out if it received an intense beam.

Closed orbit measurements were carried out by taking polaroid photographs of the signals from the 53 electrostatic pick-up stations distributed around the vacuum chamber and carrying out 106 measurements, 53 giving the horizontal positions of the beam and 53 giving the vertical positions (a collection of such measurements is shown in the article on these detectors later in this issue). Eventually the ISR computer will do the donkey work on these measurements.

The results were in excellent agreement with the predictions from the magnetic field measurements. Deviations were within ± 4 mm vertically and ± 10 mm horizontally. Both these values are very comfortably within the specified limits.

Q values were also in excellent agreement with predictions. Q is the number of oscillations about a mean position that a particle executes in making one turn around the machine and is dictated by the focusing magnetic field settings. If Q is an integral value it would mean that, if there is any force at a position in the ring (and there will be) tending to nudge the particle in a particular direction, it will feel the nudge in the same direction each time and, over many turns, will be pushed into the vacuum chamber wall. Similarly half integer values or third integer values are normally avoided since they bring particles back to the same position after two or three turns respectively (known as a second and third order resonances).

During the first run, for example, Q was measured as 8.81 in the horizontal plane and 8.67 in the vertical plane. In subsequent runs there were very important tests where the settings of pole face windings and quadrupoles were altered in small steps so as to induce changes in the Q values. When the values touched a resonance (integer sub-multiples) particle loss from the stored beam was observed. It is believed that such effects were detectable down to sixth order resonances, which imposes much more stringent conditions on setting the Q values in the ISR than ever trouble a conventional accelerator.

The r.f. system performed very well. When stacking, particularly for low intensity beams, the efficiency was better than expected. This is particularly gratifying because no attempt has been made yet, by playing tricks like Q-jump in the PS itself, to produce the best possible bunches, in terms of momentum spread. One of the stacks up to a beam current of 1 A is shown in the graph.

The intensity dependent effects seen on the first night were confirmed in the subsequent runs. In general the higher the stacked current the faster became the beam decay rate. At low intensities the lifetime was in good agreement with the predictions, given the prevailing average vacuum in the ring. Above 100 mA other effects seemed to intervene. One possibility is that the beam was running into high order resonances and certainly changing machine settings to stay clearer of resonances improved the lifetime. There is also the possibility of coupling between horizontal and vertical oscillations. In the last run it was also found that when the r.f. was brought on in the presence of a beam there was a sharp rise in pressure (in to the 10^{-6} torr region) near the r.f. cavities. There may be multipactoring in the cavities from electrons liberated by the beam in ionizing the residual gas. When clearing electrodes (to suck out electrons) are installed, it could help clear this problem.

Overall however it can be said that it has proved comparatively easy to make intense beams but more difficult to hold them once they are made. Further studies on the intensity problems are needed before they are completely understood.

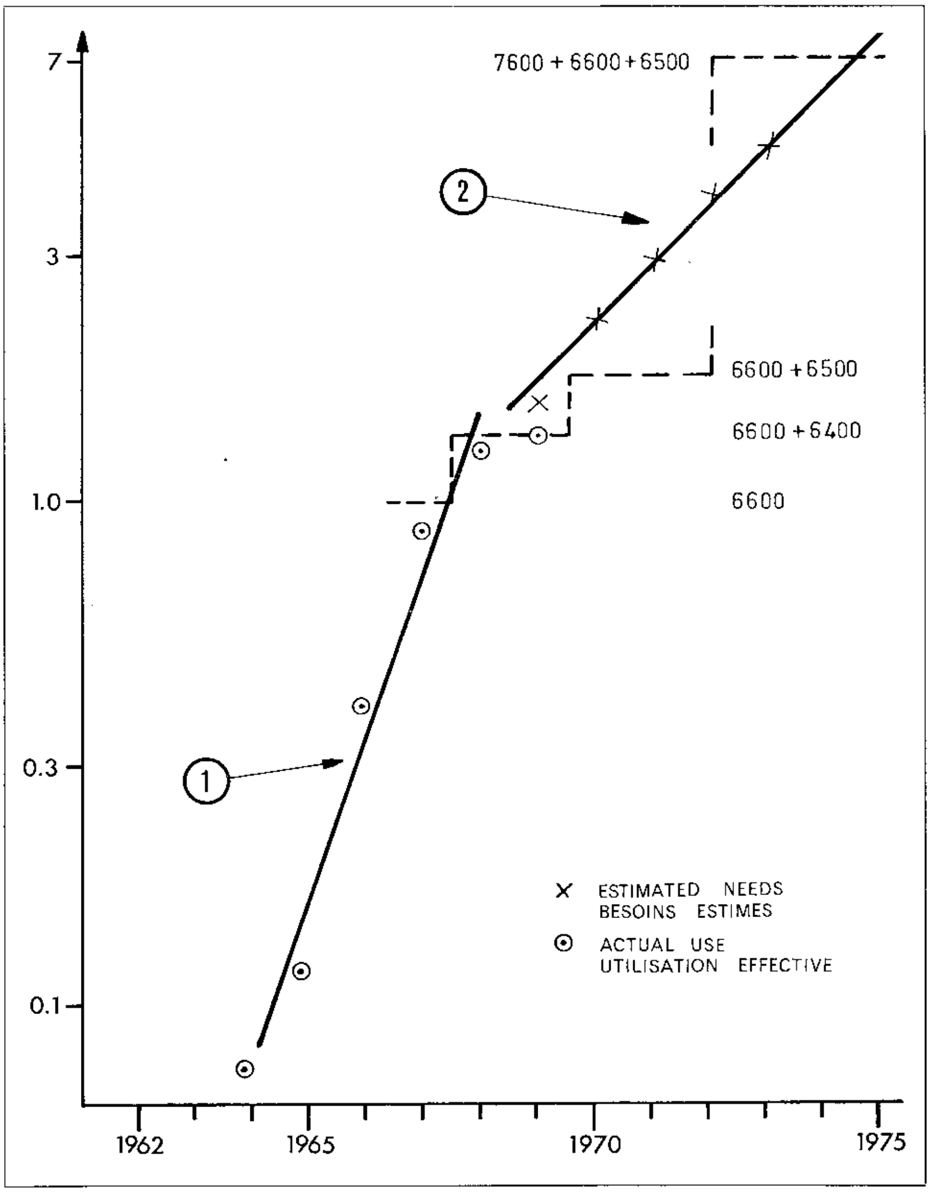
The ISR team are now breathing a little easier after a hectic three weeks, but not much easier for it is intended to start up Ring 2 at the end of January. If all goes well the first attempts at colliding beams will be made at the end of March.

Graph of the development of CERN's computing capacity requirements. The y-axis is on a logarithmic scale taking the capacity of a CDC 6600 as the unit. The first part of the graph represents the years when the requirements were doubling every year; the second part shows that this is now easing off to a doubling every 2 ½ years.

Green light for new computer

There is an ever growing need at CERN for computing capacity. However, whereas the need was doubling almost annually up to 1968/69, the curve is tending to level off and the estimated needs in the immediate future correspond to a doubling every two and a half years. In spite of this levelling-off, the capacity of the present central computers (mainly a CDC 6600 and a CDC 6500) is becoming inadequate and further capacity is needed to meet the foreseen demand up to about 1974/75.

Projections beyond this date are more uncertain, particularly in view of the range of options open for the long-term development of the Laboratory. It seems likely that the demand could well increase by another factor of two by around 1976 and budget planning has already made allowance for additional capacity at about this time. However, decisions on future extension will not be necessary for the next few years.



Following contacts with major computer manufacturers in 1968 (see CERN COURIER, vol. 8, page 204) it was decided that no new large computer was, at that time, in a sufficiently proven state to take a decision on purchase. As an interim measure the existing installation was upgraded by converting the CDC 6400 to a 6500. In the summer of 1969 a further investigation was opened to see what large computers would be available for delivery by late 1971 to cover the estimated computing needs at CERN through to about 1974. These estimates indicated that it would be necessary to triple the presently installed capacity.

This study and the subsequent call for tender showed that the most economical solution was the acquisition of a CDC 7600 which has a computing capacity about five times that of a CDC 6600. A recommendation to purchase a 7600 was submitted to the Finance Committee and approved at its meeting of 17 June 1970.

There is still no computer on the European market providing comparable capacity and, even on the American market, the CDC 7600 is the only one which both satisfies the specifications and is already in service. In addition, the 7600 has the advantage of being compatible with CERN's other large computers.

Negotiations were opened with Control Data to define the exact configuration of the new computer system to be based on the 7600, especially the number of discs and tape units, and the quality and quantity of peripheral equipment. It has been established that the 7600 will be coupled to a 6000 series computer and that considerable importance will be given to remote access (typewriter consoles, display terminals and remote stations providing card-reader and line-printer facilities). These negotiations reached fruition on 20 November with the signature of a contract involving a sum of about 40 million Swiss francs and setting the delivery for February-March 1972.

The CDC 7600

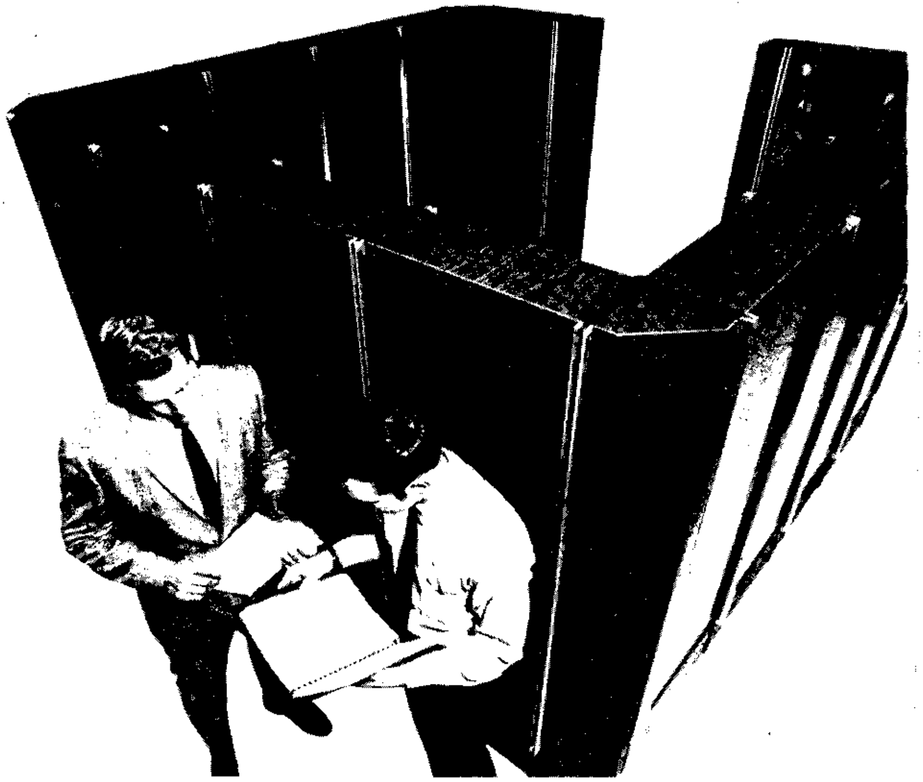
The 7600 is built with 'discrete' components and is a logical extension of the 6000 series. It has multiple-function registers and two ferrite core memories, one of 65 K words of 60 bits plus 5 parity bits and

1. The central unit of the CDC 7600, consisting of central processor, memory, 12 peripheral computers and 15 input and output channels.

2. Section of ferrite memory containing 1024 words of 13 bits, of which one is a parity bit.

3. One of the wafers forming the memory in photo 2.

4. A logic circuit comprising several tens of components. The central processor consists of 28 000 of these circuits.



1.

the other of 512 K words of 60 bits plus 4 parity bits. Input and output operations are carried out via small peripheral computers, with access to part of the small core memory. Unlike those on the 6600, these peripheral computers are independent, and up to fifteen of them may be connected, locally or remotely.

The 7600 is fitted with a maintenance control unit in the form of a peripheral computer which monitors the 7600 operation diagnosing malfunctions. This results in a significant improvement over existing maintenance methods.

The following table compares the main features of the central processors of the 7600 and 6600:

	7600	6600
Word length:	60 bits	60 bits
Main core memory:	65 K words (3.9×10^6 bits)	131 K words (7.9×10^6 bits)
Full cycle:	275 ns	1000 ns
Transfer rate:	1 word/27.5 ns	1 word/100 ns
Large core memory:	512 K words (3.2×10^7 bits)	
Full cycle:	1760 ns	
Transfer rate:	1 word/27.5 ns	
Instantaneous transfer rate of main disc:	3.3×10^7 b/s	8.9×10^6 b/s

The CDC 7600 will be installed in a new building now going up on the ISR site, where almost all the Data Handling Division's computing facilities will be concentrated. Rather than the building being split into many sections for the various functions it will have a single hall. This will ease the difficulties of lay-out of equipment and, in view of the fact that the installation will be constantly changing, this arrangement offers the greatest flexibility. It also simplifies operating problems.

The installation of a complex of this scale presents considerable difficulties which have been studied for many months. All the 7600, 6600 and 6500 central processors will eventually be interconnected and must be clustered close together because of the restrictions on cable lengths for transmitting ultra-fast signals. In addition, there are cleanliness problems due to the fact that certain units (printers, card readers and card punches) produce dust, whereas others, like discs and tapes, are highly susceptible to damage by dust. These problems will probably be solved by installing the dust generating equipment in separate areas.

The computing service cannot be suspended while the transfer of the existing computers to the new building takes place. The 7600 will be the first to be installed in the new building and it will gradually take the load off the existing centre until, after probably six months, a start is made on transferring the CDC 6500 and 6600 to the new centre with all their associated equipment. The transfer of the whole installation is currently planned to be completed by early 1973.

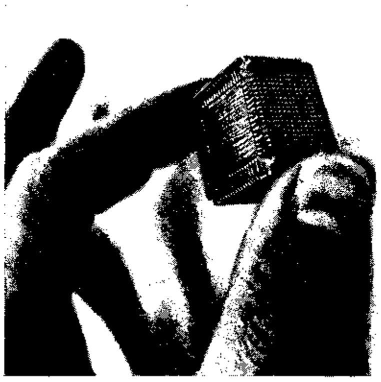
PS Shutdown

The annual shutdown of the 28 GeV proton synchrotron began on 15 November and will continue to the beginning of January 1971. As usual, the jobs to be done are too numerous to list individually and only some of the most important ones will be mentioned here.

Linac

The work within the general framework of the improvements programme, which is aimed at increasing the pulse length of the linac from 20 to 100 μs and preparing to feed the 800 MeV Booster, will be continued. This involves:

— modifying the compensation system,



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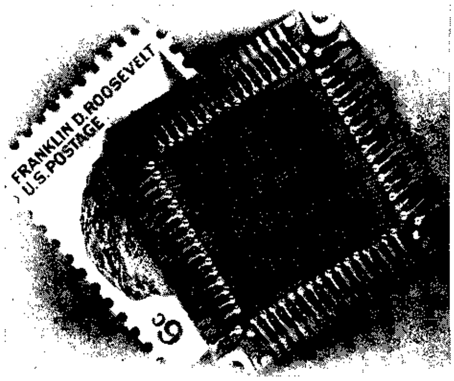

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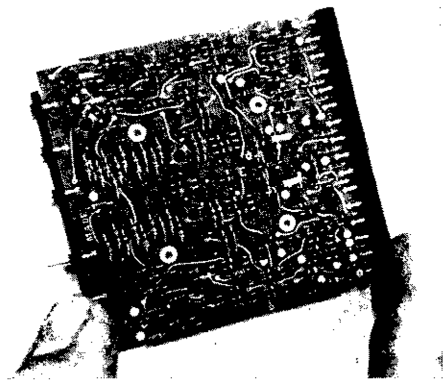

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which will become servo-controlled, for the charge induced by the passage of the beam in the 500 keV accelerating column;
— modifying the main r.f. supplies to the three linac cavities, to the buncher and to the debuncher;
— modifying the r.f. circuit used to compensate the beam charge in the cavities;
— modifying the supply to the pulsed quadrupoles of the first accelerating cavity;
— installing the beam transport line from the linac to the Booster and the beam line for beam emittance measurements (see vol. 10, page 279) — a magnet will be replaced allowing the beam to be directed either towards the PS or towards the Booster, where it can be further deflected towards the emittance measuring beam line;
— reorganizing the linac control room.

PS ring

The work here involves some necessary maintenance and improvements particularly in readiness for coming higher intensity beams:
— fitting ion pumps in sectors 5 and 6 of the ring (sectors 1, 2 and 4 are already almost fully equipped) involving modifications to nine straight sections and the vacuum chambers in five magnets;
— modifying the vacuum chamber of fast ejection beam 74 (for which magnet 74 must be removed);
— replacing magnet 8, which has been seriously damaged by radiation, by a spare one (see vol. 10, page 227);
— trials on a method (which could reduce the number of magnets to be removed) in which the vacuum chamber is cut out of the magnet and refitted by welding again in situ;
— installing new straight sections (100, 1 and 8) to supplement the number of ion pumps, and changing the vacuum chamber in magnet 100;
— replacing a septum in straight section 43 for slow ejection studies and fitting a prototype electrostatic septum in straight section 66;
— many cabling jobs, particularly in anticipation of the installation of new dipoles, the new r.f. acceleration system and slow ejection system 16 (to supply the West Experimental Hall);
— construction of a building above straight section 45 for the fast kicker power supply which will control the transfer of the Booster beams into the PS;
— bringing Booster controls into the main control room.

Experimental halls

Two major changes are under way in the East Hall. First, the spectrometer beam-line for secondary particles from a hydrogen target in e7 is being removed. Two new beam-lines are to be installed for the future. One of them, e9n, will feed a target from which a hyperon beam-line will emerge (see vol. 10, page 281); the other, e9s, will feed a target for a neutral kaon experiment comprising a spectrometer and large proportional spark chambers. Second, the b18 secondary beam-line which supplied particles for tests on detection systems is being removed.

Nearly all the work to be done on the 2 m chamber, situated at the end of the East Hall, will consist of normal maintenance, mainly because of the limited amount of time available (six to seven weeks) in view of the necessary re-heating after the shutdown and the recooling before start-up. The main items to be overhauled will be the expansion system (with which ten million expansions have been carried out since the previous overhaul about two years ago), the compressors, the vacuum systems, the cooling system and the hydrogen refrigerator.

There are no changes in the North Hall and experiments with the 81 cm hydrogen bubble chamber will continue until the middle of 1971.

The main change in the South Hall relates to beam q9, used until now for medium-energy pions. An electrostatic separator will be added to it to allow it to be used to select negative kaons and medium-energy antiprotons. The experiment which will use this beam also requires a very flat platform, to take a large analysing magnet.

Bubble chambers

On 5 November the BEBC group celebrated the completion of the first pole of the superconducting magnet for the large European hydrogen bubble chamber. In all, 23 pancakes of the superconducting coil had been wound (that is a few more than the 20 required to construct a pole). In addition to CERN staff members involved in the project, there were also representatives of the main suppliers at the celebration.

On this occasion it was noted that the rewinding of one part of the pancakes (see CERN COURIER vol. 10, page 278), had been carried out in less than six weeks, thanks particularly to the efforts of the coil winding section. At this rate, the total of 40 pancakes will have been reached by the middle of December.

This little meeting was entertained by the showing of two films taken during the manufacture of the 66 km of superconducting strip by each of the firms sharing production (Siemens and Thompson-Houston). It was possible to make an interesting comparison between the different methods used by the two firms to produce items of essentially similar specifications. The superconducting strip is one of many examples in the construction of this chamber of the very effective collaboration which research workers and industry have established for solving difficult technological problems.

In the next phase, the two poles (weighing 100 tons each) will be transported to the hall of the chamber. The pancake stacks will then be placed in the cryostats (delivered to CERN some weeks ago) early in 1971.

About four million photographs, including 2.1 million in deuterium under double pulsing conditions, have been taken in 1970 with the 2 m chamber. This period of operation has been marked, not only by the use of deuterium and double pulsing, but also by the excellent quality of the photographs and by the fact that the chamber was able to receive low-energy particles (0.8 GeV). The latter two features were the results of modifications to the chamber carried out during the 1969 shutdown.

The total number of photographs taken in the 2 m chamber by the end of October had reached the figure of 3.5 million distributed over twelve experiments with which twenty-one European research

A photograph taken in October during the winding of the coil of the superconducting magnet for the 3.7 m European hydrogen bubble chamber. The coil is built up of several strips (for cooling, insulation, reinforcement and heating). One pole of the magnet is now completed.

centres were associated, as listed in the table.

The 81 cm chamber has also worked very well without any sign of old age despite having now been in action at CERN for almost ten years, during which time it has clocked up over 15 million photographs. In 1970, 2.2 million photographs (668 000 of them in deuterium) were taken with the chamber — more than in any other year of its existence.

These photographs, taken using antiproton and negative and positive kaon beams of between 600 and 800 MeV, supplied three experiments — those carried out by CERN-Collège de France, CERN-Heidelberg, and Bologna-Glasgow-Rome-Trieste groups.

The 1.1 m CERN heavy liquid bubble chamber has been wheeled into a corner after almost ten years of operation for physics. Its retirement from active service was feted at the beginning of November by the team which has operated it and carried out experiments with it.

The chamber took its first pictures in November 1960 and has clocked up over ten million since then. Major physics experiments have included the study of the ksi zero and the identification of an excited state of this particle using one of the first high energy kaon beams, the observation of the decay of the long-lived neutral kaon into two neutral pions and a measurement of the decay rate in the elegant X4 experiment, and, of course, the two neutrino experiments in 1963 and 1967 which added a great deal to our current knowledge of neutrinos.

The heavy liquid bubble chamber has for long been the largest volume chamber in operation in the world. But now it gives way to the much bigger new generation of chambers — the large European hydrogen chamber and the heavy liquid Gargamelle at CERN, the large hydrogen chambers of Argonne and Brookhaven.

In describing the optical system of the Gargamelle heavy liquid bubble chamber in the last issue (page 312) we assigned the computer program used for optimization of the lenses to W.T. Welford. In fact the program was worked out by C.G.

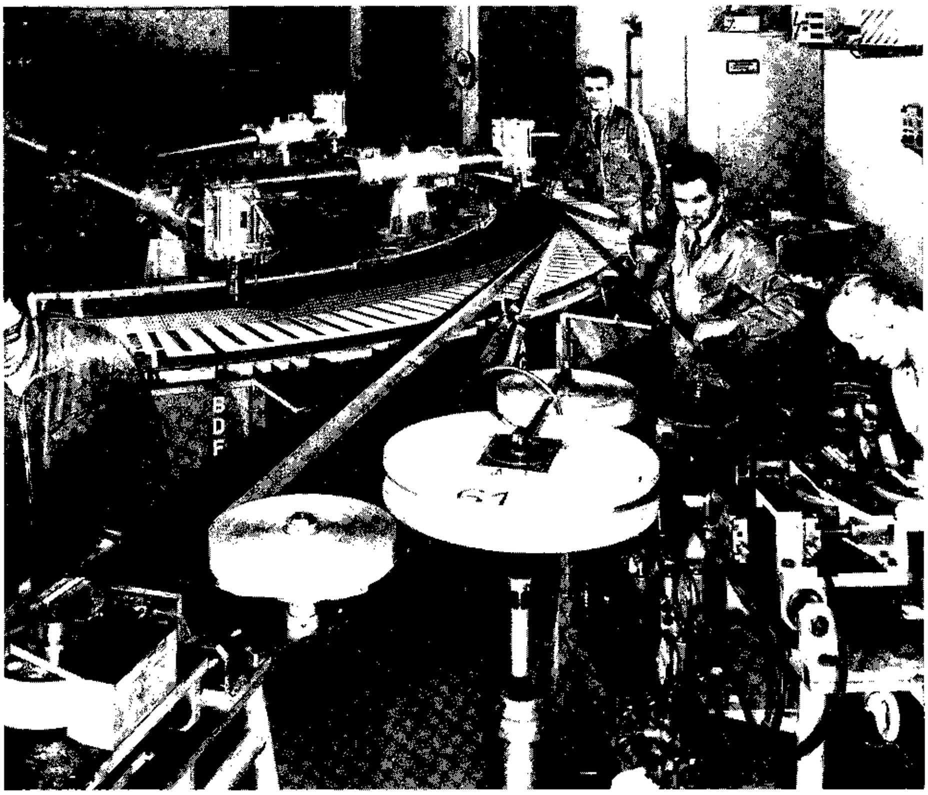
Operation of 2 m bubble chamber in 1970
(up to end of October)

Chamber filled with hydrogen

Beam	No. of photos	Laboratories
K^-, 1.4 - 1.7 GeV/c	100 000	CERN, Heidelberg
K^+, 1.2 - 1.8 GeV/c	447 000	CERN, Saclay
K^-, 0.8 - 1.4 GeV/c	442 000	Rutherford
$\bar{p}$, 1.5 - 2.0 GeV/c	449 000	Glasgow, IPN Paris, Lausanne, Liverpool, Neuchâtel
	1 438 000	

Chamber filled with deuterium

Beam	No. of photos	Laboratories
K^-, 1.2 - 1.8 GeV/c	456 000	Birmingham
π^-, 9.0 GeV/c	324 000	Bari, Bologna, Florence, Paris
K^+, 8.25 GeV/c	298 000	Brussels, IPN Paris, Saclay
π^+, 4 GeV/c	458 000	Birmingham, Durham, Rutherford
p, 19.2 GeV/c	81 000	Alma Ata
$\bar{p}$, 9.0 GeV/c	153 000	Strasburg
K^+, 5.45 GeV/c	246 000	Oxford
$\bar{p}$, 19.2 GeV/c	60 000	Scandinavian collaboration
	2 076 000	



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On the right:
Hand-plotted results on the shape of a closed orbit (radial to the left and vertical to the right) from data given by the fifty-three probes in the ring. The values were individually recorded for each probe on photographs of type 1. The estimated accuracy is ± 1 mm vertically and ± 1.5 mm radially.

Wynne. Welford as stated, has worked on the Argonne 12 feet chamber being responsible for the overall optical system.

The administrative computer

CERN first considered the use of computers in administration in 1965-66 (see CERN COURIER vol. 6, page 157) when the foreseeable growth of the administrative load was examined in conjunction with the possibility of using a computer to shoulder much of the load. The study came down clearly for the acquisition of a computer specifically for administrative purposes — it became known as the ADP project (Administrative Data Processing).

In 1967 an IBM 360/30 was installed at CERN and it was planned to bring into use an integrated information system by 1972. By 'integrated' is meant that the wide variety of tasks to which the computer can be applied will be as inter-related as possible in their use of the computer so that, for example, a piece of information fed in from one source will be accessible for other needs without need of duplication. Such a system is characterized by 'one-time data capture' where the information is fed to the computer ideally from the point where it is first generated and by means of data links then becomes accessible for many purposes.

The aim of the ADP project is twofold: 1) to provide better (faster and more accurate) information at the various levels of management and administration;
2) to absorb the increasing workload of the growing Laboratory without need to increase the clerical staff in the same proportion.

Achieving the final goal has been planned in two phases. The first phase, scheduled to last from two to four years, consists of progressively converting the computer system on a batch processing basis to tackle administrative processes previously handled by conventional methods. The second phase will carry the conversion further to achieve an integrated system.

The first phase will be completed this year when all the major CERN administrative applications will make use of computers. The Table lists these applications, the computer currently in use, and the date when the integrated version using the ADP computer is scheduled.

The present situation is only the basis for phase two of the overall plan. It is intended to design and implement, mainly in the course of 1971, new versions of several applications which are already computerized, in order to reach a substantially integrated system in the course of 1972. If this programme succeeds as expected, CERN will have built up an integrated information system over about five years (a time which is considered to be good by major management consultants in this field).

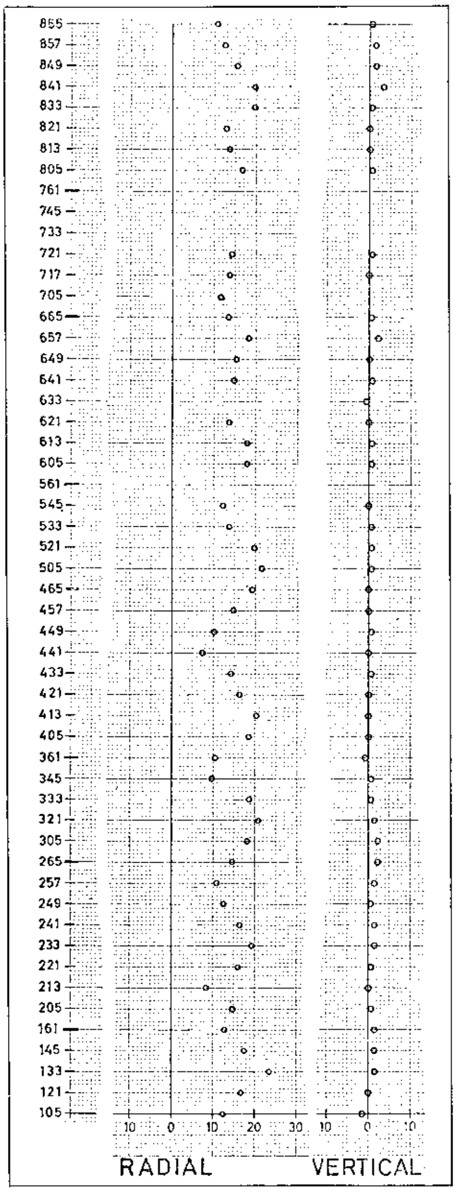
Concerning the economy in clerical staff, which it was hoped would be achieved by having the ADP computer, CERN counted 92 man-years in 1966 which could be directly affected by the ADP computer system. It was then predicted that these 92 man-years would grow to 165 in 1971 if no computer was available and only to 110 if a computer was installed. The actual figure for 1969 was 111 man-years and this figure, which includes 25 people in the ADP group itself, should not increase.

Application	*Computer used now*	*Year of implementation*	*Year foreseen for integrated version on IBM 360/30*
1. Stock control (stores)	IBM 360/30	1968	1971
2. Personnel records	IBM 360/30	1968	1971
3. Medium-term planning procedure (FPP)	IBM 360/30	1969	1971
4. Overall purchasing, accounting and budgetary control	IBM 360/30	1970	1971
5. Salaries	NCR 390	1966	1971
6. Job cost control	IBM 360/30	1970	—
7. Scientific documentation (reports and preprints)	IBM 360/30	1969	—
8. Project planning (PERT)	CDC 6600 and IBM 360/30	1969	—
9. Buildings and space inventory	CDC 6600	1969	1971
10. Electronic instruments inventory	CDC 6600	1968	—
11. Machine-tools inventory and loading	CDC 6600 and manual	1970	1971
12. Personnel monitoring/radiation (health physics)	CDC 6600	1965	(1972) ?
13. Various technical applications	manual and CDC 6600	—	1971/1972

Beam observation in ISR

The Intersecting Storage Rings are equipped with a beam observation system based on electrostatic pick-ups similar to those used in the PS (see CERN COURIER vol. 9, page 304). They produce a measurement of the beam position during the first turns following injection, and, with higher precision the orbits averaged over many turns. The system is indispensable to ensure maximum efficiency in the stacking process. It consists of 106 detectors (53 per ring), whose signals can either be seen on an oscilloscope giving information on the wide-band signals, or can be analysed by computer to achieve more precise information.

Each pick-up consists of two combined pairs of electrodes on which signals are received when a proton bunch passes directly proportional to the charge in the bunch. Moreover, the electrodes have been so designed that each pair gives a signal directly proportional to the position,



vertical or horizontal, of the 'centre of gravity' of the beam, anywhere in the aperture of the machine.

An original feature of these probes is that the electrodes are in the form of a balanced bridge, which makes it possible to neutralize the capacitive coupling between the electrodes and consequently to eliminate the guard rings which would otherwise be necessary in order to isolate the vertical and horizontal pairs of electrodes.

Though the design concept is traditional the pick-ups have been adapted to certain factors peculiar to the ISR. Thus they must be of high mechanical precision, and withstand being heated to 350° (being used in ultra-high vacuum). This limits construction materials and the electrodes have been produced in the form of stainless-steel plates held by specially designed aluminium oxide and stainless-steel supports. The coaxial feed throughs are also made from these two materials which also have a very high radiation-resistance.

The resonance frequency of the electrodes lies between 250 and 300 MHz, well beyond the frequency band which is used, between 2 kHz and 100 MHz.

The units are designed to work on a beam of protons grouped into bunches, as they are on injection into a ring; on the other hand they are not affected by the debunched beam which also circulates in the chamber (the stacked beam). One of the characteristics of the ISR is that they contain, at the same time, two types of beam which can thus be distinguished.

Information from the pick-ups can be handled in two ways :

1) In the video system, signals appear on an oscilloscope in the ISR control room. Signals coming from the 106 detectors can be selected via remote-controlled switches.

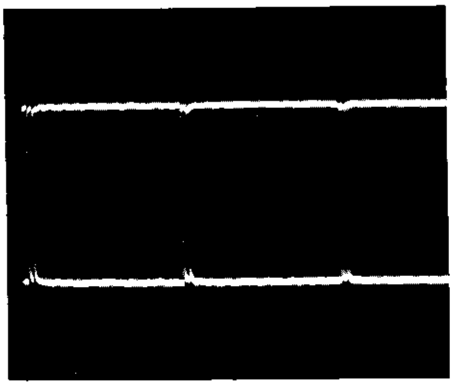
Signals from a vertical or horizontal pair of electrodes appear simultaneously on a double track oscilloscope, so that the position can be read off directly (although not with high accuracy), and the signal gives much information about the beam dynamics.

2) In the precision system which is connected to a computer, signals are converted and analysed in such a way that the complete orbit can be shown on the computer screen.

The careful construction of the pick-ups, amplifiers and signal processors makes possible a resolving power of 0.1 mm and, taking into consideration mechanical inaccuracies and positioning, an absolute precision of ± 0.5 mm.

The installation of the detectors and their controls is complete for Ring 1, and they were used in the first commissionning tests. For these tests, only the video system was in use; it gave excellent results both for the form of the signal (beam intensity, bunch form), and for orbit analysis, (betatron oscillation corrections, position measurements, observation of stacking etc.). The system will be completed in March 1971.

Photographs 1, 2, 3 and 4 show signals received from the electrostatic probes during the injection trials at the ISR.
1. Signals from the two electrodes of a probe placed where the beam enters the ring. On the left is the signal corresponding to the first passage of the beam (consisting of two bunches) on which the inflector pulse has not yet acted and which is travelling near the inside wall of the vacuum chamber. One revolution later, the inflector has acted and the beam is near the centre of the vacuum chamber. It then orbits in this position.
2. Signals from the two radial electrodes of a probe during stacking followed by debunching of the protons. The time scale here is a million times more concentrated (there are about three million revolutions recorded in the photograph). On the left, the bunched beam is centred in the chamber. It is then gradually shifted towards the outside of the chamber still in bunches. Thereafter it debunches, resulting in a considerable reduction in the intensity of the observed signals.
3. Signals from one of the two radial electrodes of a probe and corresponding to the successive injections of two bunches.
4. The sum of the signals provided by two radial electrodes on one sweep of an 'empty bucket' through the beam. The peak-to-peak value corresponds to the density of the stored beam as a function of energy. The current was 200 mA.



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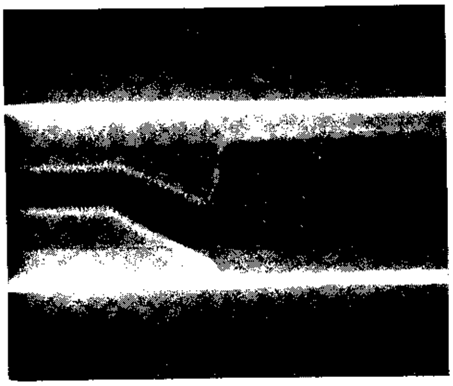

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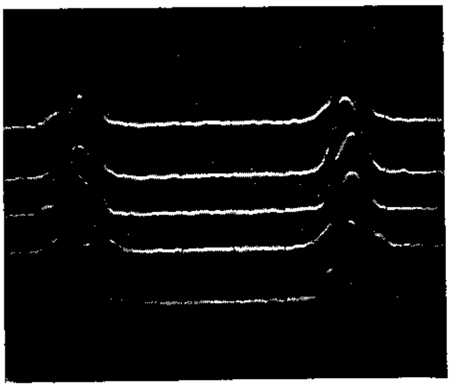

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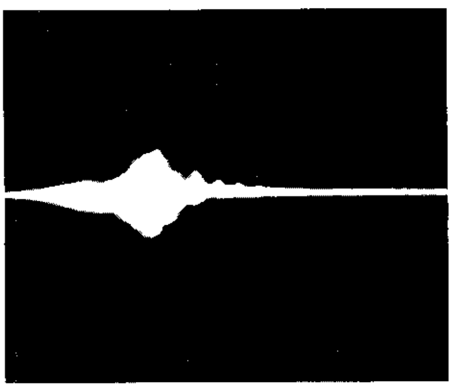

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HYBUC coming together

A small high field bubble chamber, specially designed for an experiment to measure the magnetic moment of the positive sigma hyperon, is now being assembled at CERN. The experiment will be carried out by a team principally from the Max Planck Institute, Munich, with the Niels

A simplified schematic diagram of HYBUC (the hydrogen is under way. The superconducting assembled at CERN. The positioning of the superconducting coils, the camera and expansion systems, and the evacuated 'finger' where the beam enters, can be seen.

Bohr Institute, Copenhagen, and Vanderbilt University, USA. Most of the components of the chamber could be used in further hyperon magnetic moment measurements and it has therefore been baptised 'HYBUC' for HYperon BUbble Chamber.

The values of the hyperon magnetic moments provide important checks of various theories of the electromagnetic structure of particles. There are many predictions of each of these values coming from theories based on current algebras, the quark model and SU3 symmetry. Precision measurements of the magnetic moments and comparison with the well measured magnetic moments of the proton and neutron are therefore a way of selecting between the theories.

Just recently a result has emerged from the Ankara, CERN, Lausanne, Munich, Rome collaboration who used the nuclear emulsion technique in improving the accuracy of the measurement of the magnetic moment of the lambda hyperon. The experiment was described in some detail in vol. 6, page 86. Their result gave the magnetic moment as -0.70 ± 0.09 nuclear magnetons which compares with the previous world average of -0.73 ± 0.20. It would be hard to push the lambda measurement much further and the HYBUC team are concentrating initially on the positive sigma hyperon where the best measurements to date have an accuracy of about ± 1.0 nuclear magnetons and give a world average value of $+2.57 \pm 0.52$ nuclear magnetons. It is hoped that this can be improved to an accuracy of 0.15 nuclear magnetons or even as far as 0.10.

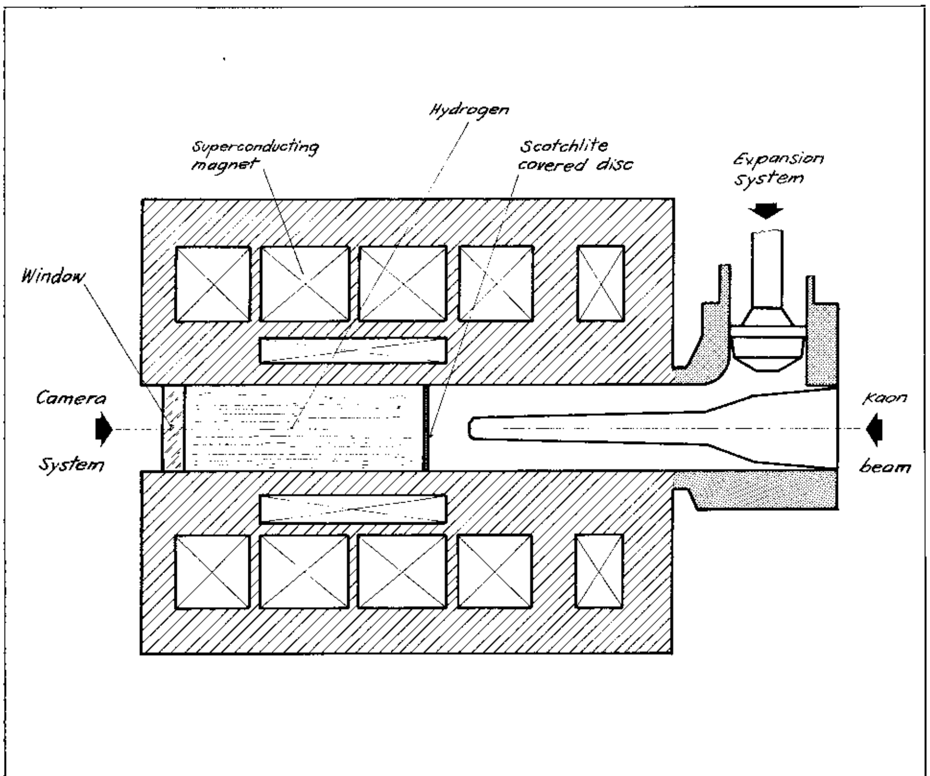
The experiment will proceed as follows. A specially designed pencil beam containing 20 to 30 negative kaons of momentum about 500 MeV/c will be produced from a beam-line in the North Experimental Hall at the 28 GeV proton synchrotron. It will be directed along the axis (parallel to the magnetic field) of a small hydrogen bubble chamber where interactions with protons will produce positive sigmas polarized perpendicular to the magnetic field.

$$K^- + p \rightarrow \Sigma^+ + \pi^-$$

The kaon beam momentum has been selected to give a maximum yield of polarized sigmas.

The sigmas, which have a lifetime of 10^{-10} s, will travel about 1.5 cm in the chamber before decaying. During this time the polarization direction will precess in the magnetic field (swinging around like the finger of a clock) and the amount by which it precesses is directly proportional to the magnetic moment of the sigma and to the strength of the field in which it travels.

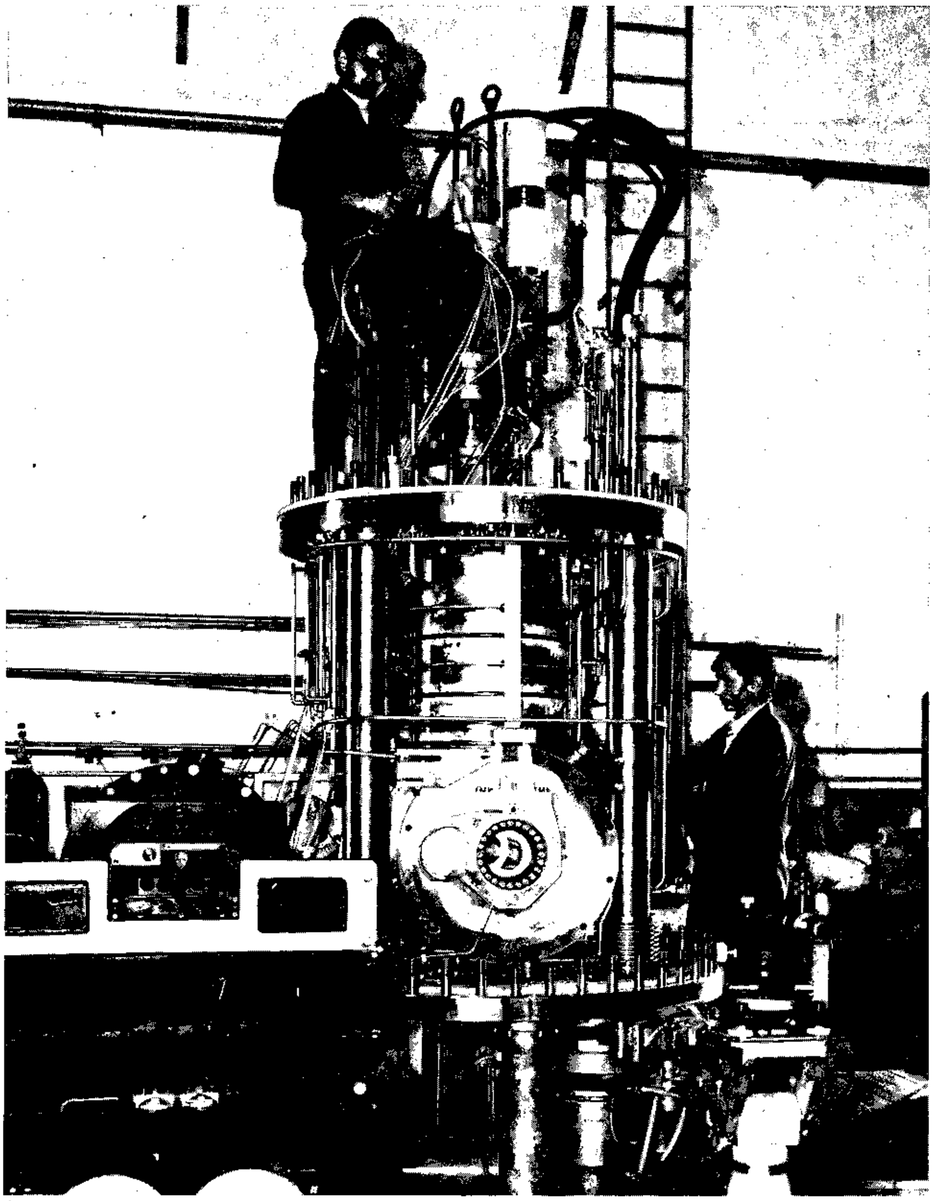
Approximately half of the sigmas will decay to give a proton and a neutral pion. The proton and pion must emerge in the same plane (to conserve momentum) and this is known since the proton, like the sigma, will leave a track in the chamber (the neutral pion will almost certainly escape unobserved before converting into charged particles). The plane containing the most probable directions of emission of the proton and pion is the plane into which the sigma polarization direction has processed. Analysing the bubble chamber pictures thus gives enough information to be able to calculate the magnetic moment. From somewhere near a million pictures it is hoped that sixteen thousand showing the event sequence required can contribute to the calculation.



Description of the bubble chamber

The major features of HYBUC are illustrated in a simplified way in the diagram. The useful hydrogen volume is 32 cm long and 12.8 cm diameter bounded at one end by the optical window and at the other by a freely suspended disc covered with Scotchlite. Within most of this volume the magnetic field is parallel to the axis of the cylinder along which the pencil beam enters. The chamber body, which has been built in the CERN central workshop, extends beyond the useful volume into an expansion region and the pressure changes are applied via a hydraulically driven piston made of laminated epoxy. Positioning the expansion system away from the useful volume makes it possible to crowd magnet coil all around the volume. The chamber can pulse as many as ten times per second and several pictures could therefore be taken in one PS cycle. To retain the beam travelling in vacuum for

HYBUC being prepared for its initial tests with nitrogen. The tests went well and conversion to hydrogen is under way. The superconducting magnet constructed in the USA is expected to arrive at CERN shortly.



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as far as possible a 'finger' which is evacuated, extends into the expansion region almost as far as the useful volume.

The optical system consists of one viewing lens (objective) on the axis of the chamber and four others positioned around it. All five views are brought onto a single film. The film transport system is an extended version of that developed for the CERN 2 m chamber.

Perhaps the most interesting technical feature of the chamber is the superconducting magnet which is designed to give a field of at least 110 kG at the centre of the chamber. This probably ranks among the highest fields (not pulsed) over such a volume ever attempted. The magnet consists of a three part system of coils. A set of outer coils (28 cm inner diameter, 47 cm outer diameter, 48.2 cm long) is constructed of niobium-titanium superconductor designed to produce a field of 70 kG at its centre. Within the bore of these coils is another coil (with dimensions 17.8 cm inner diameter, 26.4 cm outer diameter, 27 cm long) constructed of niobium-tin superconductor. Niobium-tin will retain its superconducting property within the field produced by the outer coil and should itself add up to 50 kG to the field.

A further niobium-titanium coil at the expansion end of the chamber completes the magnet system. It will produce a field in the opposite direction to the other coils so as to bring the field where the beam enters to a low level.

The magnet has been manufactured in the USA and is the joint property of the Max Planck Institute and Vanderbilt University. When the experiment at CERN is concluded it is expected to return to the USA to be used in an experiment at Brookhaven. This would also be concerned with the sigma magnetic moment and would involve operation of wire chambers inside the magnetic field.

During the design and construction of the bubble chamber, the HYBUC team benefited from the close collaboration of members of the Track Chambers Division at CERN and in particular of the group constructing the large European bubble chamber (BEBC).

Assembly of the chamber, without the magnet, began at CERN at the beginning of September and tests with liquid nitrogen have been completed satisfactorily so that tests with liquid hydrogen can now proceed. The magnet, which is now complete, has been undergoing acceptance tests in the USA and is expected to arrive at CERN shortly. If all goes well the chamber will be moved into the North Hall early next year, where further tests will be carried out on a beam before it takes up its final position for the experiment.

Adiabatic trapping

Experiments are being carried out at the proton synchrotron on a new method of 'trapping', for further acceleration, the particles which are injected into the machine. To see the advantages of this method requires a brief discussion of the phenomenon of trapping itself.

The linac sends into the PS what can be considered for the purpose of this discussion as a continuous ribbon of protons, the width of which is mainly governed by the energy spread of the particles around the linac energy of 50 MeV (those with the highest energy occupy larger radius orbits and vice versa).

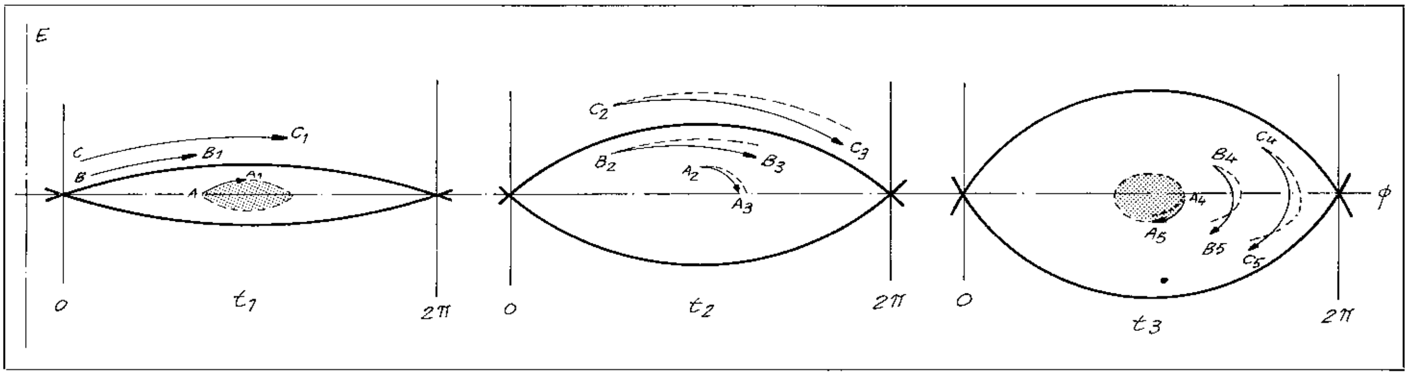
The accelerating voltage applied in the synchrotron ring is sinusoidal and the r.f. accelerating system can only trap and accelerate those particles arriving at the r.f. cavities during certain intervals of time when the voltage in the cavities is right. The beam is thus cut into pieces where trapping takes place. The trapping zones can be represented on a graph of energy plotted against phase and, because of their shape, they are nicknamed 'fish'. When the PS first came into operation, the r.f. system was such that only about 50 % of the injected particles could be trapped in the fish and this theoretical figure was not reached in practice.

In 1960, it was found that higher trapping rates could be achieved by a preliminary concentration of the particles into regions of the beam by initially tuning the r.f. to a slightly different frequency from the one corresponding to the passage of the protons through the cavities. By coinciding these regions where protons are concentrated with the fish gives a theoretical

1. Three diagrams illustrating three stages of adiabatic trapping. The r.f. voltage increases progressively, while the stable phase is maintained at zero. Particle trajectories deviate towards the centre, both outside and inside the 'fish'. The particles inside (A) describe ellipses of ever-diminishing width and increasing height, whose surface-area decreases progressively until it reaches a minimum. The particles outside (B and C) also show this centripetal tendency, which brings them so near to the boundry of the fish that a tiny increase in its surface-area captures them. It is the small increases in the voltage applied to particles as they pass successive accelerating cavities which cause the trapping.

2. At the top of the photo, is the r.f. voltage as it grows during adiabatic trapping. At the bottom, is the contour of a proton bunch recorded at the same time; the size of the bunch is very stable.

3. and 4. Computer print out simulating two types of trapping. 3. represents the situation at the end of a 'gross trapping'. The proportion of particles in the fish is smaller than that left outside which will be lost. There is also significant dilution. 4. represents the situation at the end of adiabatic trapping (not perfect because of the limitations in applying this method at the PS); the proportion of particles captured is much higher, and dilution is low.



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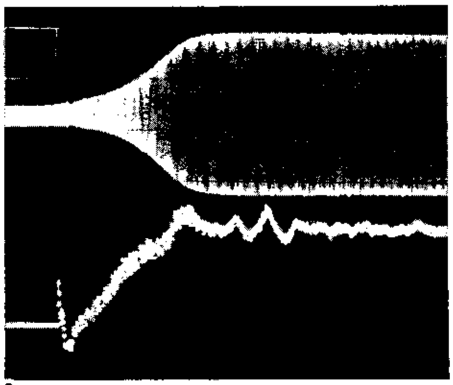
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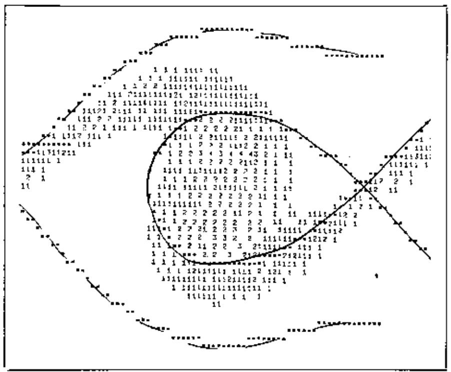
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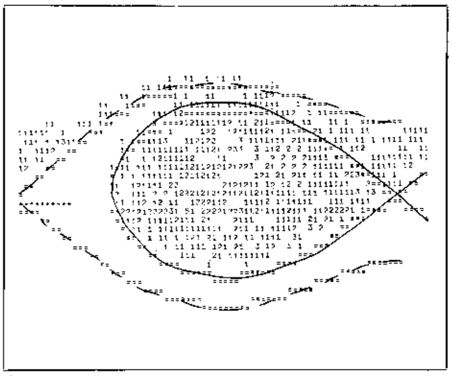
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trapping efficiency close to 70 % (in practice about 50 % is achieved). The method, known as 'high trapping' is now in routine use at the PS.

However, a 'dilution' problem is encountered with both these methods. The area of the fish is not fully occupied by the particles and this room for manoeuvre inside the fish results in an increase in the longitudinal emittance of the beam.

A few years ago there arose the idea of 'adiabatic trapping' which could, theoretically, allow 100 % of the particles to be trapped, while reducing the dilution to a minimum. The method involves starting with a reduced peak accelerating voltage and a voltage applied to the synchronous particle equal to zero. What is done is to increase these two voltages progressively (adiabatically) gradually blowing up the area of the fish until it is at least equal to that of the beam which we want to enter the fish. Particles would not normally cross the boundry of the fish but, with this method, all the particles initially outside can, surreptitiously, be manoeuvred in.

It offers so many advantages that it was adopted in the design of the Booster. Then, in the course of tests on the PS to develop the technique, it seemed possible to adapt it to the PS itself, and a detailed study began. The work has led to a series of successful experiments which have been carried out for a month on the PS. From the beginning, they have given excellent results.

The method cannot be applied to the optimum in the PS because it is not possible either to have the r.f. voltages near to zero or to obtain a very slow increase in the magnet fields (which must keep in step with the accelerating particles). With a rate of increase of field set at 25 % of its maximum value the theoretical trapping efficiency is limited to 90 %. The practical rate is restricted to about 70 %, which is however considerably better than with 'high trapping'. It is affected by two factors. The first is the transverse instabilities (betatronic resonances) which the particles undergo during the time for which the lower voltage is applied. This effect is quite normal but is not so pronounced with high capture when they are passed through more quickly. Methods of correcting this are at present being studied, and consist essentially of harmonic corrections. The second factor is the energy spread of the linac beam.

When, the improvement programme at the PS is complete, the linac will provide 100 μs pulses (instead of the present 20 μs) and multi-turn injection will be used. This type of injection, which requires a slow increase in the field, is in tune with the conditions of adiabatic capture, which is not the case with single-turn injection used at present.

Adiabatic trapping should prove of particular benefit as regards the provision of bunches by the PS for the ISR. We mentioned above that the earlier trapping techniques could result in an increase in the longitudinal emittance. Adiabatic trapping, however, so fills the fish that this effect is not so pronounced. This reduction in dilution will be a great advantage from the point of view of ISR operation since the luminosity of the ISR varies with the square of the longitudinal emittance. It is here, even more than in the increased trapping efficiency, that the great attraction of this method lies.

Röntgen Prize

On 17 October the 1970 Röntgen Prize was awarded to G. Backenstoss (of CERN and Karlsruhe) for his work on 'exotic' atoms. The story of the latest discoveries in this field, where sigmic and antiprotonic atoms were identified, appeared in CERN COURIER two months ago (vol. 10, page 251). Observation of X-ray emission from exotic atoms is a source of a great deal of information on the nucleus.

The Röntgen Prize is awarded by the Science Faculty of Justus Liebig University in Giessen, Federal Republic of Germany, where Röntgen was Professor of Physics at the end of the last century when he discovered X-rays in 1895. It is given for distinguished work in experimental physics. It has not been awarded since 1967 and this year has therefore seen a triple award on the occasion of the opening of a 'Radiation Centre' at the University where research in physics and biophysics will be carried out using a 60 MeV electron linac. In addition to Backenstoss the Prize went to E. Stuhlinger of the Space Research Centre, Huntsville, Alabama, for his research in extra-terrestrial X-rays carried out using detectors in rockets and to T. Kirsten of the Max Planck Institute Heidelberg for his discovery of double beta decay.

The Röntgen Prize was awarded to J.B. Adams in 1960 for his leading role in the construction of the CERN proton synchrotron. This new award is a tribute to the whole team from CERN, Heidelberg and Karlsruhe who for about five years have been producing important results, first on mu-mesic and pi-mesic atoms working at the synchro-cyclotron and more recently on K-mesic, sigmic and antiprotonic atoms working at the proton synchrotron.

BERKELEY

'Proton decay' confirmed

...not, be it hastily said, the decay of the proton itself but the first clear observations of the radioactive decay of a nucleus by means of proton emission. The possibility of such a decay mechanism has been realized for a long time. It is possible to produce nuclei which are 'proton rich' such that the energy binding the proton in the nucleus falls to zero or to negative values. But to identify the process occurring is not easy. This has now been done at the Lawrence Radiation Laboratory, Berkeley, following previous work at Harwell in the UK. The achievement was reported in Physics Letters on 26 October.

Four mechanisms of radioactive decay are well established - beta decay (emission of an electron or positron), alpha decay, gamma decay and spontaneous fission. 'Proton decay' is now added to the list. It has been looked for during the past few years particularly at Dubna where a team, led by V.A. Karnaukhov, has done much of the original thinking on this topic and reported some results, which were not conclusive, at the 'Conference on the Properties of Nuclei Far from the Region of Beta Stability' held at Leysin, Switzerland, from 31 August to 4 September 1970.

The results from the experiments at Harwell were also, by themselves, not conclusive. They were carried out by K.P. Jackson, C.U. Cardinal, H.C. Evans, N. A. Jelly and J. Cerny using the Variable Energy Cyclotron (built for Harwell by the Rutherford Laboratory) to accelerate oxygen ions which bombarded a calcium target. In the reaction, a cobalt isomer $^{53}Co^{m}$ can be produced, which is proton rich and is a comparatively long-lived excited state of cobalt-53. Though nuclei in the ground state which are proton unstable have not been found, the cobalt isomer is an unusual case where a high energy state is proton unstable. Its high spin value (19/2) prevents decay by electromagnetic radiation. In the Harwell experiments, protons which could have come from proton decay of the nucleus were observed but they could not be unambiguously distinguished, firstly because of the complexity of the oxygen-calcium nuclear interaction, and secondly because it could not be proved that the emerging protons were not of the 'beta-delayed' type.

Beta-delayed proton emission has been known since the early 1960s from the work of Karnaukhov at Dubna and R.E. Bell at McGill, Canada. In this phenomenon the fundamental decay process is beta decay which is followed by the emission of a proton from the highly excited state of the daughter nucleus. It is not true radioactive decay by proton emission, though it also provides considerable information about nuclear properties. Studies on delayed proton emission are under way at CERN with ISOLDE (see CERN COURIER vol. 10, page 4) and the latest results were reported at Leysin.

Following the Harwell experiments, Cerny returned to Berkeley and, together with J.E. Esterl, R.A. Gough and R.G. Sextro, was able to carry out a 'cleaner' search using the 88 inch cyclotron to bombard iron-54 with protons again to produce nuclei of cobalt-53 m.

$$^{54}Fe + p \rightarrow {}^{53}Co^{m} + n + n$$

The cyclotron provided beam for 0.8 s and was then switched off while the iron target was observed for 0.6 s. Emerging protons were detected in a counter telescope and the absence of simultaneous beta particles confirmed that true proton decay of the cobalt isomer was being observed.

STANFORD (SLAC)

Half a SPEAR

As mentioned in the last issue of CERN COURIER, page 320, Stanford Linear Accelerator Centre are going ahead with the construction of an electron-positron storage ring which is a trimmed down version of their project SPEAR (Stanford Positron Electron Asymmetric Rings) described in vol. 9, page 271. SPEAR consisted of two asymmetric rings (slightly pear-shaped) overlapping to provide two beam interaction regions.

What is now being built is a single asymmetric ring in which both electrons and positrons will orbit in opposite directions. Two 'low beta' regions, where the beam will be specially concentrated, will be available for collision experiments. Initially, a single r.f. cavity will limit peak energy to 2.5 GeV though the ring magnets are being designed to produce good field up to a field strength equivalent to 4.5 GeV so that performance figures can be extended if more r.f. and magnet power are made available later.

The ring will contain 34 bending magnets and 51 quadrupoles with standard fields of 6.3 kG and 590 G/cm (corresponding to 2.5 GeV) and with sextupoles for refined beam control. The r.f. cavity will provide up to 200 kW of power (180 kW into the beams) at 42.35 MHz with a peak voltage of 300 kV. Energy loss at 2 GeV due to synchrotron radiation will be 110 keV.

Electron and positron beams will be injected from the 20 GeV linac at an energy of 1.5 GeV and taken to higher energies by the r.f. cavity in the ring itself. The ring is to be operated in the 'one-bunch' mode. In each beam there will be two bunches but one bunch of electrons will collide with one bunch of positrons in an interaction region. At the position around the asymmetric ring where, as they orbit in opposite directions, they would collide again, they are kept apart by locally distorting the orbits with an electric field.

In order to set up two orbiting bunches per beam, particles have to be injected in two bursts of 7 ns during the normal 1.5 μs pulse of the linear accelerator. The accelerator gun will be modulated to crowd more particles into the two short storage ring injection intervals. Bursts can be injected 20 times per second into the ring and to achieve the design stored intensity of 2×10^{12} particles per beam (0.5 A per beam) a filling time of six minutes is needed for storing the positron beam, the electron beam being stored faster during the positron filling. The time for which experiments can be carried out between fillings will be in excess of two hours.

The vacuum chamber will be constructed of aluminium and the design pressure is below 10^{-9} torr. Distributed ion pumps, designed at SLAC, using the magnetic field near the bending magnet pole edge, will provide most of the pumping capacity. A small number of conventional ion pumps will be installed to keep the chamber pumped down when the magnet ring is switched off.

The interaction positions are at the centre of two 5 m straight sections with ample room (above, below and sideways) for the installation of experimental equipment. The design luminosity is 10^{32} cm^{-2} s^{-1} when the ring is operated at 2 GeV.

Construction is beginning and it is hoped to store the first beams in 1972. The performance parameters could be increased later if more money became available. In addition to the extension to higher energy mentioned above, the second ring which was included in the initial SPEAR design could be added to push luminosities higher.

RUTHERFORD
Autumn treble

The Rutherford Laboratory Bulletin on 16 November records three recent events:

During the week-end of 24, 25 October the 7 GeV proton synchrotron, NIMROD, achieved a new record intensity of 3×10^{12} protons per pulse. In the course of the run the ejected proton beam down the beam line X3 into the large Experimental Hall 3 was 1.18×10^{12} protons per pulse measured at the external target station.

A contract at a cost of £ 3.6 million has been placed for a new large computer, an IBM 360/195, to be installed at the Laboratory in autumn of 1971. It will replace the existing IBM 360/75 as the main Laboratory computer being about six times more powerful. The computer will be accessible to Laboratory staff and to University teams involved in high energy physics research, to process data from experiments at the national accelerators and from experiments at CERN. It will also be available to the nearby Atlas Computer Laboratory to support its extensive computing services to Universities and other research institutes.

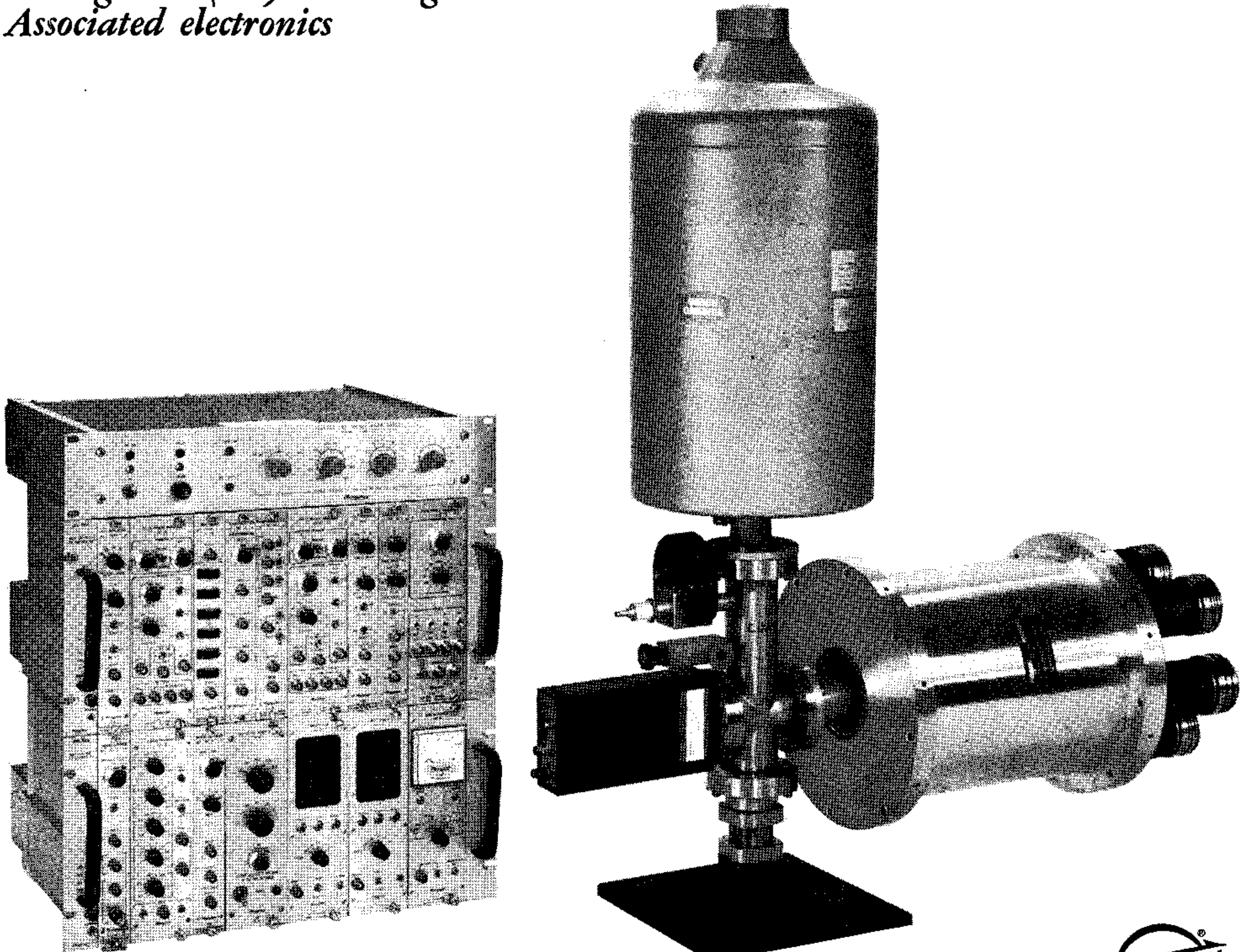
A successful series of tests were carried out in the second week of November on a superconducting quadrupole constructed from intrinsically stable conductor (see vol. 8, page 185). Currents of between 95 and 97 % of the critical current (1360 A) were repeatedly achieved with an overall current density of 27 kA/cm^2 in the winding cross-section. This corresponds to a peak field of 40 kG in the 12 cm bore of the quadrupole. It is believed to be the first clear demonstration, on a full scale magnet, of the properties of this type of conductor which was evolved in the Superconducting Applications Group at the Laboratory.

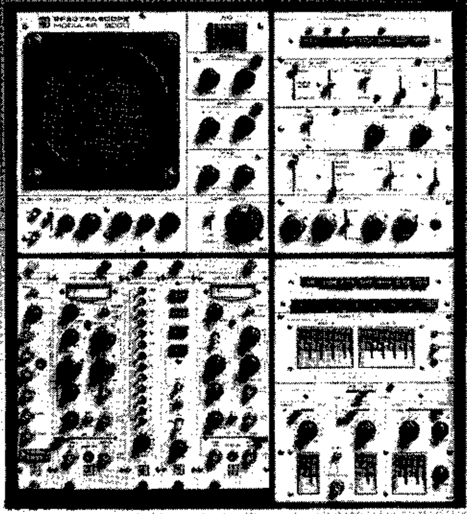
CORNELL
Photon Conference

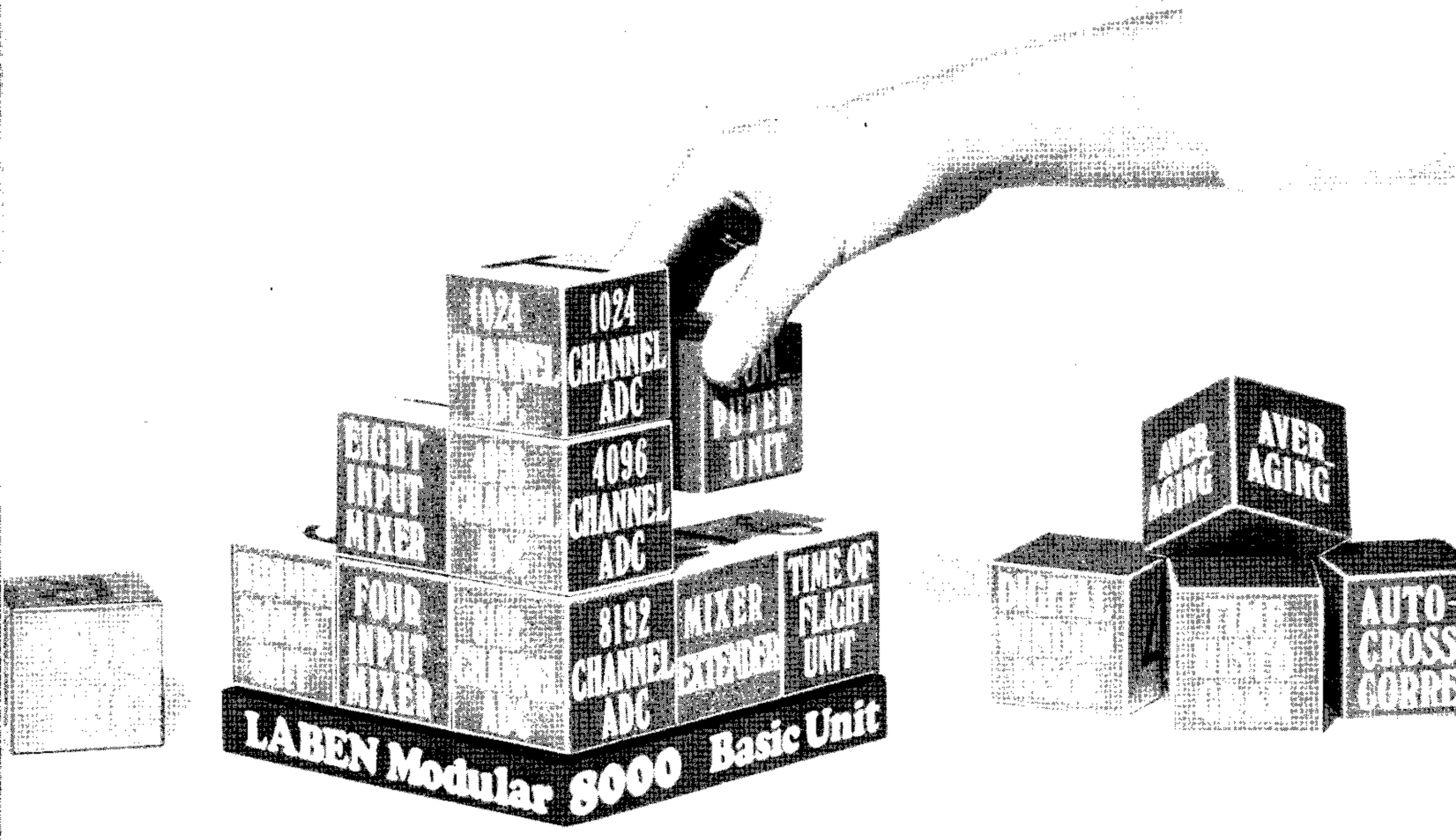
The 1971 International Symposium on Electron and Photon Interactions at High Energies, sponsored by Cornell University, the US Atomic Energy Commission, the National Science Foundation and IUPAP, will be held from 23 to 27 August, 1971, in Ithaca, New York.

Attendance will be by invitation only. To assist the Organizing Committee, anyone who is interested in attending this conference should write to the Conference Secretary before 1 January, 1971, at the following address :

Conference Secretary,
Laboratory of Nuclear Studies
Cornell University
Ithaca, New York 14850, USA.







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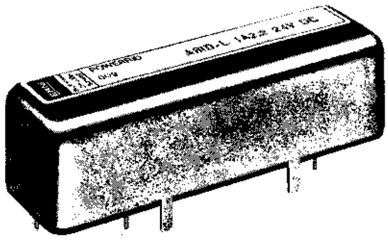

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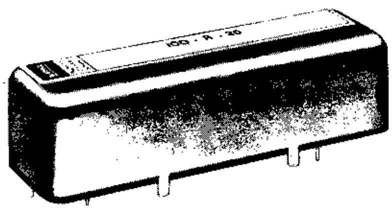

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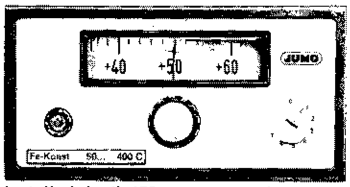

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from DM 280.– for thermocouples

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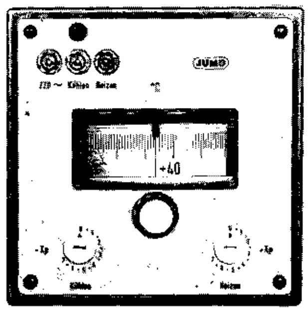

with measured value indication, installed depth 120 mm, gross prices:
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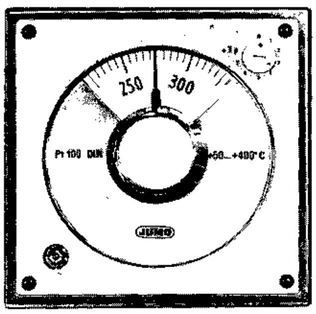

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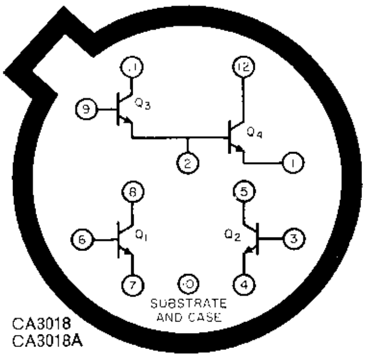
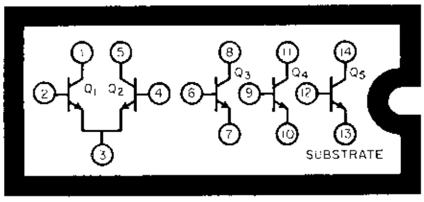
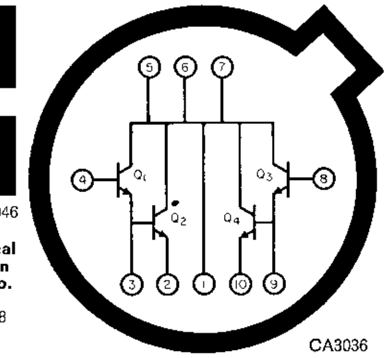


CA3018
CA3018A

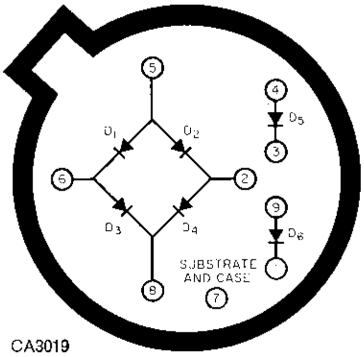


CA3045 CA3046

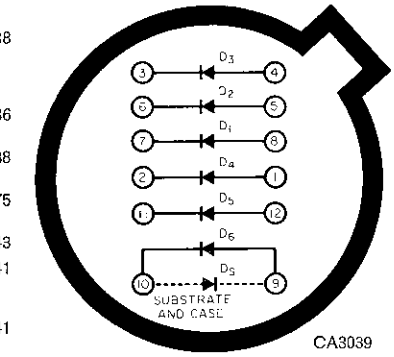


CA3036

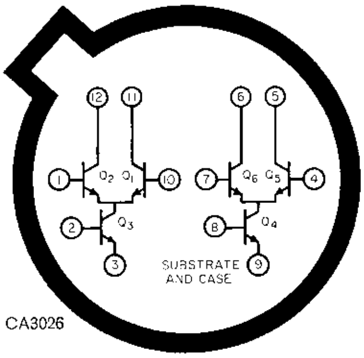
Device Type	Package	Description	Technical Bulletin File No.
CA3018	12-lead TO-5	Two isolated transistors and Darlington-connected transistor pair	338
CA3018A	12-lead TO-5	Premium version of CA3018 (performance controlled)	338
CA3019	10-lead TO-5	One diode-quad, two isolated diodes	236
CA3026	12-lead TO-5	Dual differential amplifier	388
CA3036	10-lead TO-5	Dual Darlington array	275
CA3039	12-lead TO-5	Six matched diodes	343
CA3045	14-lead DIL ceramic	Differential amplifier and three isolated transistors	341
CA3046	14-lead DIL plastic	Differential amplifier and three isolated transistors	341
CA3049	12-lead TO-5	Dual independent differential RF/IF amplifiers	378
CA3054	14-lead DIL plastic	Dual independent Differential amplifiers	388



CA3019

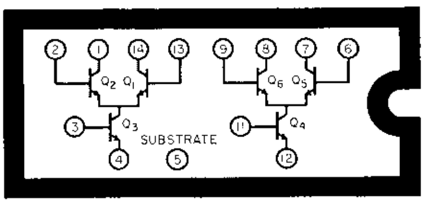


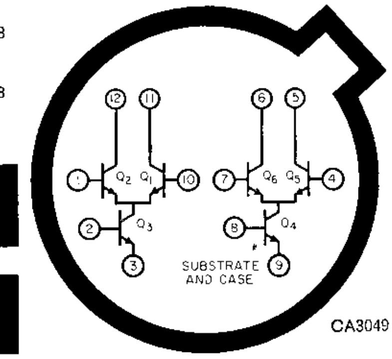
CA3039



CA3026

CA3054





CA3049

For further Details ask for the above mentioned Technical Bulletins

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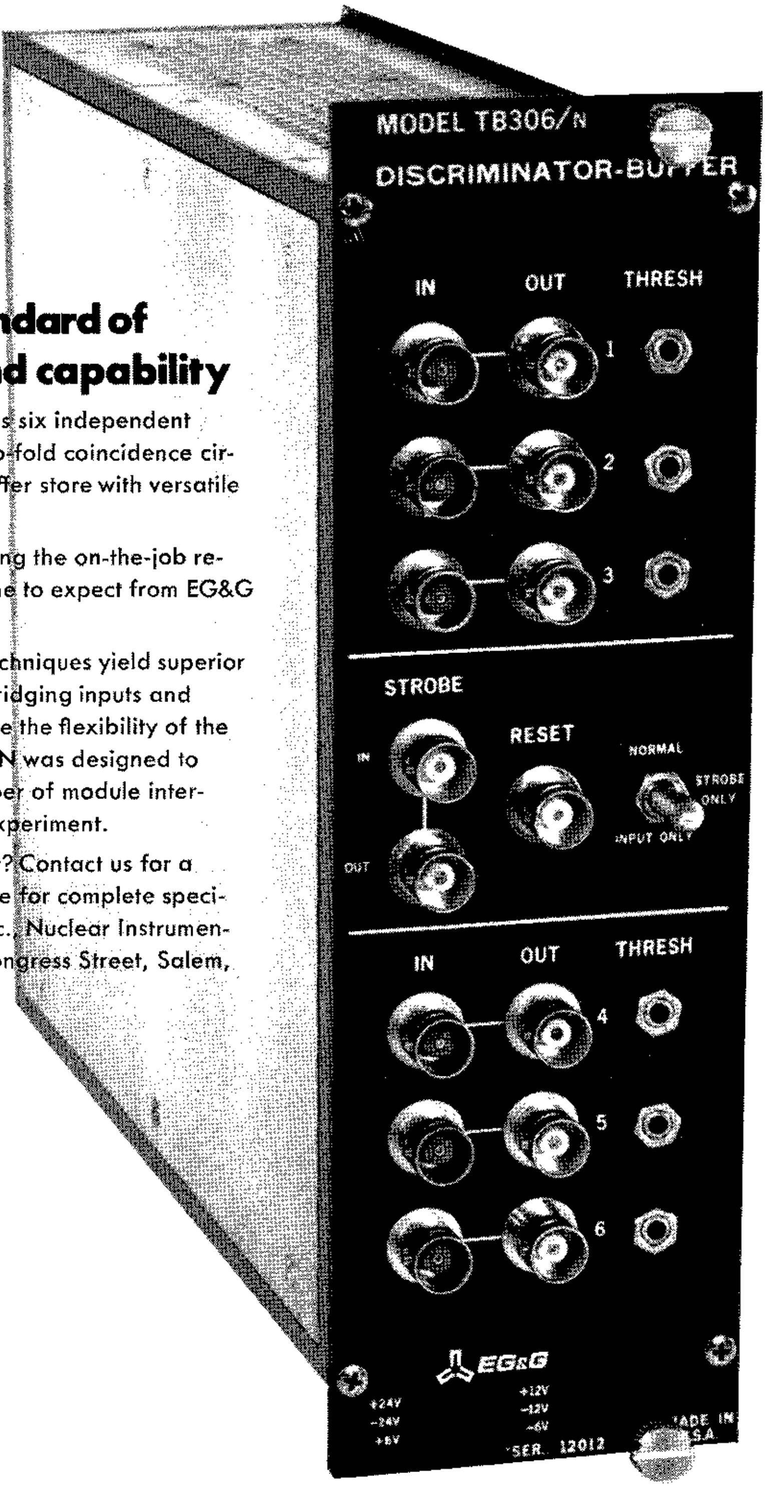

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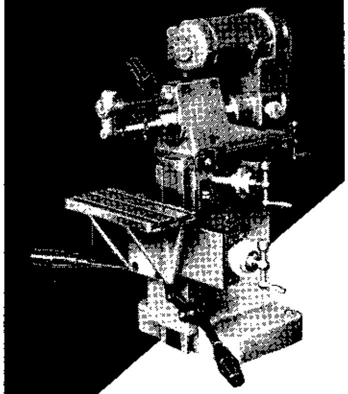
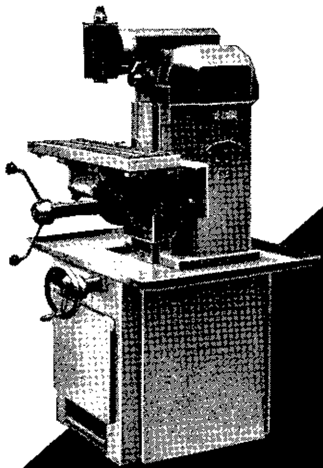
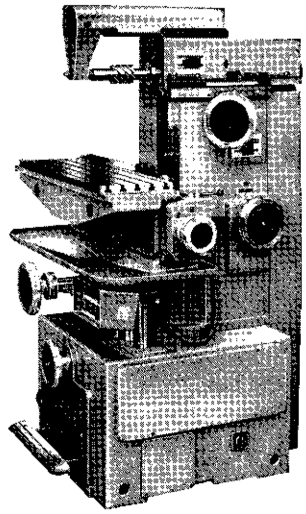


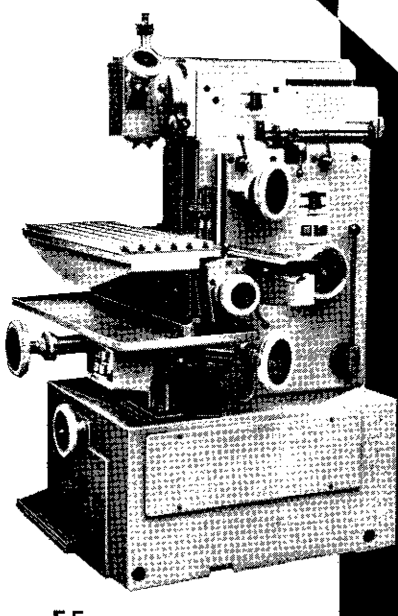
F1
100 × 220 mm



F3
200 × 600 mm



F4
250 × 800 mm



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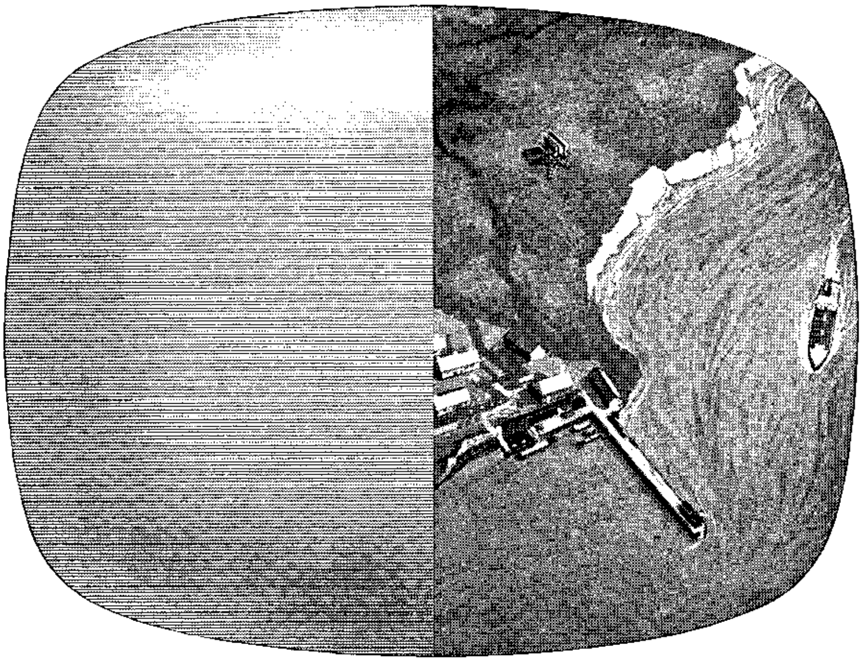

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