CERN COURIER

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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 1500 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 382.9 million Swiss francs in 1973.

CERN Laboratory II came into being in 1971. It is supported by eleven countries. 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 1973 is 188 million Swiss francs and the staff will total about 370 people by the end of the year.

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Cover photograph: A rendering of the PS at the cross-roads. The beam pipe in the foreground brings particles at 50 MeV from the linac to the four superposed Booster rings. Going across the picture are the beam pipes where the 800 MeV protons from the Booster are recombined (from four levels to two to one) en route for the 28 GeV proton synchrotron. The machines are currently having a wash and brush up in the course of the annual shutdown. (CERN 25.10.72)

49th Session of CERN Council

The Council met on 20, 21 December under the Presidency of Professor W. Gentner

Physics at Laboratory I

The Session opened with the customary progress reports from the Directors General of Laboratory I and Laboratory II. Since we came up-to-date with Laboratory II news in the last issue, we will concentrate here on topics from the report of Professor W. Jentschke concerning the physics programme at the PS and ISR.

The field of high energy physics does not progress so much by single sensational discoveries but can be compared rather to a mosaic where one progresses piece by piece to obtain the whole beautiful picture. Only the continuous interplay of experimental data with theoretical ideas leads to a better understanding of the structure of elementary particles and their interactions and eventually to new concepts describing the microworld.

One of the most fundamental problems is the structure of particles. Elastic scattering of high energy electrons from protons and neutrons has shown that these particles have a rather complicated distribution of electric charge and magnetic moment with an average radius of a little less than 10^{-13} cm. The question then arose whether a structure could be seen if one used a different sort of 'light' (used a different kind of probe). Elastic scattering of hadrons would allow us to study the distribution of mesonic matter inside the particles and one expects more detail to emerge the shorter the wavelength of the 'light' (the higher the energy of the particles). Hence the ISR is an excellent instrument to perform such experiments.

Measurements at the PS and elsewhere showed that the diffraction peak continues to shrink as the energy increases; in other words, the proton radius (or region of influence) increases with energy. Two groups continued this study at the ISR. At extremely small angles at ISR energies, the scattering amplitude is purely imaginary — the scattering corresponds to that of an absorbing sphere. Observations at large angles revealed a beautiful diffraction pattern with a dip and a maximum which helped in understanding the somewhat surprising behaviour of the differential cross-section at PS energies. The detailed interpretation of these data will provide information on the average radius of the distribution of mesonic matter inside the proton, on its fuzziness at the edge and on other parameters.

If the proton behaves like a black disc one expects the total cross-section for p-p interactions to become constant at high energies. ISR measurements are not in disagreement with this expectation but are not yet accurate enough to test more sophisticated models which predict a logarithmic rise of the total cross-section.

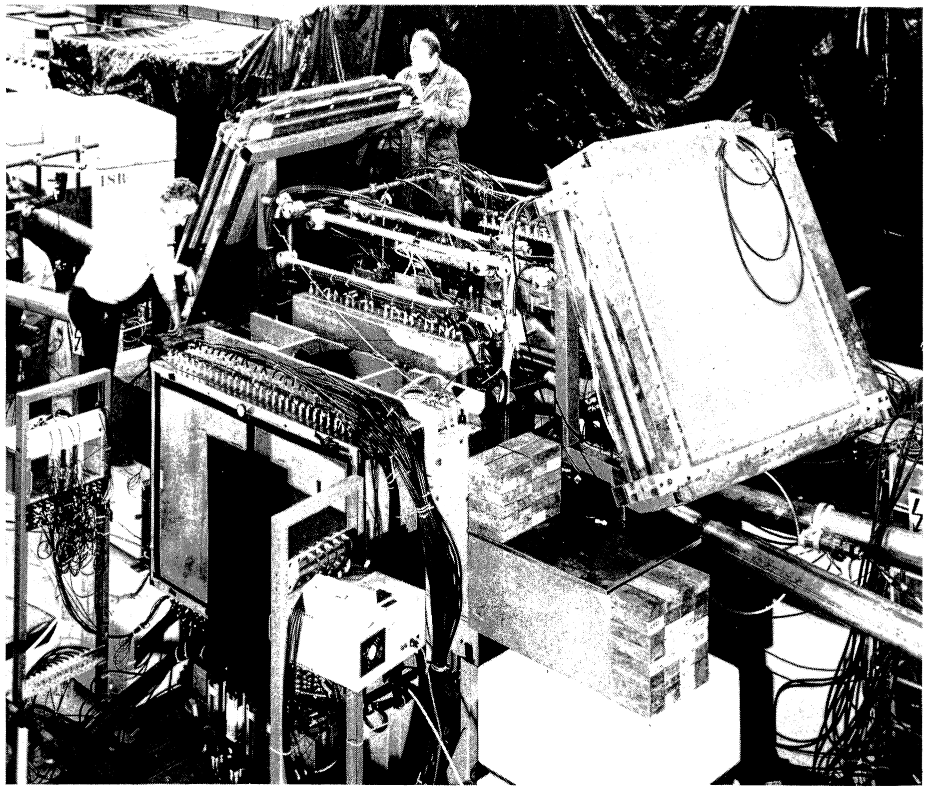
Elastic scattering thus gives information on the 'geometrical' properties of elementary particles but it does not give immediate information on any constituents. The deep inelastic electron scattering from protons and neutrons carried out at Stanford several years ago indicated that nucleons contain point-like constituents. This was deduced from the observation that the probability of electrons to be inelastically scattered at rather large angles is much larger than one would expect if the charge of the proton were smoothly distributed over its volume. If this interpretation is correct, the result of these experiments would be the analogue of the Rutherford experiment of 1911, where the large angle scattering of alpha-particles by atoms led to the conclusion that the positive charge is concentrated in a small region — at the nucleus of the atom. The point-like constituents have been called partons. It is possible that they are identical with quarks whose existence is suggested by the symmetry of the particle classification scheme.

The intriguing question was why partons were noticed only in electromagnetic but not in strong processes. Two recent ISR experiments have given results which might indicate point-like constituents also in strong interactions. In these experiments the distribution of transverse momenta is studied around 90° for charged and neutral pions. For both kinds of particle it is found that the rapid exponential decrease observed at small momenta does not extrapolate to momenta larger than 1 GeV/c where the distribution gets flatter and depends on the total energy. This is perhaps up to now the most exciting, unexpected, result from the ISR. A complete understanding has not yet been achieved but one theoretical attempt relates it to point-like structures as in deep inelastic electron scattering.

Having obtained evidence for new constituents by electromagnetic and strongly interacting probes the question arises whether they manifest themselves also in weak interactions. The answer came from an experiment in the heavy liquid bubble chamber Gargamelle in which the total cross-section for neutrinos and antineutrinos was measured. Preliminary results show that both cross-sections rise linearly with energy in the range from 1 to 9 GeV and the ratio between antineutrino and neutrino cross-sections is one third. These results are in agreement with parton models and in favour of partons being quarks. In detail they imply that the nucleon consists of three quarks and some quark-antiquark pairs.

There is now multiple evidence for point-like new constituents in nucleons and some indication that they should be identified with quarks, but

Intersection region I-1 at the ISR where the CERN, Columbia, Rockefeller team (whose detection system can be seen in the photograph) and the Saclay, Strasbourg team observed high momentum particles emerging at wide angles — described by the Director General in his progress report as 'perhaps, up to now, the most exciting unexpected result from the ISR'.



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such particles have not yet been found free. One reason could be that their mass is high and that conventional accelerators do not provide sufficient energy. Hence experiments are carried out at the ISR where quark masses up to 22 GeV could be observed. In one experiment no particles with fractional charges, predicted for the quarks, have been seen among about 10^9 ordinary charged particles. Why then does one notice a granular structure of the nucleons if one scatters electrons, hadrons or neutrinos off them but why is it not possible to knock out one of these grains? It could be that their masses are still beyond our presently available energies. Or maybe they are just mathematically useful concepts in describing particle behaviour without correspondence in physical reality.

Multiparticle processes are perhaps the most intensively studied topic in high energy physics at present. Most ISR experiments are devoted to this field and at lower energies there is a wealth of bubble chamber data from experiments at the PS.

(a) In high energy collisions it is observed that the emerging secondaries have surprisingly small momenta perpendicular to the direction of the collision. These transverse momenta have an average value of 300 MeV/c and are virtually independent both of the type of particle investigated and of the centre of mass energy. At the ISR, however, the average transverse momenta are somewhat different for pions, protons and kaons. These small values of the average transverse momenta are one of the basic features of high energy inelastic processes. According to the thermodynamical model, it implies that an absolute maximum temperature of hadronic matter exists.

(b) Multiplicity increases only gradually and probable logarithmically with the centre of mass energy; for example, at 1500 GeV the average multiplicity is 12, but events with 20 or more particles are not too rare. Processes with many particles in the final state are very difficult to measure in detail and also their interpretation is difficult because of the many kinematical variables. As a first step, interest concentrated on single particle inclusive events where, for example, one observes a proton or a pion and the remainder (anything) is not measured. Theoretically, a number of approaches to such reactions have led to the prediction that at high energies the cross-sections, if expressed with the proper variables will be independent of the collision energy. Predictions of this kind are known as scaling predictions.

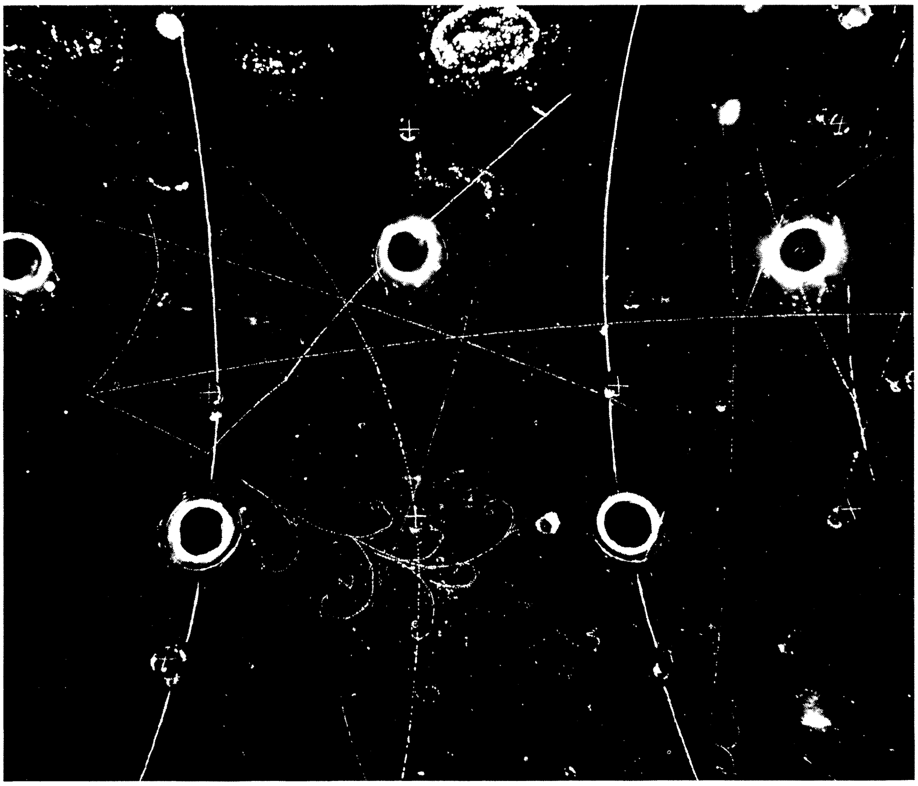
One of the important findings at the ISR is that the particles produced in very high energy collisions are falling into two classes. Those which originate from the break-up of one of the incident particles and hence go mainly in the forward directions and those particles which are produced more or less isotropically by a kind of 'evaporation' or 'ionization'. At PS energies, a clear separation was not possible but at the ISR the two different production mechanisms can be studied independently.

The large amount of data can be summarized by saying that at ISR energies limiting distributions are reached — the distributions no longer depend on the total energy. It is reached earlier in the fragmentation region than in the central region and sooner for pions than for heavier particles.

The next step, to obtain more detailed information, is to go from single particle spectra to particle correlations and the main emphasis of the next generation of ISR experiments will lie on such investigations.

For some time, the possibility that the weak interaction is mediated by a charged heavy boson has been considered, the range of the interaction being determined by the mass of the boson. This particle might play in weak interactions a similar role to the pion in strong interactions and to the photon in electromagnetic interactions. If this is true it should be possible to observe the bosons as free particles provided the available energy is sufficient to produce them. Hence the ISR is again the best available instrument to search for these particles and three groups are looking for electrons and muons which could originate from the decay of such bosons. The results obtained so far do not give a definite indication for the existence of the intermediate boson and upper limits for its production cross-section can be deduced.

One of the most exciting developments which is presently under way is the work on a new renormalizable field theory, trying to unify the theory



An antineutrino interaction recorded in the heavy liquid bubble chamber, Gargamelle. The interaction produced a muon (which travelled across the chamber at high energy), a negative pion (which was of low energy and stopped in the chamber) and a positive pion (which interacted again to give a neutral pion decaying into gammas which materialized in electron-positron pairs in the heavy liquid). The neutrino experiments in Gargamelle are providing crucial information on several topics of great interest at present in the field of high energy physics.

for electromagnetic and weak interactions. If these attempts are successful they could be of similar importance to the unification of electric and magnetic phenomena in the last century. The models make detailed predictions concerning the properties of intermediate bosons and the so far unknown heavy leptons. For example, the unified models require an electrically neutral boson in addition to charged ones. This neutral boson corresponds to the photon which mediates the electromagnetic interaction and would give rise to elastic neutrino-electron or antineutrino-electron scattering. This has been looked for in the film from a recent Gargamelle experiment but no event was found. The experiments in progress should lead to a decisive answer on the simplest model.

Many other important results have come from experiments at the PS — the first observation of hyperon production in weak interactions, further information on CP violation in neutral kaon decay including a much more precise measurement of the short-lived kaon lifetime, and so on — and a full programme promising much important new information is lined up for the PS and ISR for the coming year.

The overwhelming part of the physics programme at CERN is carried out by physicists from other research centres and the number of physicists using CERN is constantly increasing. Even neglecting the new field of nuclear structure experiments done at the PS, there is an almost linear rise which still shows no sign of flattening off. With the Omega and SFM spectrometers coming into operation in 1973 this trend is likely to continue. At the end of 1972 about 1500 physicists were using CERN's research facilities. These numbers also do not seem to have reached a plateau.

On one hand this development is very positive since it demonstrates the attractiveness of CERN. On the other hand, it poses a serious problem to the CERN administration since the visitors need office and laboratory space, technical help and administrative support.

This is occurring at a time when CERN Laboratory I is experiencing difficult problems under restricted budgets. It will need the continuing excellent cooperation between the Council, the European community of high energy physicists and CERN to find the solutions.

Financial situation for the coming years in Laboratory I

With the go ahead for the construction of the synchrotron to produce energies of hundreds of GeV in Laboratory II, Laboratory I's previously foreseen programmes were cut back to help towards finding the money for the new project. At 1969 prices, the cut back amounted to 210 million Swiss francs during the construction period. The problem years for Lab. I are particularly 1974 and 1975 when the budgets were trimmed from an anticipated 340 MSF to 300 MSF (again 1969 figures). During these years, the budgets are also expected to support the preparation of the PS to serve as injector for the new machine and the equipping of the West Hall for 200 GeV physics.

The Council had asked CERN to review carefully the programme for 1974/75 and its budgetary consequences. Budget Analysis and Programme Evaluation Committees set up in 1971 continued in action in 1972 and the situation for the coming years in Laboratory I emerges as follows . . .

Considerable savings have been achieved by such measures as reducing the staff numbers below the agreed figure of 3100 (a reduction of about 150 will be reached in 1973). The costs involved in administration and services are being held down, despite the expansion of the experimental programme, the growing number of visitors and the site extensions. Long term development work has been reduced considerably (and there is a worry that if this is sustained for many years the future quality of the Laboratory could be jeopardized). Limitations have been imposed on the scientific programme and it is operating below the levels foreseen when implementing the PS improvements (though it has still grown compared with previous years).

Measures such as these have trimmed back the Laboratory I 'deficit', in terms of the likely available money to carry out the work scheduled over the years 1973 to 1976, to about 40 million Swiss francs. It is hard to see any major savings from pushing the above measures further and the next victims will almost certainly have to be items

Professor Francis Perrin, right, in conversation with Professor Jentschke (Director General of CERN Laboratory I) during a break at the Council meeting. Francis Perrin, who has been prominent in CERN affairs from the early 1950s, was attending his last meeting as French delegate. It will seem strange not to see his distinctive features behind the 'France' label when the Council next meets in June but he will continue to come to CERN for meetings of the Scientific Policy Committee.

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from the present physics programme. Possibilities are — closing the South experimental hall which houses electronics experiments, reducing the number of experiments at the ISR, reducing the bubble chamber programme, closing down the synchrocyclotron etc.... Decisions will probably be taken mid-1973.

The problem is aggravated by the fact that the agreed 'budget profile' for Laboratory I over the years of construction of the SPS does not line up ideally with the anticipated annual expenditures. It is however difficult for many Member States to agree to change this because of their internal science budget planning. Some relief for the heavy spending years of 1974 and 1975 has been sought by advancing the payment on the new CDC 7600 computer installation using money saved in 1972 and, as mentioned below, by placing 1973 savings in a reserve fund to be used for SPS physics preparations.

Budget decisions

Council approved the following budgets for 1973 — Laboratory I: 382.9 MSF; Laboratory II: 188.0 MSF. A 6.4 % cost variation index (which is designed to take account of price movements since the budget estimate was agreed) has been applied in arriving at these figures rather than the 6.6 % given by the usual formula. The reduction was achieved by awarding a lower salary increase to CERN staff than that given by the salary index. In the course of the budget discussions for Laboratory I, it was agreed that whatever savings could be made within the budget for 1972 (savings estimated at 20 MSF) can be placed in a special reserve fund to be used later for the preparations for physics with the SPS.

The firm estimate for the Laboratory I budget in 1974 was fixed at 367.6 MSF (1973 prices) and the same figure was approved as a provisional determination for 1975. Normally a 'provisional determination' would have been agreed for the following year (1976) also but, because of the complicated situation in coming years and the financial problems in the science budgets of some Member States, the figure for 1976 was not voted.

Elections and Appointments

The Council re-elected Professor W. Gentner (Federal Republic of Germany) as its President for 1973. Two new Vice-Presidents were elected — Professor Th. Kouyoumzelis (Greece) and Dr. G.H. Stafford (UK) who will succeed Professor J.K. Boggild and Ambassador E.F. Buresch. The Scientific Policy Committee and the Finance Committee retain the same Chairmen — Professor A.G. Ekspong and M.P. Levaux respectively. Professors B. Hahn and A. Merrison are leaving the SPC and Professor M. Conversi has been re-elected.

The Council was also informed of the setting up of a new Experiments Committee, which since the Council meeting has been given the name SPS Experiments Committee. Like its equivalent Committees concerned with the SC, PS and ISR experimental programmes, it will be chaired by someone from outside CERN — Dr. P. Lehmann from Orsay has been appointed for the first two years. Another forthcoming change in the experimental committees is that Professor H. Schopper will succeed Professor B. Gregory as Chairman of the Intersecting Storage Rings Committee.

Professor Schopper will be leaving CERN in March and will be succeeded as Assistant to the Director General for the Coordination of the Experimental Programme by Dr. J.H. Mulvey. Dr. Mulvey will move to CERN for a three year period beginning in September. Other internal appointments are — Professor P. Falk-Vairant will succeed Professor J. Steinberger as Director of the Physics I Department for three years; Mr. G. Munday will succeed Dr. P. Standley as Leader of the Proton Synchrotron Division; the Synchrotron Injector Division ceased to exist at the end of 1972 (the job of building the machine being complete) and the Division Leader, Dr. G. Brianti, has been jointly appointed by the two Directors General as Leader of the Experimental Areas Group preparing for physics at the SPS. Dr. C.J. Zilverschoon, Director of the PS Department, and M. H. Laporte, Leader of the Site and Buildings Division were both reappointed for a further three years.

Professor Francis Perrin

Council business concluded with a tribute by the President to Professor

Francis Perrin who was attending Council for the last time as delegate for France.

Professor Gentner said:

'We are very sorry to say goodbye to Francis Perrin after an association which has been so close, pleasant and fruitful.

Professor Perrin belongs to that small nucleus of energetic and enthusiastic people to whom we largely owe the coming into being of CERN. In his capacity as Haut Commissaire à l'Energie atomique, he was most active, from the very beginning, in the discussions held at UNESCO in December 1951 which led to the signature of the Agreement setting up the interim Organization, the European Council for Nuclear Research, on 15 February 1952. His signature is on that document as well as on the Convention establishing CERN.

From then on Professor Perrin has been one of us in the Council, and from 1959, also in the Scientific Policy Committee, where fortunately he will stay on for quite a number of years. For more than twenty years we have had the benefit of his wisdom, influence and unwavering faith in the daring venture called CERN. We could always rely on him whenever we were faced with difficulties to speak up for and defend the primacy of the physics activities of the Laboratory.

His dream has come true: the CERN of today and of tomorrow owes him a great deal. On behalf of all of us I wish to tell him how deeply grateful we are for all he has done for the Organization and how much we have appreciated his sound judgement, his brilliant spirit and his ever youthful enthusiasm.'

Annual shutdown

The 28 GeV proton synchrotron accelerated its last particles for 1972 on 23 December and the experimental teams who had been using the PS and the ISR went home. In their absence, however, the machines have not been the scene of peace and quiet. After allowing a week for the PS to cool down (for induced radioactivity levels to fall) annual shutdown work began in earnest and will continue there and at the ISR until 21 February with a list of a thousand jobs to be done.

Many of the jobs are of a routine maintenance nature. Anyone who periodically checks the electrical equipment in his home will be well aware that screws come loose and wires come adrift for no reason whatsoever. All the more so is this sort of check needed on highly complex equipment which has been effectively switched on and off many millions of times during the year as the synchrotron pulsed. But this routine maintenance is not what we will be concerned with here. We have simply picked out some of the major features of the shutdown work at the PS and ISR in the experimental areas and intersections regions.

At the PS

The 50 MeV linac is having a careful wash and brush-up to try to ensure greater stability and reliability. Everyone leans on the linac and its good performance is obviously crucial; in particular the 800 MeV Booster is a more demanding customer concerning linac beam quality than the PS.

The r.f. system in particular is being completely overhauled. New high stability charging circuits for the modulators and new phase and frequency stable circuits will be installed. Delay line pulses will be cleaned up and the r.f. will be brought on again for tests by 5 February so as to have it in good shape in advance of the PS needing beams.

This will follow a complete overhaul of the vacuum system in the three linac tanks. The first drift tube in Tank I will be removed and repaired since it has been badly damaged by the beam. The alignment of all the drift tubes will be checked. Beams in the reassembled linac are scheduled for 9 February.

In the PS ring the touch of human hand will be felt on almost half the total circumference. 45 of the 100 straight sections will be opened up (16 for the installation of new correction magnets — dipoles, quadrupoles and sextupoles — ten for major modifications such as the installation of equipment to excite betatron oscillations for machine studies) and 15 magnets need attention (one of them — magnet No. 2 — is being replaced because of radiation damage and ten others need repair for the same reason).

Repair because of radiation damage is becoming a regular heading in describing PS shutdown work. We now seem to be losing a magnet a year and others need clamping because of deterioration of the adhesive holding the end block laminations where most radiation is received. When the laminations move as the magnet pulses, they can damage pole face windings. Other work in connection with radiation and to improve the machine vacuum is the completion of the change to metal joints in the vacuum system.

As the Booster begins to supply higher intensity beams during 1973 instabilities will need more attention. This is the reason for the correction magnets mentioned above to keep the beam in order and preparations for the installation of still more correction magnets, which have not yet arrived, will also go on during the shutdown.

The concrete jungle of the East experimental hall at the proton synchrotron. Only someone with a very good reason (or someone from whom all reason has departed) would start introducing changes in here. During the present PS shutdown beam-line modifications are limited to linking the m6 beam-line to the 2 m bubble chamber and to improving the feed to the hyperon beam.

The injection region will experience a major upheaval. Multiturn injection has been in satisfactory operation for some months now and it has therefore been decided to uproot the single turn injection inflectors in straight sections 27 and 28. A small kicker magnet will, instead, be installed in straight section 30 to come into action if problems occur with the multiturn system.

Other PS work includes new cooling plant at the centre of the ring so that r.f. equipment, ejection equipment and correction magnets will no longer rely on experimental hall cooling water supplies. Two more of the old type r.f. cavities will be removed. Finally, all 100 magnets will be realigned (involving six weeks work) and the PS is scheduled to be ready for action again on 21 February.

PS Experimental Areas

It is the South Hall which will see most upheaval (for a rundown on the previous situation see vol. 12 page 272). The k17 beam which feeds the Karlsruhe, Stockholm experiment on mesic atoms is being modified. The converted beam will be known as k18 and will have about twice the acceptance of its predecessor which will be particularly useful in augmenting the negative kaon flux.

Magnets will be installed in preparation for the Birmingham, CERN, Genoa, Rutherford, Stockholm experiment on two body interactions ($\pi^+p \rightarrow \Sigma^+K^+$, $K^-p \rightarrow \Sigma^+\pi^-$), which will later use the beam-line d31. A complete transformation is taking place in the m beam-line, m7 becoming m13. A further separator will be installed and it will be used by the Geneva, Saclay team to study kaon decay into four particles including an electron.

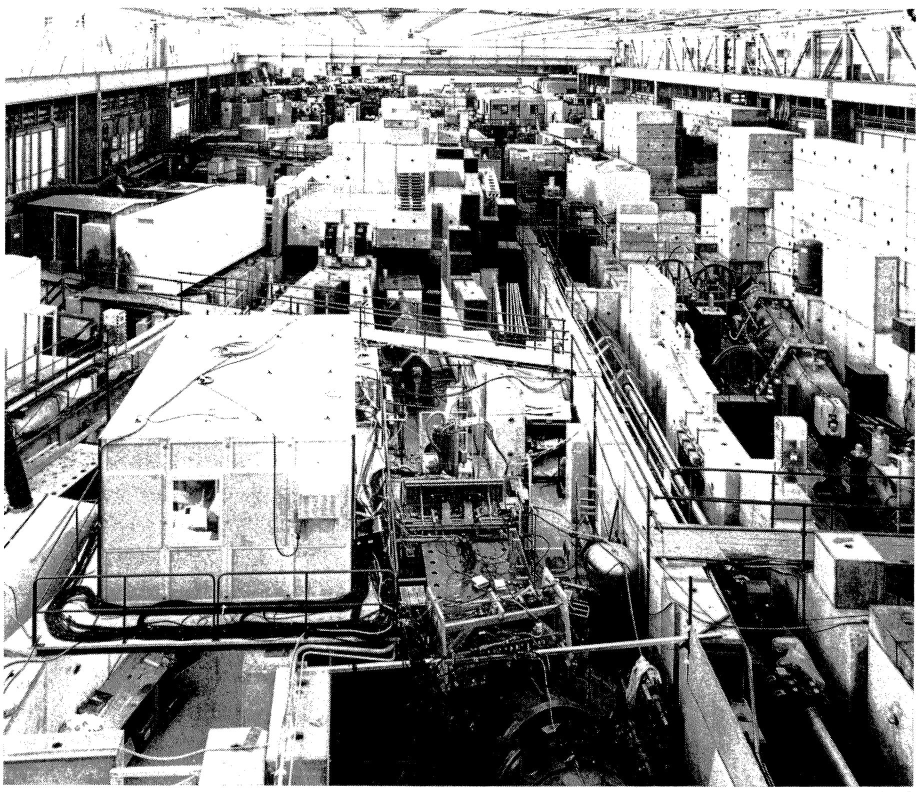
The beam-line to the HYBUC bubble chamber in the North Hall remains untouched as also does the beam-line to Omega (apart from small modifications) and to BEBC in the West Hall. In the concrete jungle of the East Hall the big transformation is to bring the beam-line m6 to the 2 m bubble chamber rather than the r.f. separated beam-line u5. Also the e9n region will be revamped to improve the hyperon beam.

Storage Rings

The ISR has had a year of intensive use since the last shutdown and therefore a programme of rather routine maintenance tasks is under way both on the rings and in the control room where the layout is being reorganised. There are also machine improvements being implemented and most of them concern the vacuum system — underlining yet again the importance of the pressure and surface cleanliness in the rings in determining the machine performance.

Titanium sublimation pumps are being installed in 82 more positions, including some located for the first time so that they can pump from the centre of the long magnets. This brings their total in the ISR to 400 and another 100 are intended for installation later. In fact, during the shutdown cabling is being done for all 500 sublimation pumps.

In positions where it is at present difficult to install these pumps such as the physically difficult regions around the injection septa, the chambers are being demounted and cleaned by running an argon glow discharge in them for several hours combined with bake-out (see vol. 12 page 361). This is also being done in the four arms of the new vacuum chamber at the I-6 intersection region and in some parts of the inner arc of Octant 5. Four new fast acting valves are being installed around I-8 and those around I-6 are being replaced. The valves enable a



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Late news: The Omega superconducting magnet, with two coils in action, reached design performance on 10 January. On 16 January it was successfully tested with the yoke configuration for the first experiments. The refrigeration plant is performing well.

section of the rings to be shut off in 20 ms should it experience a serious leak. The valves can shut before the pressure wave reaches them.

New installations for beam observation and control include the sodium curtain equipment for Ring 2. This type of beam profile monitor was described in vol. 11 page 324. It involves a jet of sodium, crossing the beam at an angle of 45°, from which liberated electrons give an image on a fluorescent screen. Also the last of four deflectors which will help improve the stability of stacked beams has been installed. They will operate in a feedback loop to damp out beam oscillations, either in the vertical or horizontal plane when their build up is observed.

Ion chambers are being installed at 170 positions and will serve to locate beam loss to within about 10 m. The computer read out for these detectors is not yet complete and they will be used in conjunction with an oscilloscope display system initially.

Intersection Regions

Five intersection regions used for experiments up to now are seeing major changes in the course of the shutdown and an additional region is receiving detectors for the first time. Let us go round them in sequence:

I-1 Complete clear out. The massive dilepton searchers (CERN, Columbia, Rockefeller) have completed their experiment and their detectors are wheeled out to make room for the Saclay team to return to extend their study of high transverse momentum particles. They will have a large aperture magnet (installed at 90°), Cherenkov and shower chamber, as they had in this region before, but this time with an almost identical detection system on the opposite side to see what they can learn about correlation of their high momentum particles with particles emerging from the collisions in the opposite direction. They are likely to be there throughout 1973 and may be joined by the CERN, Columbia, Rockefeller contingent who would add their lead glass counters to the detection system making it almost symmetric.

I-2 The CERN, Holland, Lancaster, Manchester study of stable particles at small angles will have the spectrometer realigned. The Bologna experiment on particle production at medium angles stays virtually as it is until March (when the Argonne septum magnet will be repatriated). The same goes for the Scandinavian, UK experiment mentioned in the last issue (page 418). There is however a proposal to suspend a magnet up in the air from their equipment to serve for calibration in the UK Universities intermediate boson search on the opposite side of the beams. They want to calibrate their large muon detector using the cosmic rays passing through this analysing magnet.

I-4 This region is being cleared ready for the installation of the Split Field Magnet (see vol. 12, page 235), probably about May. In the meantime it will be used for testing the multiwire proportional chambers (MPCs) which will be installed in the magnet and all their data collection chain right through to the computer.

I-6 Complete clear out also. The CERN, Rome elastic scattering measurements at very small angles are complete (the well known Roman pots are therefore being taken out) and the complementary Aachen, CERN, Genoa, Harvard, Turin experiment is being radically modified. They will now study the Δ^{++} joined by UCLA and their two magnets will be rebuilt into a single unit with an aperture extending above and below the downstream side of one of the beams. This will not be ready for installation during the shutdown and the team will therefore start with more elastic scattering measurements using a new thin-walled bicone chamber at the intersection point and adding MPCs to their detection system as they become available.

I-7 This region will be used for experimentation for the first time and will see the first application of a 'visual' detection technique all around one intersection of the ISR. A streamer chamber is to be used by an Aachen, CERN, Munich team. It will be wrapped around a bicone vacuum chamber and triggered by counters. We will be coming back to this streamer chamber soon after it starts recording particles. It is likely to stay in I-7 for about a year; later on this intersection is needed for low beta insertion studies aiming for higher luminosity.

I-8 The present inhabitants (Pisa, Stony Brook team) will stay virtually undisturbed except for the addition of lead converters to help in the detection of neutrals in their measurement of total cross-section. They will be joined by the CERN, Rome team with an exotic detection system which has posed some intriguing installation problems. They will study particle production in the forward direction using a single arm spectrometer taking negative particles emerging beyond the first magnet of the ring after the collision region. A special vacuum chamber is being prepared for this magnet and the location of the spectrometer requires the reversal of another ring magnet (this had been anticipated and reverse yoke magnets, with special vacuum chambers because of the aperture configuration, are available). A septum magnet followed by four Cherenkovs, a neutral detector and shower counter will all be movable by remote control.

When the ISR comes on again after the shutdown, its experimental programme will be renewed as a result of all this new installation.

Around the Laboratories

Schematic diagram of the recirculating linear accelerator (RLA) proposed at Stanford. The existing 25 GeV electron linac accelerates from left to right in the diagram feeding experiments via the beam switchyard (BSY). If electrons are alternatively stored in the recirculator, while the linac prepares for another pulse, they can be accelerated again reaching almost twice the present peak energy.

STANFORD
Recirculating linac

Of all the proposals for new machines, or major developments of existing machines, currently under discussion in the USA, the Stanford Recirculating Linear Accelerator (RLA) seems the one most likely to roll in the fairly near future. Other proposals, such as the superconducting high energy storage rings (ISABELLE) promoted at Brookhaven, the proton-electron-positron (PEP) storage rings promoted by Berkeley and Stanford or the NAL energy doubler, would open up more physics but are likely to be much more costly and technologically difficult. They will thus almost certainly require more time in the digestion process before any of them is given the go-ahead.

The RLA is designed to increase electron energies available at the Stanford Linear Accelerator (which currently yields peak energies of around 25 GeV) by passing the electron beam a second time through the linac. This idea of making multiple use of a linac is not new (see for example A.A. Kolomensky at the Cambridge Accelerator Conference in 1967, vol. 7, page 201). It has been under serious study at Stanford for about two years. Particularly when difficulties were encountered in realizing the potential of superconducting cavities, a recirculating scheme seemed the best bet for achieving higher electron energies. This is additionally true when the accelerating unit already exists and when account is taken of the difficult life that synchrotron radiation gives in circular electron machines of high energy.

The main features of the proposed RLA at Stanford are as follows: The electron beam is accelerated in the existing machine to 20 GeV and fired into the recirculator which is a storage device consisting of two long straight sections (which will sit above the present accelerator in the same tunnel) linked by two loops where magnets bend the electrons round to travel back through the tunnel in the opposite direction. The total distance around the recirculator is 6.9 km and each loop has a radius of 95 m.

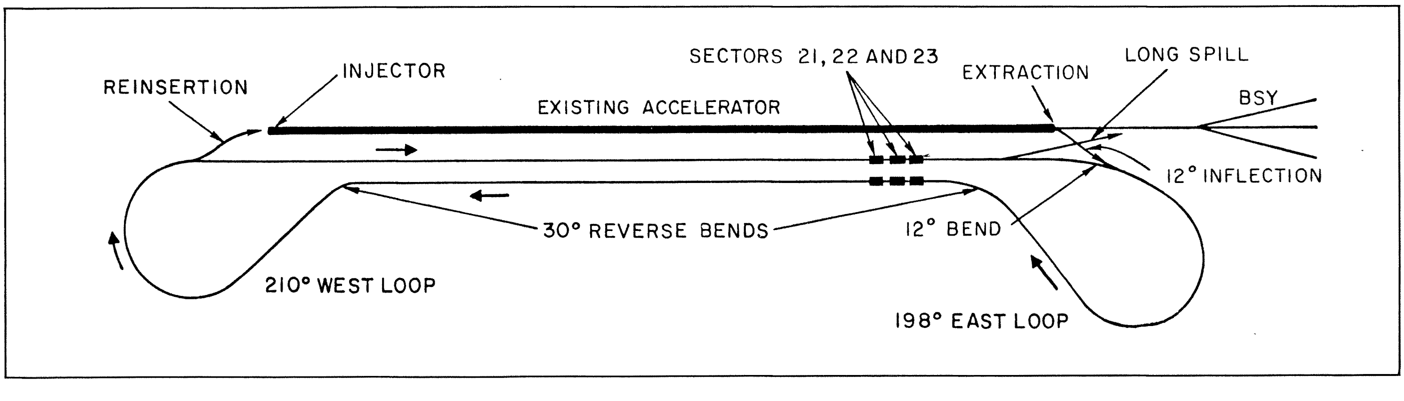
When the electrons have swirled around this system 120 times (taking 2.8 ms) the klystron units of the accelerator are ready to fire again and the beam can be reinjected at the input end of the linac to receive the full 25 GeV as additional energy. The peak energy is thus raised to 45 GeV. There is another interesting possibility which gets around the low duty cycle limitation of electron linacs to some extent — the stored beam could be "spilled" to experiments over many turns around the recirculator. Using the RLA as a beam stretcher, spilling about 1 % of the beam per revolution, could take the duty cycle to 7 % compared with the present duty cycle of 0.06 %.

Since the electrons are forced around bends, the old problem of synchrotron radiation has to be taken into account. R.F. accelerating stations will therefore be installed in the recirculator to put back the lost energy. The aim is to be able to cope with 20 GeV beams of low current or 17.5 GeV beams in excess of 20 mA. Systems involving two or three sectors have been considered and the favourite variant at present is a two sector system powered by klystrons with a peak power of 500 kW.

Also in a straight section will be the beam stretcher system. Two techniques are being studied (Coulomb scattering and magnetic perturbation methods) and each seems capable of efficiencies in the 95 % range.

In the loops, alternating gradient magnets will be used with one focusing and one defocusing magnet per cell. Each cell achieves a 5° bend giving a total of 160 magnets. Their detailed design is under study. Other bending magnets are needed in the reverse bends connecting the loops to the straight sections. In addition there will be about 100 quadrupole focusing magnets of various types.

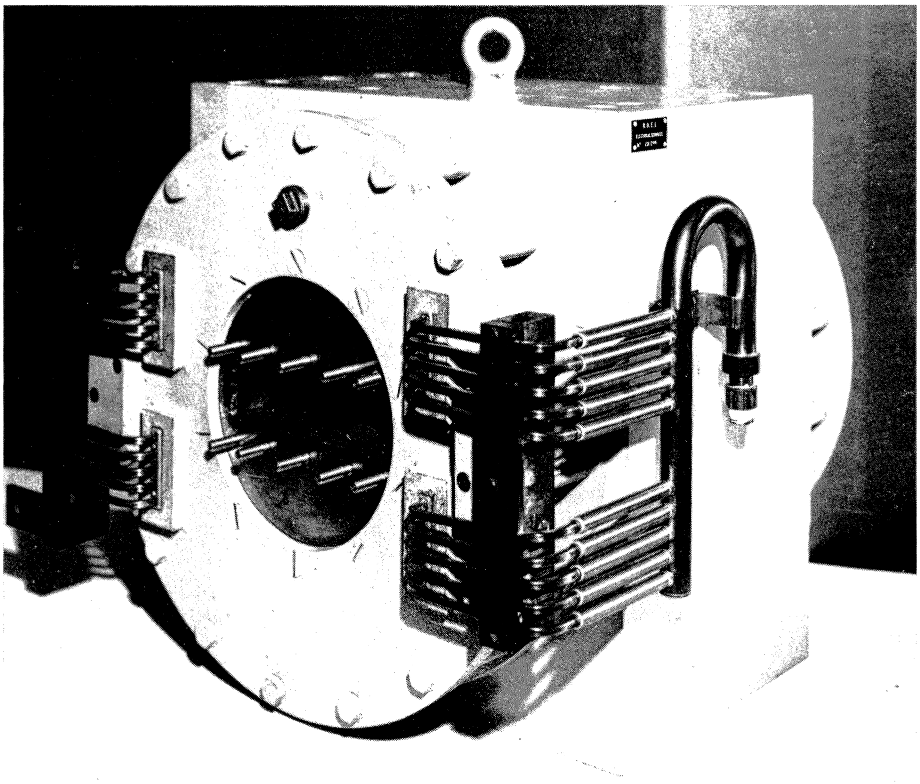
Careful design is needed to ensure that the beam quality is retained in the recirculator so that no trouble will be experienced when the high energy

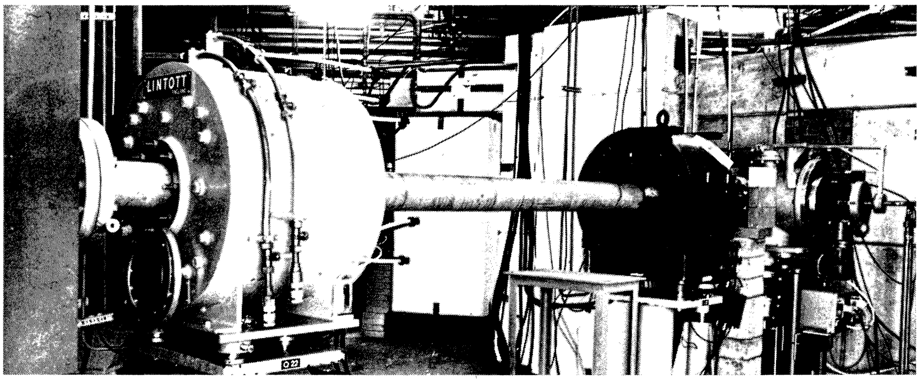


Concrete magnets now in action:

1. A bending magnet built at Rutherford which has since been installed in a beam-line at Daresbury.
(Photo Rutherford)

2. A quadrupole built at Lintott Engineering Ltd. which is shown installed in a beam-line at DESY. It has already outlived a conventional quadrupole in the radiation environment to which it is exposed without sign of deterioration.
(Photo Lintott)





electrons are passed again through the linac. To retain a repetition rate of 360 pulses per second, the accelerator will have to cope with both a "new" low energy beam and the stored high energy beam going through its structure at the same time (otherwise the repetition rate will drop to 180 pulses per second). The quality of the stored beam must therefore be capable of being handled by the focusing system which handles the low energy beam. The beam optics of the RLA are therefore receiving a lot of attention.

An RLA Steering Group was set up at Stanford in the autumn of last year with several of the Laboratory's leading accelerator physicists devoting their full time to pushing the project forward. The Group consists of J.R. Rees, W.B. Herrmansfeldt, D. Coward (beam switchyard), A. Lisin (chief mechanical engineer), R. Scholl (chief electrical engineer) and P.B. Wilson (r.f. system). Cost estimates are in the region of $ 15 million and the recirculator will take three years to bring into action from the time the project is authorized.

RUTHERFORD/DESY/ DARESBURY Concrete magnets

Several years ago (see vol. 9 page 172) the idea of using concrete in magnets as an insulation material extremely resistant to radiation came up at the Rutherford Laboratory from the work of R. Sheldon and G.B. Stapleton. After a period of research on the use of mineral materials, it was demonstrated that magnets could be effectively insulated using water setting cements. Two prototypes have now been constructed which can act as replacements for conventionally insulated magnets. One of them is a bending magnet constructed at the Rutherford Laboratory, and the other a quadrupole, constructed at Lintott Engineering Ltd. The dipole is in action at Daresbury and the quadrupole at DESY.

The bending magnet is similar to the standard dipole H5 used at the Daresbury Laboratory and has 160 turns producing a field of 1.14 T at 375 A. When the magnet had been conditioned to completely dry-out the insulation, it was tested and gave the following results: the resistance was 0.184 Ω at 20°C; the insulation was 400 MΩ at 2 kV d.c. between the conductor and earth and between the coil pancakes.

The magnet has now had approximately 1000 hours in service at Daresbury at a low radiation level and has performed without trouble. It is now planned to reinstall it in another region where it will be required to sustain a much higher radiation dose.

The quadrupole design is similar to the standard DESY quadrupole magnet and has 35 turns per pole to produce a field gradient of 0.17 T/cm at 1000 A. The measurements after dry out were: a resistance of 0.038 Ω at 20°C and an insulation of 54.5 MΩ at 2.5 kV d.c. The magnet was then despatched to Hamburg for installation at DESY.

A convenient opportunity for testing the abilities of the concrete insulation arose when a conventional quadrupole in a high radiation position just downstream of the linac failed for reasons most probably due to radiation damage. This occurred after some 5000 hours of operation and examination of the coils showed considerable blackening which intensified in the horizontal plane. Blistering and cracking was observed and, in the most exposed region, resin degradation which looked like charring. Monitoring the coil with a hand probe indicated that the regions of highest induced

Recent photographs from the National Accelerator Laboratory, Batavia:

1. Aerial view of the site looking from the north-west side. In the foreground is the central laboratory area. The shapes of the high rise building and of the Booster pond are easily distinguishable. The main ring, 2 km in diameter is picked out by the water channel and the service buildings. The ejected proton beam goes off to the experimental areas bottom left.

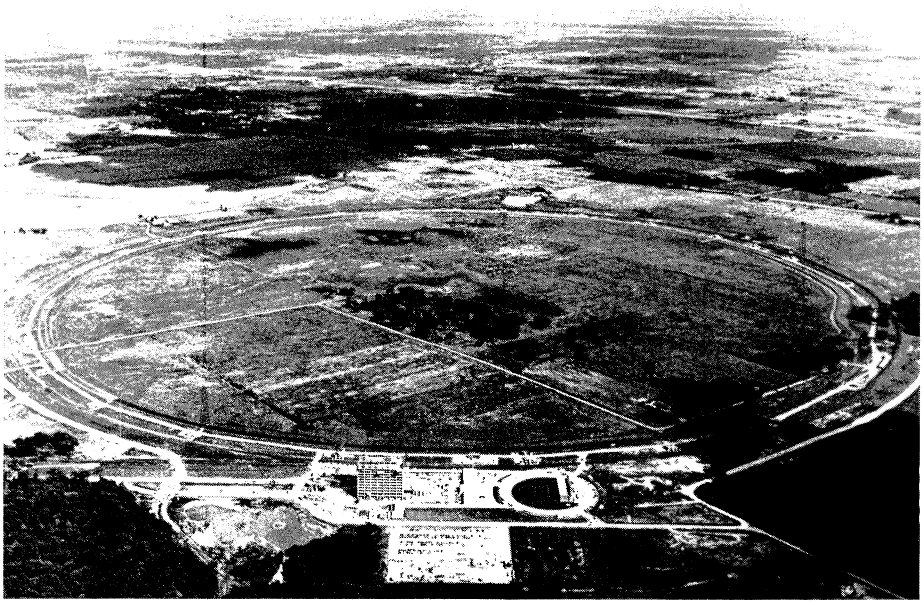
2. Zooming in on the central laboratory area, this photograph was taken from the high rise building looking out over the Booster pond where the water sprays are part of the machine cooling system. On the right is the linac feeding the Booster ring at 200 MeV. On the left parallel to the linac is the 'transfer hall' where the 8 GeV beam is sent to the main ring. (The Booster incidentally provided its design number of 13 successive pulses for the main ring for the first time on 13 December.) Joining these two parallel buildings is the 'cross gallery' with the main control room at its centre. Just visible in the foreground of the picture is a part of the circular auditorium which is linked to the high rise building.

radioactivity corresponded to those showing the severest degradation. It is difficult to estimate the dose the magnet received since it is not known if the irradiation was sustained throughout the total period or if the major dose occurred over a limited period. Comparing the appearance of the epoxy resin of the coil with specimens of epoxy irradiated to high levels in the laboratory suggests that the highest dose could have been well in excess of 10^{10} rads. However, it is possible that radiation heating aggravated the degradation.

The concrete quadrupole was installed in this position and after being in service for a similar time to that of the conventional magnet, continues to perform without problem. The only superficial signs of radiation are degradation of the paintwork; this is mainly on the upstream face in a horizontal band some 5 to 10 cm wide across the median plane. A new insulation test between the conductor and ground gave a resistance in excess of 50 MΩ.

Some concern had been expressed about the condition of concrete after prolonged irradiation, although experience with reactors suggested that the properties of concrete would not be significantly affected. In order to examine the concrete in contact with a coil, a dryout plug was removed from a position corresponding to the region of highest dose. The concrete exposed by removing the plug was found to be extremely hard with no signs of any crumbling or other mechanical damage. It is expected that this magnet will continue in action in its high radiation environment.

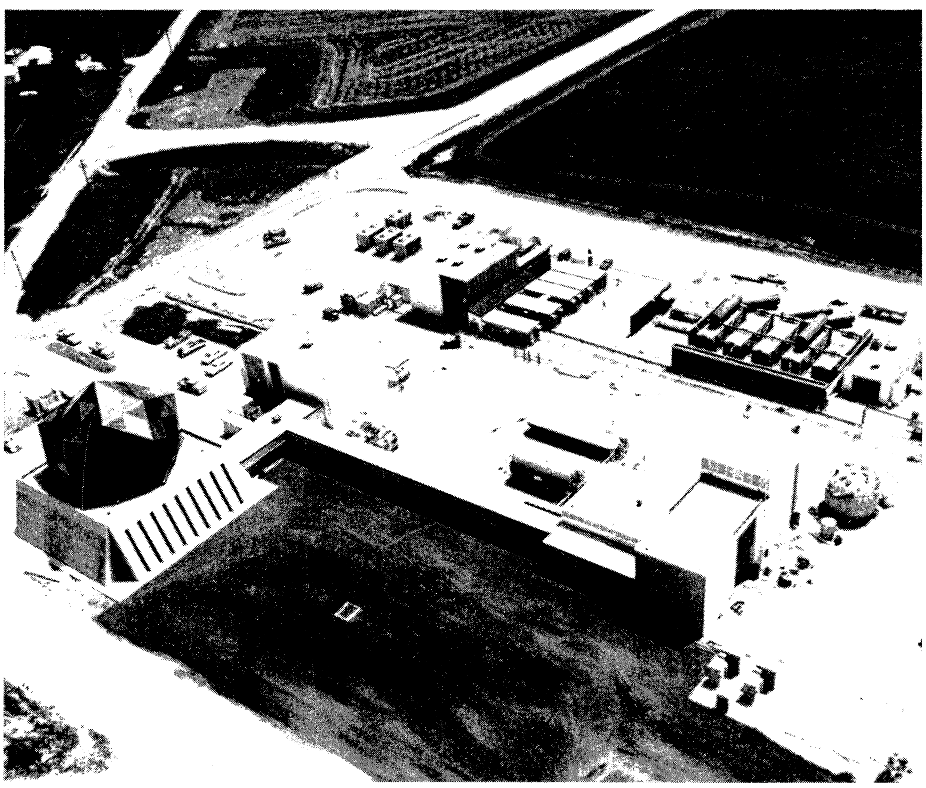
Following these encouraging results, a larger quadrupole magnet is being designed at Rutherford. It is intended to replace a conventionally insulated quadrupole in a high dose region close to an extracted proton



3. The high rise building itself. The full sixteen floors have now been constructed and the offices etc. will be ready to receive Laboratory staff after March of this year. All the activities which have been based in the NAL village, for example, will be moved to this Central Laboratory Building.

4. The Neutrino Laboratory. This is one of the three experimental areas (the others being known as the Proton Laboratory and the Meson Laboratory) and is the location of the two bubble chambers. The large building top centre, which has temporary barrack offices in front oe it, houses the 30 inch hydrogen bubble chamber. The largd building bottom right, with the sphere outside, houses the 15 foot chamber. The bubble chamber control room can be seen topped by its geodesic dome which is made from panels of 'pop cans' sandwiched between epoxy sheets.

(Photos NAL)



beam target at the proton synchrotron, Nimrod. This magnet will be constructed during 1973.

Throughout the preparation and construction work on these magnets the Rutherford Laboratory has had the help and advice of J.F. Raffle of Loughborough University of Technology where research is under way on the application of concrete mixes for magnet insulation.

DARESBURY
Polarised target in photon beam

The Liverpool University polarised proton target has been improved by replacing the He^4 cooling system by a He^3 system thus increasing the polarisation. This is the first time an He^3 system has been used for this purpose at an electron accelerator. The target temperature is about 0.5 K giving an initial polarisation of about 60 % in a butanol target. The target is playing an essential role in the programme of pion photoproduction experiments in progress at the 5 GeV synchrotron.

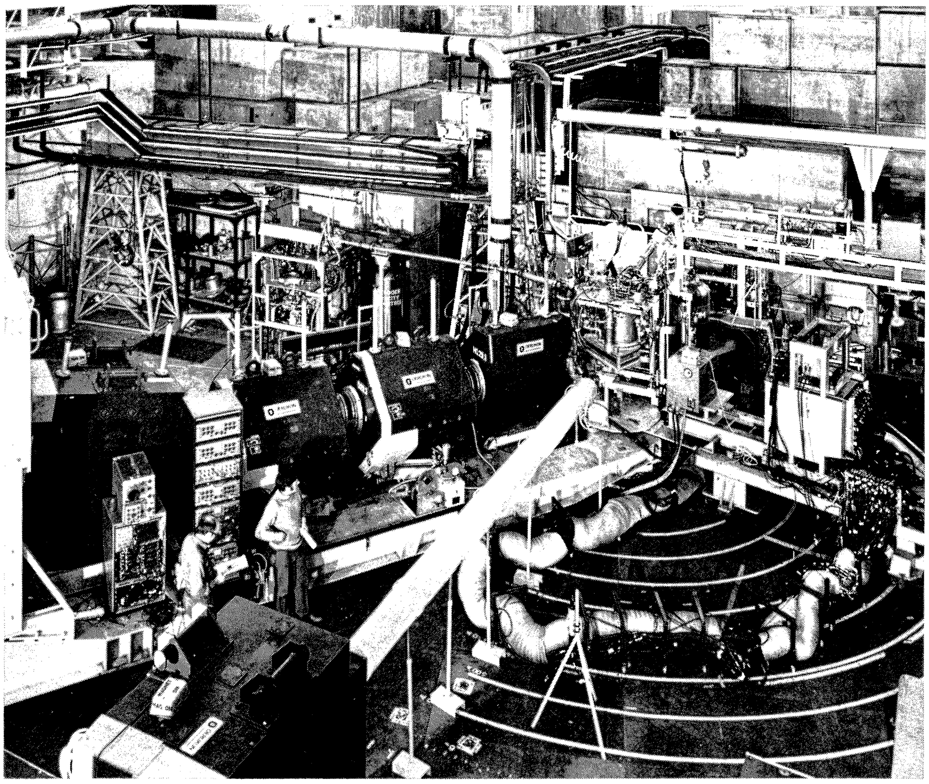
Photoproduction experiments can be classified into three groups according to the incident photon energy. Below 2 GeV there is the resonance region, above 3 GeV is dominated by Regge exchanges and in between lies a region of rapid transition from resonance to Regge. All three regions are being studied at Daresbury. The primary objective in the resonance region is to obtain the electromagnetic couplings (i.e. the radiative decay widths of the nucleon resonances). Just as radiative transitions in nuclei play an important role in elucidating nuclear structure, so radiative decays of nucleon resonances play an important role in elucidating baryon structure.

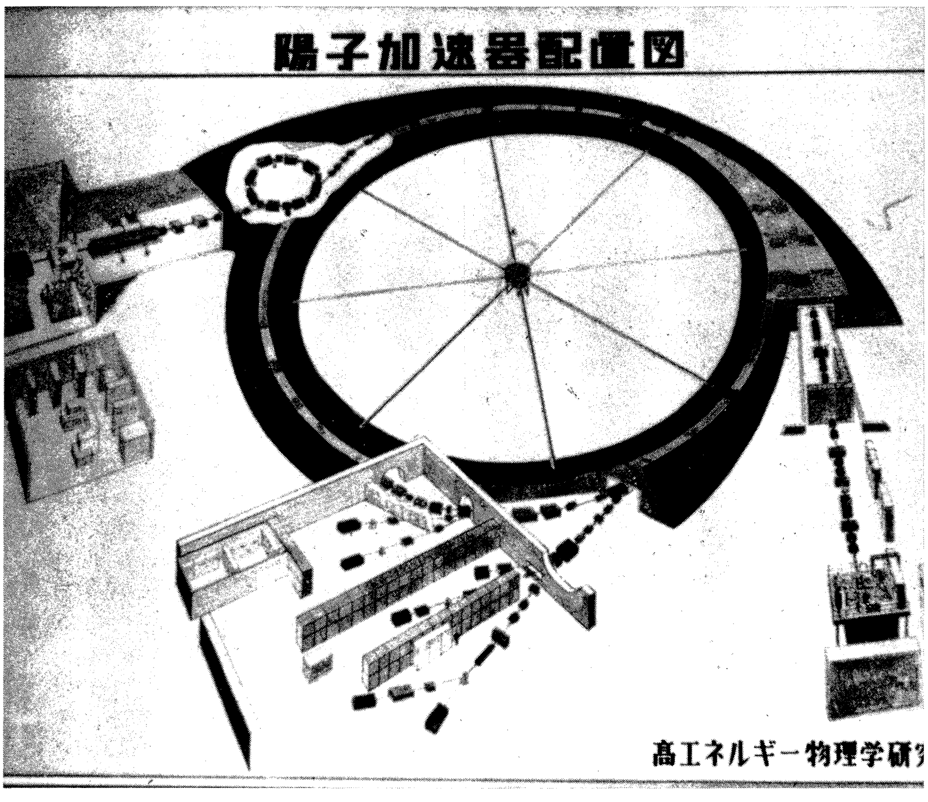
The photoproduction experimental area at Daresbury showing part of the high resolution proton spectrometer arm. In the centre is the polarized proton target recently refurbished with a He^3 cooling system to achieve a target temperature of 0.5 K. On the right is an array of lead glass Cherenkov counters. The apparatus is being used to study photon-polarized proton interactions giving neutral pion and proton.

(Photo Daresbury)

A model of the 8 GeV proton synchrotron being built at Tsukuba near Tokyo, Japan. A 20 MeV linac feeds a 500 MeV booster which in turn feeds the main ring. Experimental areas will be prepared for electronics experiments and for a bubble chamber (to the right).

(Photo National Lab. for HEP, Japan)





The reasons for studying high energy reactions are precisely the same as in hadron induced reactions — to investigate the nature of the reaction mechanisms and to try to understand the connection between the resonance and Regge regions (to try to put substance into such concepts as duality which says, in a rather ill-defined way as yet, that the resonances build-up the Regge poles and conversely the Regge poles build-up the resonances).

Pion photoproduction at a given energy and angle can be described by four independent helicity amplitudes (four complex numbers). An analysis requires as much data as possible on differential cross-sections, polarised target asymmetries (or recoil nucleon polarisation) and polarised photon asymmetries. A survey of world data reveals the paucity of polarisation data which makes the use of polarised targets and polarised photon beams at electron accelerators particularly important. The Liverpool target has been used for photoproduction experiments at Daresbury for eighteen months and commissioning of a polarised photon beam is under way.

The current target uses He^3 as refrigerant to obtain a temperature of about 0.5 K and superconducting coils in the split pair configuration to provide a magnetic field of 2.53 T. The target material is butanol with 5 % water in the form of frozen beads contained in a holder 15 mm in diameter and 24 mm long. The polarisation and the radiation dose are measured every 8 seconds and are calculated and displayed by an on-line computer as well as being transmitted to the central computer for storage and later use.

Currently, the beam enters the target between the super-conducting coils at right angles to their axis. The protons are polarised perpendicular both to the incident beam and to the scattering plane. However, an advantage of split pair coils is that the direction of beam entry can also be parallel to their axis and the protons are then polarised parallel or anti-parallel to the beam. Plans to achieve this longitudinal polarisation arrangement are well under way.

Radiation damage of the target is a serious problem in pion photoproduction experiments because of the high intensity photon beams required. The radiation damage not only reduces the polarisation but can also reduce the accuracy of the polarisation measurement when the beam intensity distribution is not uniform. it is, therefore, necessary to make frequent stops during data taking to anneal out radiation damage and eventually to change the target material.

The first two polarised target experiments at Daresbury — the first ever on neutral pion photoproduction in the Regge region — were carried out using an He^4 cooled target operating at 1 K. The third experiment (in the resonance region) which has just been completed, used the new He^3 system. The effect of radiation damage at 0.5 K proved to be less than at 1 K. It was also found that, even at the maximum usable photon beam intensity (about 4×10^{10} equivalent quanta per second), loss of polarisation due to beam heating is negligible. Thus the change to the He^3 system, resulting in a large increase in polarisation, has made the target more efficient for the continuing study of pion photoproduction.

JAPAN Synchrotron construction

The first components of the 8 GeV proton synchrotron are coming together at the National Laboratory for High Energy Physics at Tsukuba near Tokyo. The preinjector platform is installed and high voltage tests with the 750 kV pre-injector have begun. Manufacture of the 20 MeV linac tank and the drift tubes (being made to unusually high tolerences) is under way. Prototype magnets have been made for the booster and main ring.

The linac will feed a 500 MeV fast cycling booster using multi-turn injection. The booster is a combined-function machine, 12 m in diameter with a peak magnetic field of 1.1 T and a repetition rate of 20 Hz. Its space charge limit is 3×10^{12} protons per pulse. Nine pulses will be transferred to the main ring per machine cycle.

The main ring is 108 m in diameter and is designed for 8 GeV initially but with the possibility of climbing to 12 GeV later by increasing the peak magnet field which is 1.2 T for 8 GeV. The magnet aperture is 14×5 cm^2. The main ring is separated-function and is designed for a beam intensity of 2×10^{12} protons per pulse or above (the calculated space charge limit is 10^{13} ppp) with a pulse repetition rate of 0.5 Hz. Power supplies for both the main ring and the booster will use the static compensator system.

Laboratory personnel has now grown to eighty people and by the time the accelerator is operating is expected to reach 270. Budgets have been agreed through to the completion of machine construction in 1975. The total cost over four years up to this date is fixed at about 120 million Swiss francs of which about 40 MSF is allocated to the accelerator itself.

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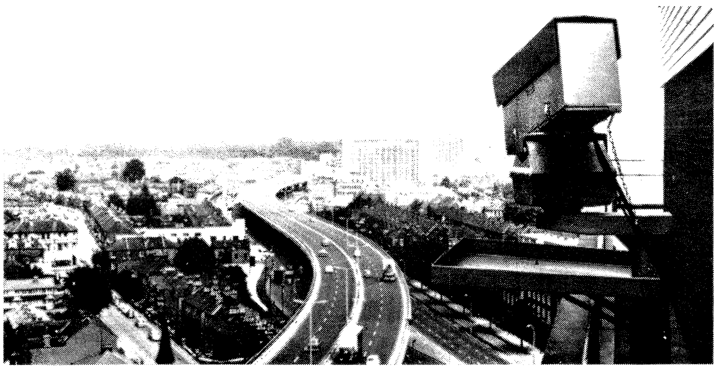

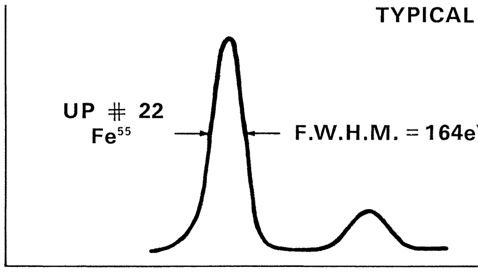

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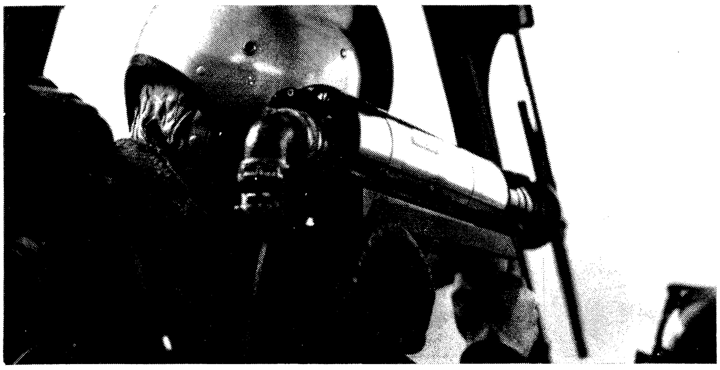

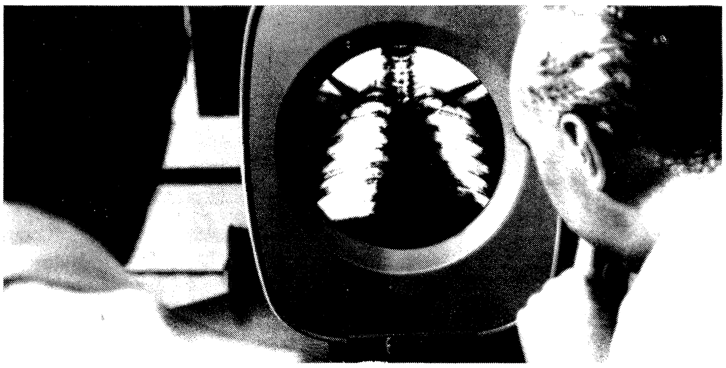

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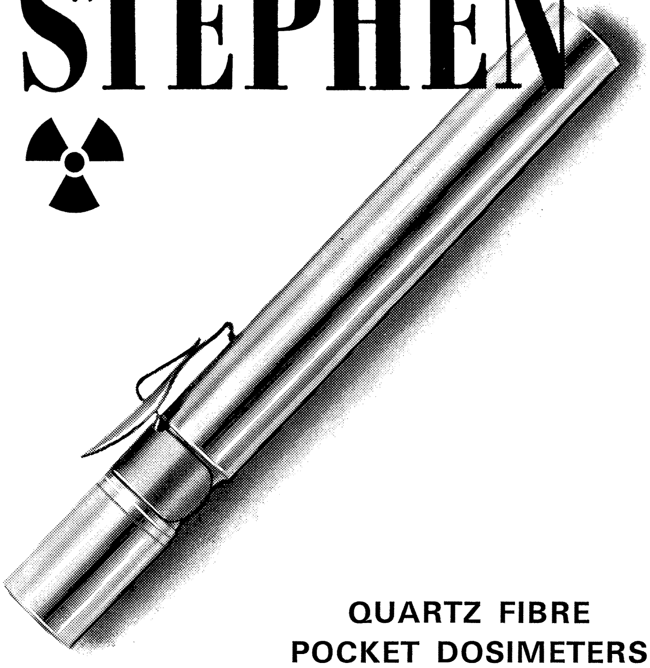

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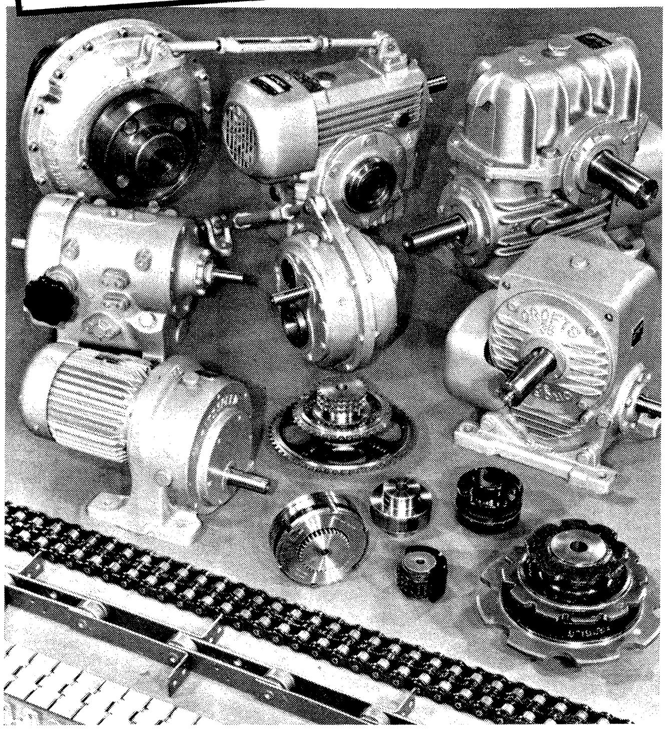

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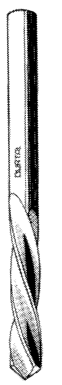

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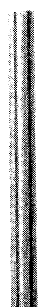

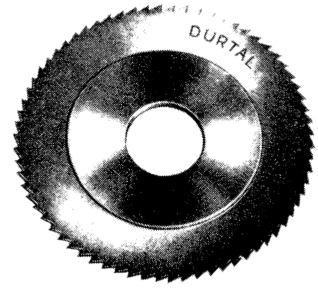

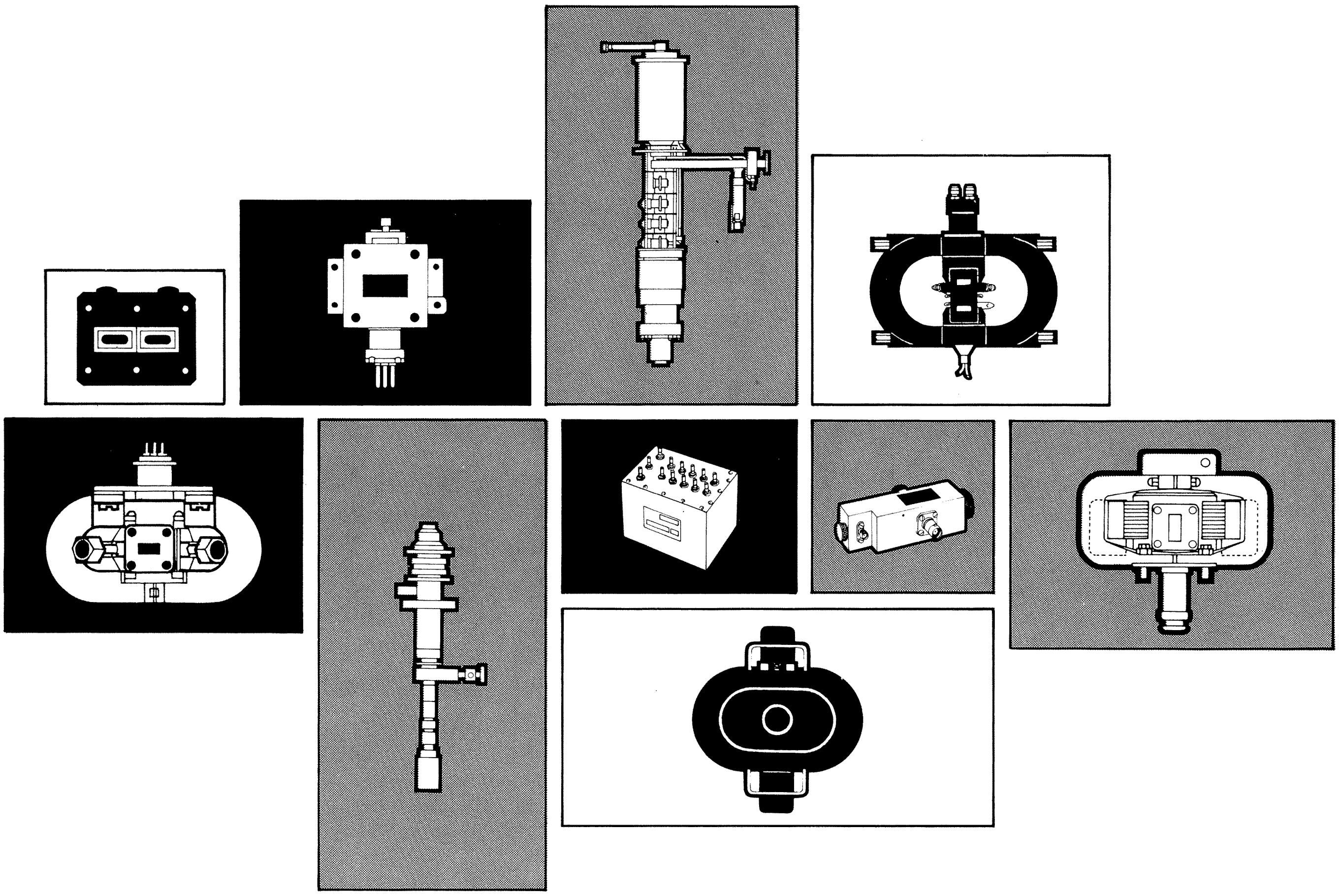

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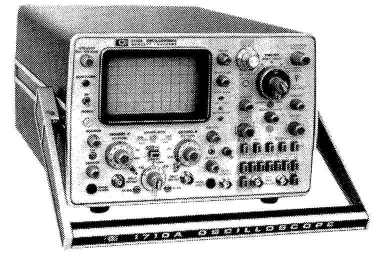
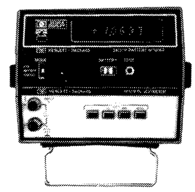
Son grand écran de 6 × 10 cm permet une visualisation nette et lumineuse des impulsions rapides rencontrées fréquemment dans les circuits modernes. D'autre part, un mode nouveau d'utilisation permet de doubler la luminosité, sur une échelle réduite, pour la représentation de phénomènes ultrarapides jusqu'alors invisibles à l'oscilloscope. Cet instrument possède également quelques autres particularités intéressantes:
Une impédance d'entrée commutable de 50 ohms ou 1 mégohm, une sensibilité de 5 mV par cm sur toute la largeur de bande, des possibilités multiples de déclenchements électroniques, ainsi qu'une double base de temps.

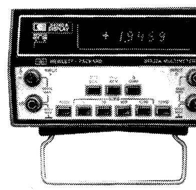


Une démonstration vous convaincra certainement des possibilités étendues de cet oscilloscope portatif. N'hésitez donc pas à nous contacter.

Le voltmètre digital multiforme

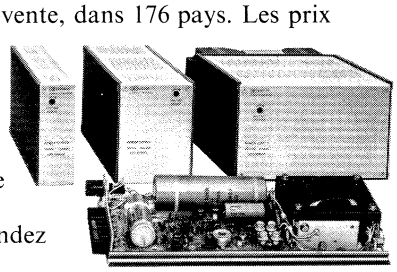
Combien de fois vous est-il arrivé de chercher en vain, un multimètre digital, aux qualités multiples, pour le prix modéré d'un instrument analogue?
Hewlett-Packard offre aujourd'hui une solution à ce problème et vous présente son modèle 3470. Il représente beaucoup plus qu'un voltmètre digital habituel. Il s'agit en fait d'un instrument de mesures pratique, polyvalent, exemplaire quant à son prix et à ses performances.
Combinez vous-même le modèle qui vous convient le mieux, en utilisant l'unité d'affichage d'une part, et les différents modules de mesures d'autre part. Faites-en par exemple un voltmètre à courant continu de 4 gammes, ou encore un multimètre DC/AC possédant en outre 6 échelles de mesures de résistances.
Pour une utilisation indépendante du réseau, il est facile d'intercaler un élément batterie. De plus, en nouveauté, un module BCD interchangeable vous est offert pour coupler votre multimètre à une imprimante numérique. D'autres éléments sont en préparation, qui vous permettront d'étendre ce système à d'autres types de mesures, à tout instant et pour un prix minimum.
Prenez contact avec nous pour une présentation.





La tension qu'il vous faut!

Une heureuse nouvelle pour les constructeurs d'équipements! Une série entièrement nouvelle de sources stabilisées est offerte à votre choix, et quand nous parlons de choix, nous pensons effectivement qu'il s'agit de pouvoir choisir!
Nous mettons à votre disposition des blocs d'alimentations modulaires de la série 62000, qui existent actuellement pour les tensions de 3 à 48 volts. De plus, chacun d'eux est livrable en 4 intensités différentes. Tous ces appareils bénéficient du réseau local de services après-vente, dans 176 pays. Les prix également ont été ajustés pour satisfaire à votre demande, et des rabais OEM sont offerts.
La fiabilité de ces appareils répond aux exigences les plus poussées, chaque élément étant d'ailleurs surdimensionné. Tous les modules possèdent en outre une protection contre les surtensions, une limitation réglable du courant, des sorties indépendantes, en fait tout ce que vous attendez d'une alimentation de qualité Hewlett-Packard.
Les modules de la série 62000 sont livrables à courts termes. Demandez une documentation détaillée.



Hewlett-Packard (Schweiz) AG, 9, ch. Louis-Pictet, 1214 Vernier, tél. 022 41 49 50, télex 27333 *HEWLETT hp PACKARD*

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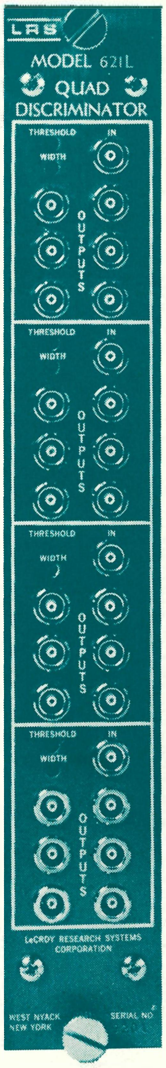
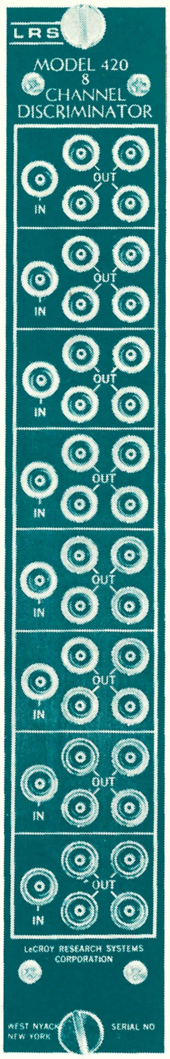
The new standards in discriminators



Model 621L Quad Variable Threshold Discriminator is an extremely versatile instrument with performance characteristics especially chosen for large-scale general-purpose use.

- **Continuously variable threshold** from −50 mV to −300 mV. Low minimum threshold permits proper back-termination of phototubes or allows use of small photomultipliers without the necessity for a separate amplifier.
- **Fiddle-free threshold and width controls** are screwdriver-adjustable. Recessed behind the front panel, they cannot be changed inadvertently during the course of an experiment.
- **Continuously variable output width controls** from 5 ns to 1 μs is the widest continuous range offered by any discriminator in its class.
- **100 MHz operation:** The double-pulse resolution of 8 ns provides ample speed for most large-scale general-purpose applications.
- **High fan-out:** Each channel offers six separate normal NIM outputs.
- **No multiple-pulsing:** One, and only one, output pulse is produced regardless of input duration or amplitude.
- **Low time slewing:** $<$1 ns.
- **Deadtimeless operation** updates the output pulse to reflect the most recent input signal.
- **Compact packaging and low power consumption** permit up to 48 discriminator channels (288 outputs) in one standard NIM bin.
- **740 Sw Fr per channel** in unit quantities.



Model 420L 8-Channel Discriminator contains eight identical pulse amplitude discriminators designed for use with hodoscope and similar large-scale applications where moderate speed and flexibility are required.

- **Low input threshold** of −70 mV provides compatibility with lower gain hodoscope counters or with signals which may have been degraded by long cable delays.
- **Excellent threshold stability** of $<$200 mV/°C preserves threshold value over varying operating environment.
- **High fan-out** of four −1 volt signals can each drive up to two 50 Ω loads.
- **Fixed 4 ns output width** is independent of input duration, amplitude, and rate; no need for width cables.
- **Low time slewing** provides accurate timing signals regardless of the distribution of input amplitudes.
- **Short input-output delay** minimizes need for long compensating delay cables and provides prompt system outputs.
- **Compact packaging and low power consumption** permit up to 96 discriminators to be housed in one standard NIM power bin.
- **430 Sw Fr per channel** in unit quantities.

If you have designed fast logic systems, you have seen optimum system designs scrapped because of inadequate discriminator fan-out. Either you've had to compromise the over-all logic design to accommodate the fan-out limitations, or you have had to increase and unbalance the logic delays through insertion of fan-out modules in the system.

We do not think this is how it should be . . . and we have done something about it. Two new LRS discriminators attack the fan-out problem directly. The Model 420L, the most compact and economical discriminator available, offers four independent outputs per channel, each capable of driving two 50 Ω loads. The new Model 621L, based upon the proven design of the world's most widely used discriminator, the LRS Model 321B/50, provides six independent outputs per channel, each capable of driving two 50 Ω loads. This rather phenomenal fan-out capability of LRS discriminators is achieved through a simple new output stage design which does not strain normal NIM power limits or require special voltages (e.g., $\pm$6 V).

With the Model 420L for your hodoscope counters and the Model 621L for fast trigger logic and general-purpose use, you will enjoy:

- **Lower system cost**
- **Smaller system size**
- **Shorter, uniform delays**
- **Simpler system design and setup**
- **Higher reliability from low-dissipation circuits that run cool.**

For further information, call or write *Alan Michalowski,* Sales Manager, LRS Particle Physics Division, or your local LRS Sales Office.

LRS

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