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UCRL-3401

UNIVERSITY OF CALIFORNIA
Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

REPORT ON OBSERVATIONS AT SACLAY, HARWELL, EINDHOVEN, CERN AND BROOKHAVEN

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May 1, 1956

Printed for the U.S. Atomic Energy Commission

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Summary

Observations were made on electronic materials, equipment, techniques, fast circuits, and particle accelerators at Brookhaven, CERN, Harwell, Philips Research Labs at Eindhoven, Andre Lallemand's Photomultiplier Lab at the Paris Observatory, and Centre d'Études Nucléaires de Saclay.

Introduction

It was my privilege to be invited by the Commissariat a l' Énergie Atomique (France) to observe the progress, methods, and proposed schemes for the rf system of the proton synchrotron under construction at Centre d'Études Nucléaires de Saclay. The time of the visit was during the first three months of 1956. During this period, short visits of 1 to 3 days were made, on behalf of the U.S.AEC, to the various other installations mentioned above. I was primarily interested in the fields of fast electronic circuitry with applications to monitoring of high-energy particle-accelerator nuclear events, and of the rf systems of proton synchrotrons. This report is thus necessarily restricted to the materials, equipment, techniques, and circuits that were encountered, in the short time available, in the fields of interest.

Materials

Europe has several companies producing ferroceramics. The best known, the Philips Company at Eindhoven, Netherlands, has the largest facilities. The Steatit Magnesia Company, Werk Porz, Germany, is fairly well known. However, the Lignes Télephoniques et Télegraphiques, near Paris, France is not so well known. The LTT Company produces a ferrite with a Q of about 80 for use at 10 Mc and below, as well as many other types of ferrite.

Many companies are beginning to produce semiconductor devices. Originally, the manufacture of diodes by the Dutch Philips Company was the only important production of semiconductors. Now, however, in addition to Philips, working with transistors the LTT people, under license from Bell Labs, are making transistors of reportedly very good quality; other companies are also in the preliminary stages of production.

The situation with respect to receiving-size vacuum tubes has been much improved recently. Almost all the important American types are being produced under license in Europe; in addition, the Philips Company has many excellent tubes. Philips is producing the interesting new types, with most other companies concentrating on American types.

Transmitting-size tubes are in good supply. Although there are no European superpower shield-grid triodes, there is almost everything else from megawatt klystrons on down: water-, vapor-, and air-cooled; coplanar, disc seal, and conventional construction, are all available. None using ceramics in place of glass were seen.

A special beam-switching type for use as a very fast (millimicrosecond) binary scalar is being developed by Mullard, of England. The Dutch Philips people were shown an advance copy of Q.A. Kerns's suggestions[1] of EFP 60 modifications. The ideas were well received. Philips workers were also interested to learn of the desire for a tube of the EFP 60 type that would have a somewhat lower secondary-emission ratio (2.5 to 3 instead of 4 to 5), but with greater stability than is presently realized with the existing EFP 60. Their attitude was that not much could be done, however, since there is insufficient demand. It seems to me that there would be a large demand for such an advanced type EFP 60 — a demand even greater when the existence of such a tube became widely known. Many people would like to use the EFP 60, but cannot, because of the 300-Mc resonances, or the instability, or both. A few people are forced to use it because it is the only tube that can be used. As a result, few people use it, and those who do, dislike it. The Philips commercial attitude is clearly noticeable in their version of the 417 pentode. The same high transconductance is preserved, but the very short leads of the early Bell version are gone; as a result, the tube is valuable only to the low, instead of the middle, hundreds of megacycles.

The situation with regard to resistors, capacitors, and general hardware is very good. Deposited-carbon resistors, in particular, are in an advanced state in Europe. Tantalum-type electrolytics are just appearing on the market. The cable connector field is even more confused than in America--not only are there many European types, but in addition, the American types are widely used also.

Equipment

The equipment situation is quite mixed. German middle-range signal generators are quite good. The French have good multimeters and vacuum tube voltmeters. England (Metropolitan Vickers) has a sampling type[2] oscilloscope with a 300-Mc bandwidth. In general, the mid-range equipment ordinarily used is available in quantity in Europe. Except for the Vickers unit mentioned, the specialized equipment involving very high or very low frequency, or very wide range, is still imported. Examples are: Tektronix 535 and 517 oscilloscopes; Hewlett-Packard distributed amplifiers, 650 and 202 signal generators.

[1] UCRL Engineering Note 4311-03-E2.

[2] I.A.D. Lewis, Millimicrosecond Pulse Techniques, McGraw-Hill, 1954, p. 208.

Techniques

Circuit techniques are still conventional. The use of etched wiring boards is just beginning. Racks utilize panel sizes for vertical division similar to the American system, but in addition, panel space is divided horizontally to allow plug-in subunits horizontally. "Erector-set" type standard parts allow building several different-sized subunits.

The shortage of trained personnel skilled in pulse-circuit techniques, is even more acute than in the U.S.

Fast Circuits

The largest and most advanced group in millimicrosecond pulse techniques is at Harwell under Dr. Kandiah. The state of their art is well known by the publication "Millimicrosecond Pulse Techniques" by Lewis and Wells (Dr. Lewis is no longer at Harwell). The Harwell group is now working to keep up with the demand for the existing circuits; thus the major effort is in exploiting the existing circuits, rather than further research. Development is going on presently of "time sorters" and "kick (pulse height) sorters," with emphasis on few vacuum tubes, as well as a traveling-wave oscilloscope.

The Philips Research Labs is not concerned with fast circuits for nuclear research purposes now. They are investigating the hysteresis loops, at high frequency, of the small ferrite cores used as "memory" units in electronic computers. Dr. H.G. Bruijning has developed a sampling-type oscilloscope capable of resolution time of 10^{-9} sec. He hopes to reduce this time by utilizing diodes in the sampling circuit.

The Brookhaven National Laboratories has an "Electronic Instrumentation" group doing fast circuitry. A sampling-type oscilloscope with a rise time of about 0.5×10^{-9} second has been constructed by Robert Sugarman. Much of the work at Brookhaven has been reported[3] already.

There are two groups doing fast circuitry at Saclay. The Physics Department's group, under Dr. G. Valladas, was engaged in fast-coincidence circuits. The Electric Services group was working on trigger and scaling circuits. The Physics group stated modestly that they were in the learning stage; they attained a coincidence time of 3×10^{-9} second with Garwin-type and 6BN6 circuits. The Electric Services Group (J. Mey) has a scaler with a speed of about 30 Mc. The Physics group's handicap was lack of high-level manpower, and Electric Service's handicap was lack of good pulse sources and oscilloscopes. The two groups worked well together, cooperating to avoid duplication of work, and providing mutual assistance.

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[3] Nucleonics, McGraw-Hill, April 1956, p. 33.

Photomultipliers

The Electric Services Department has a group working on photomultipliers in close cooperation with CSF, a French company. The emphasis is presently on large-area scintillators and photocathodes (in conjunction with conventional multiplier structors). The largest units are on the order of 1 foot in diameter.

Andre Lallemand's photomultiplier group at the Paris Observatory manufactures units that stress sensitivity and very low dark current. The laboratory forms their own multiplier units (Venetian blind type), deposit their own photocathodes (Sb, Cs_3, and $AgCs_2$-O), and in fact do all the manufacturing processes from the sheet metal and glass blanks on through the finished unit. About 50% of a production run have a sensitivity of 100 μa per lumen, 10% have 120 μa per lumen. The transit-time spread is on the order of 1×10^{-8} second; as the unit is intended for astronomical use, no attempt was made to decrease the transit time, or the spread in transit time. Production quantity is but a few per week, not quite enough to supply the demands of astronomers.

Particle Accelerators

The Saclay proton synchrotron[4] had progressed to the point where sufficient numbers of magnet sections had been tested to allow the start of the assembly of the magnet. The magnet power supply and injector (both from outside suppliers) were not yet delivered. A model of the final amplifier and full-scale cavity was about to be tested statically. Technically the magnet is of interest because of the use of an air gap between the pole tips and the yoke. The magnetic measurement technique[5] was interesting in that it employed the principle of the system of the Birmingham switched integrators, but with a much simplified read-out system, utilizing standard decade scalers. The rf system was envisioned as utilizing the field-integrator system of the Cosmotron, with a Bevatron-type stabilizing system for the integrator, and the Bevatron frequency-programing system (no diode computer--the integrator output directly operates a Bevatron-type ferrite saturating circuit in a Cosmotron-type pilot oscillator system). The output of the oscillator will drive a wide-band class A driver, which will in turn drive a Class A1, push-pull, self-tuned, tetrode final amplifier. Through a very careful testing program, and extensive calculations, a design was arrived at which utilizes three types of ferrites and a wide-tolerance programed rotating capacitor. The results expected are a peak rf power of only 2 kw, and varying by only a factor of 2 through the range, at 3 kv across the accelerating gap (about 1.5 times threshold for equilibrium phase angle of 30°). The second-harmonic operation places the 3.6-Mev injection at about 750 kc and the final energy of about 1.8 to 2.7 Bev at about 8.5 Mc (845 cm radius, 10 to 14 k gauss).

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[4] H. Bruck and R. Levy-Mandel, Sur le projet du synchrotron à protons de Saclay, Nuovo Cimento N. 1 del Supplemento al Vol. 2, Serie X (1955), p. 423.

[5] J. Taieb, H. Guillon, A. Gobet, and J. Mey, Appareillage de mesure d'un champ magnetique variable; l'onde electrique, Nov. 1955, p. 1076.

It is of interest to compare the proposed saturation systems to be utilized in the self-tuning schemes for the cavities at Saclay, Brookhaven, and CERN. The common problem is to prevent coupling between the saturation current and rf current, without incurring a large penalty in loss of rf power, saturating power, or speed of response. The Brookhaven solution proposes cavities arranged in pairs, and connected so that when the cavity skin is used as an rf and saturation winding simultaneously, the rf voltages due to each separate cavity add to zero at the saturation supply input. This arrangement is expected to give fairly low coupling and a low rf and saturation impedance level, and thus a fast efficient saturation system is possible at the relatively low cost of a low-impedance rf design. CERN proposes a close-fitting cavity skin, allowing an external magnetic (steel) yoke to be brought in close proximity to the ferrite. The coupling problem is removed owing to the toroidal rf flux and crossed saturation flux. This provides an efficient rf arrangement, but the speed of response is low and the saturation supply large. The Saclay solution is to provide separate saturation and rf windings within the cavity. The ferrite loading frames are arranged in two groups on each side of the accelerating gap. The rf winding is then the "one turn" loop formed by the half-wave cavity. A hollow metal tube, called a "chimney," then threads the groups of ferrites, similar to the rf winding in the Bevatron master oscillator main reactor,[6] in such a way that the rf voltages induced by one group of ferrite frames is canceled by the next group. The chimney thus forms a closed rf shielded system within the cavity. The chimney is to be filled with a convenient number of saturating turns. This results in low coupling, and a reasonably fast, efficient polarizing supply, at the price of a slightly larger ferrite arrangement (to make room for the chimney).

At CERN, the first few hundred feet of the concrete shell for the 25-Bev machine has been poured. A final amplifier cavity has been constructed and is being statically heat tested. Dr. C. Schmeltzer just finished a paper on a proposed analogue for the investigation of the effect of noise in a proton synchrotron. The analogue is quite simple, requiring only two integrators, a programed potentiometer, a signal source, and a phase-adjustable sampling system.

At Harwell, Dr. Pickavance's group is assembling the tank on the first section of the linear accelerator for the CERN injector system. The success of the external beam experiments with the Liverpool cyclotron has caused abandonment of the 500-Mev linear accelerator project. The group is considering ways to obtain a high-beam-intensity machine, of the order of 6 Bev. Current thinking is: injection, 5 ma at 5 Mev (Van de Graaff); repetition rate, 1 per second. The obvious problem is the magnet power supply. Reduction of magnet-energy storage is felt to be the key to a magnet power supply of reasonable-size. The group reasons that since a high-beam-current machine requires a large horizontal aperture, they can (1) use strong vertical focusing to reduce the vertical aperture, or (2) use two magnets--a large unit for acceleration to the order of 1 Bev, and a small magnet for 1 to 6 Bev.

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[6] C.N. Winningstad, The rf System of the Bevatron, UCRL-2543, p. 17.

At Eindhoven, the accelerator program consists of "stock" cyclotrons and Cockroft-Walton generators. Dr. Vester is currently supervising the production of prototype compact, enclosed Cockroft-Walton units, and of deuterium ice targets.

At Brookhaven, the electron analogue machine neatly demonstrated the practicability of a "bootstrap" type frequency-generating system. A one-turn beam is injected into the machine; a sumtype induction electrode picks up the beam rotation signal, which is fed to a phase-shifting amplifier, supplying the acceleration potential. The phase shifter is operated by the error signal produced by the equipment that indicates radial-position. Observation of the beam by means of the sum induction electrode discloses only a gradual factor-of-2 loss during the acceleration cycle; the phase transition point is difficult to observe on the sum signal, but is easily marked on the radial-position error signal. The reversal of the phase of the rf occurs over the period of many rf cycles (and beam tours), but causes a very small beam loss.

This work was done under the auspices of the U.S. Atomic Energy Commission.