STATUS REPORT OF THE ORSAY LINAC

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ORSAY - FRANCE

Main Characteristics

In January 1965, the Linear Accelerator Laboratory of Orsay decided to increase the performances (Energy and Current) of the Accelerator while carrying on the intensive operation of the existing machine.

The leading purposes of this extension are as following :

1. The increase of energy should match with increase of peak-current, average current (duty cycle), stability and fast adjustment of the machine.

2. The increase of performance is only possible with improvements on the existing machine.

3. The project of the extension should be carried out while the existing machine is used at its best. Accordingly, the whole work must be executed in a separate building, so as to be independent of the existing machine which has to run during the construction, and to reduce as much as possible the time needed for connecting the two parts.

4. The extension must allow the acceleration of an intensive and high energy positron beam. Although the money for the e^- - e^+ conversion set and e^+ beam focussing set has not yet been obtained, we must foresee some low impedance sections able to accelerate electron high current at the head of the machine.

5. From the experience of the laboratory acquired by exploiting the existing machine, we decided to our selves design the details of the project and manage the engineering.

Figure n° 1 shows the comparison between the existing and future machine characteristics.

The difference of energy between 50 and 150 c/s results from the fact that on the existing machine it is only possible to reach 150 c/s, keeping the same average power, 3 Kw RF, in the sections. Indeed the calorific dissipation and temperature gradient between copper and water of the section of the existing machine do not allow to triple the average power.

On the other hand, the new sections are designed to dissipate 12 Kw average power and accept at 50 and 150 c/s a peak power of 25 Mw to 20 Mw for the existing ones.

The main particularity of our "mini-monster" after the extension will be the multiplicity of the possible modes of operations (Figure 2

As a matter of fact we have 5 experiments rooms n° I, II, III, Igloo and Aco.

Rooms III and Igloo were originally equiped to hold the high energy beam coming from the main injection n° 1.

In Aco room there are two beam transport systems ; one of them for e^-, the other one for e^+.

For the existing room II the beam transport system is now limited at 500 MeV, but will be equiped to hold a 1,5GeV beam from Injection 1

The 38 accelerator sections are distributed among 9 sectors of 4 or 5 sections each. The 16 new sections are set into 4 sectors at the head of the existing machine.

The injection of the existing machine at the head of sector 5 is maintained and allows the use of low or intermediate energies in the five rooms. It should be used simultaneously with injection 1 during the tests or maintenance of the 4 first sectors.

The injection at the head of sector 9, which has been running for two years, allows the filling up of Aco with e- and tests of equipment in Igloo. It can be simultaneously used with the dispatch of the beam from injection 1 or 5 in rooms I, II, III or the filling up of Aco with e^+.

So far the injection gun 9 is set or removed by hand. Later on the operations will be done by remote control, as will be the injection gun 5.

We will have got 3 sources of positron production according to the wanted energy or intensity.

Two of them are used now on the existing machine, the first one R6 at the head of sector 6 produces e^+ up to 1 GeV in Igloo and room III. The other one R8 at the head of sector 8 produces a 250 MeV e^+ beam of higher intensity.

We intend to settle the radiator 3 at the head of sector 3 to produce e^+ which could be accelerated up to 1,9 GeV in Igloo.

At least, two deflecting systems, A after injection 1 and B, at the end of the four new sectors will be used to test the accelerator at these points.

With these 5 target rooms, 9 deviations, 3 positron sources and 3 injections able to work apart or simultaneously, the laboratory will have got a large number of possibilities.

The operating mode is defined by :

- its injection location
- its type of particles e^+ or e^-
- what beam transport system is used.

26 possibilities of operation are already expected.

Control of the Accelerator

Every mode of operation requires particular apparatus and interlock system.

The complexity of the problem is beyond the ability of the operator. A special logic has been defined for preparing and controlling the operating modes.

This logic is based on the notion of independent units (injection, sectors, e^+ converter, beam transport system) each of them including some "imperative" or "facultative" conditions.

For example ; one injection is linked to the conditions of modulator, vacuum, focussing, steering etc... Information, signals and remote controls with regard to these conditions are put together on a control panel as a graph which shows up logic connexions and the origin of defects. All the imperative conditions are summarised according to this logic by means of "AND" circuits using photo-diodes, and the result shows that the unit is "ready".

The units needed for a given operating mode are then totalized with some conditions peculiar to this mode and show that this peculiar beam may run.

This specific logic forms an "interlock" for the fundamental conditions of an operating mode.

It is an elementary process for a "real-time" control of an accelerator. To obtain a complete management by a real-time computer it should be neccessary to reach the next steps:

A. recording and storing of all run parameters

B. statement of correlations between these parameters

C. control of these parameters by a computer which runs the accelerator.

We have successfully tested a program adapted to an Univac 1107 computer in order to realize the step "A".

When we will have enough data to obtain reliable statistics we will be able to proceed with step "B" with the same program.

The decision to proceed with the last step is not taken and may only be taken after the success of step "B".

Some technical points of the design

It is neccessary to stabilize fundamental parameters of the accelerator. Some of the chosen solutions are briefly described.

- Frequency and RF Distribution
- Klystron high voltages
- Temperature

RF synchronization of the klystrons

The chain is : (Figure 4)

- a 3 G c/s Master oscillator
- a 1 Kw cw separator
- a single 5 Mw pulsed preamplifier
- Then the RF lines and couplers.

The master oscillator (Figure 3) can put out 200 mw cw at 3 G c/s with a frequency long term stability better than 10^{-6}. It is a reflex klystron = its output signal is mixed with the signal of an external crystal running at a fixed frequency of 3 G c/s + 30 M c/s with a long term stability of 10^{-8}. The phase of the 30 M c/s signal is locked through the reflex voltage on the phase of a 30 M c/s tunable oscillator which is remotely controlled from the control room and allows a frequency adjustment of $\pm$ 1 M c/s.

The separator is a 802 D permanent magnet Varian Klystron with a d.c filament supply. The high voltage stability is 10^{-4} so that we get a clean 1 Kw cw signal with a frequency stability of 10^{-6}.

The preamplifier is a 2012 Thomson-Varian klystron supplied by a very stable delay line modulator. The preamplifier is already in operation and met the technical specifications which were a phase stability of 1 degree on the top of the pulse and from pulse to pulse for 12 hours under the following conditions :

- Peak power : 4 Mw
- Pulse length (flat top) 5 μs
- Repetition rate : 50, 100, 150, 200 or 300 p.p.s.

As we need a high power level to supply the 38 klystrons from the beginning of the machine (the 22 low gain klystrons are far away) we must use a waveguide RF line, which, due to waveguide dispersion give a phase variation of 13 degrees on the last klystron for a 100 Kc/s change in frequency.

RF level and phase are adjusted at the imput of each klystron by a phase shift free attenuator and a lossless phase shifter. Both are remotely controlled from the control room and we hope to have the phase shifter automatically controlled by some sort of phasing system.

In order to allow new klystron processing during beam operation, a special triggering system is designed :

Let f_r be the beam repetition rate. The preamplifier is triggered at 2 f_r. The main modulators may be triggered by to different circuits, both at f_r but shifted in time by 1/2 f_r. On the first circuit the klystron accelerates the beam ; if it switched on the second one it does not see the beam, but see the preamplifier. The second circuit is called "outgassing" circuit ; it may also be used in the automatic phasing sequence.

Klystron high voltage stabilization

The 38 modulators are supplied directly from the power lines through a transformer and a dispatching system without any regulation. Klystron high voltages can be remotely controlled from the control room, separately or together by means of induction regulators located at each modulator imput. (Figure 5) at the beginning of high voltage operation, high voltage simultaneously increases on all the klystrons from a single control knob. But all the klystrons cannot go up to the top voltage. As soon as a klystron is turned off by its own interlock system it is switched to a indivudual control knob. We thus get fast klystron adjustment without loosing flexibility.

The loop of the remote control is also used to regulate the d.c. high voltage of the modulators within 1 % when it reaches its operation level whatever that level is.

In addition, there is a "De Q'ing" system (Figure 6) on the delay line charge. The delay line voltage is compared with a reference voltage stable to 10^{-4}. In order to only lose less than 10 % of the power, the reference voltage follows the d.c. high voltage. But as the "De Q'ing" level is more stable than the d.c. voltage, there is a 1 % gate : the "De Q'ing" system follows the d.c. voltage only if the d.c. voltage changes by more than 1 % that is to say if we want it to change since the high voltage is regulated within 1 %.

With such a "De Q'ing" system we get a pulse stability better than ± .2 % between 150 and 250 KV at 50 and 150 p.p.c.

Section water cooling system

12 Kw per section of the new machine and 3 Kw per section of the old machine have to be dissipated and imput water temperature should be constant within 1°C.

The copper temperature will be about 1°C higher than the imput water in the new brazed sections and is 6°C higher in the old sections. In order to keep copper temperature constant all along the machine the water temperature of the old machine will be 5°C lower than for the new machine.

The water cooling system is made of 5 loops (Figure 7), one for each new sector and the fifth one for the whole old machine, each of them collecting about 60 Kw and being separately temperature adjusted. The temperature regulation is achieved by only injecting cold water from a common primary circuit through an automatically controlled valve. In order to keep the primary water always colder than for the secondary loop, the operating temperature of the copper is chosen to be 32°C.

The main advantages of such a cooling system are : simplicity first, fast response (when a section is suddenly turned on or off for instance), because there is not heat exchanger. In addition the cold water flow is very small as compared with hot water flow.

The fifth loop (Old machine) is now in operation and the system seems to work very well keeping imput water temperature constant within ± 2°C including transients.

Present state of accelerator and estimate program

Unlike the existing machine which had been ordered as a whole from a private company (C.S.F.) and acceptance tests made on the performances of the beam, this extension and the modifications of the existing machine have been designed and carried out to a great extent by the Linear Accelerator Laboratory.

The totality of sections, klystrons and modulators, without their stabilization , we have spoken about, and which has been realised by the laboratory, has been ordered to the previous firm. The acceptance tests will be made separately on RF performances.

RF master oscillator, RF distribution, vacuum, cooling, spaces between sections and sectors with their beam intensity or position monitors, injection, focussing, steering, beam phase and position automatic controls, interconnections, power plant, new control room, modification of the existing modulator and sections are realised directly by our laboratory.

The building is finished :

- building (Fig. 8)
- new control room (Fig. 9)
- hall (Fig. 10)
- beam tunnel (Fig. 11)
- technical tunnel (Fig. 12)
- the first modulator has been delivered : (Fig. 13)

The acceptance tests on the first section are in progress at C.S.F.

All modulators of the existing machine have been modified to include the improvements we have just talked about.

Six sections of the existing machine are already modified with metallic joints and titanium pumps.

Now we think we will be able to achieve our program:

- July 67 : end of the RF tests of the extension
- August - September : stop of physics experiments with the existing machine and connection of this one with the new one
- October - November : beam test
- December 67 : High energy beam available for physics experiment.

DISCUSSION

P. BRUNET, Orsay

Hendricks, Univ. of Minnesota: Are you taking steps to keep oxygen and carbon dioxide out of your water systems to eliminate clogging of the lines?

BRUNET: No, we are not.

HENDRICKS: We have had some difficulty with this at Minnesota, although maybe under more severe conditions, in our resonatrons; and we have found this necessary.

CORK, LRL: How do you propose to shield the machine for radiation?

BRUNET: I did not show this part of the picture of the building, but there are two 2-m thick baritine shielding walls all along the accelerator tunnel.

VOGEL, ANL: What kind of focusing system do you intend to use for your positron beam?

BRUNET: First, as I said, there are three locations of positron converters. Two of them are used now, and we do not yet have the money for building the third, so we did not study the third one. On the first one, which is for high energy positrons, there is only one lens with a magnetic field of 6000 gauss, and after that we have a focusing axial magnetic field along only one 6-m section. The intensity of this magnetic field is only 500 gauss. This is for the first positron converter. For the second one, that for the positrons for ACO, we have the money now and plan to use a much stronger field. We will have a strong field close to the radiator. After that we will have an axial magnetic field all along the accelerating sections, that is five sections of 6 m. The axial magnetic field after that, all along the five sections, will be about 2000 gauss.

LOEW, SLAC: Could you say a few words about your new injector and about how much time it takes to insert or remove the positron sources?

BRUNET: For the positron sources, it is not long because they are remotely controlled. It is just the radiator that we put in the beam. It is more difficult to put in or remove the gun. Fortunately, it's a very simple gun. It is a diode gun working at 30 kV and not too difficult to put in and remove. It takes about one hour, after radiation cooling.

LOEW: I did not mean the second gun. I mean the injector at the beginning.

BRUNET: The main injection system will include a Varian gun able to work up to 120 kV, then a chopper cavity, then a prebuncher cavity, all going with the gun and made by Varian Associates. After that we will enter a homemade section with a variable phase velocity only in the first four cavities. This section is a 2-m section, and we hope to get a beam out of the injection system of about 20 MeV with currents up to 500 mA.

MALLORY, SLAC: Do you have any trouble with possible double pulses when you switch the klystrons from the accelerating mode to the outgassing mode?

BRUNET: Installation has not been completed, and we do not know what will happen. However, we do not expect any major difficulty because there are very few klystrons in that position.

	Present Characteristics	Expected Characteristics	
Peak beam current	60 mA	60 mA	
Current Pulse Length	1 μs	1,2 μs	
Repetition rate	50 c/s	50 c/s	150 c/s
Electron energy unloaded	1,35 GeV	2,35 Gev	1,75 GeV
Electron energy, 60 mA loaded	1,25 GeV	2,2 Gev	1,6 GeV
Average beam current	3 μA	3,6 μA	10,8 μA
Maximum Positron Energy	1,0 GeV	1,9 GeV	1,3 GeV
Useful length of accelerator	132 m	228 m	
Accelerator length	220 m	350 m	
Number of accelerator sections	22	38	
Number of klystrons	22 x 20 Mw	22 x 20 Mw and 16 x 25 Mw	
RF pulse length	2 μs	2,2 μs	

Fig. 1.

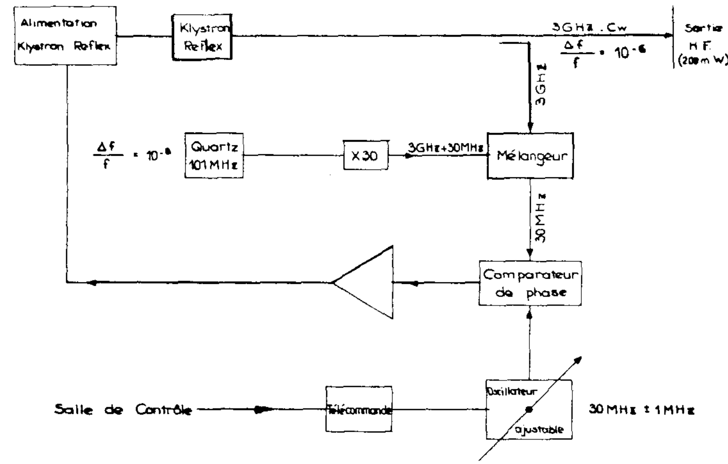

Fig. 3.

-MAITRE - OSCILLATEUR- 3GHz

.ACCELERATEUR LINEAIRE. ORSAY.

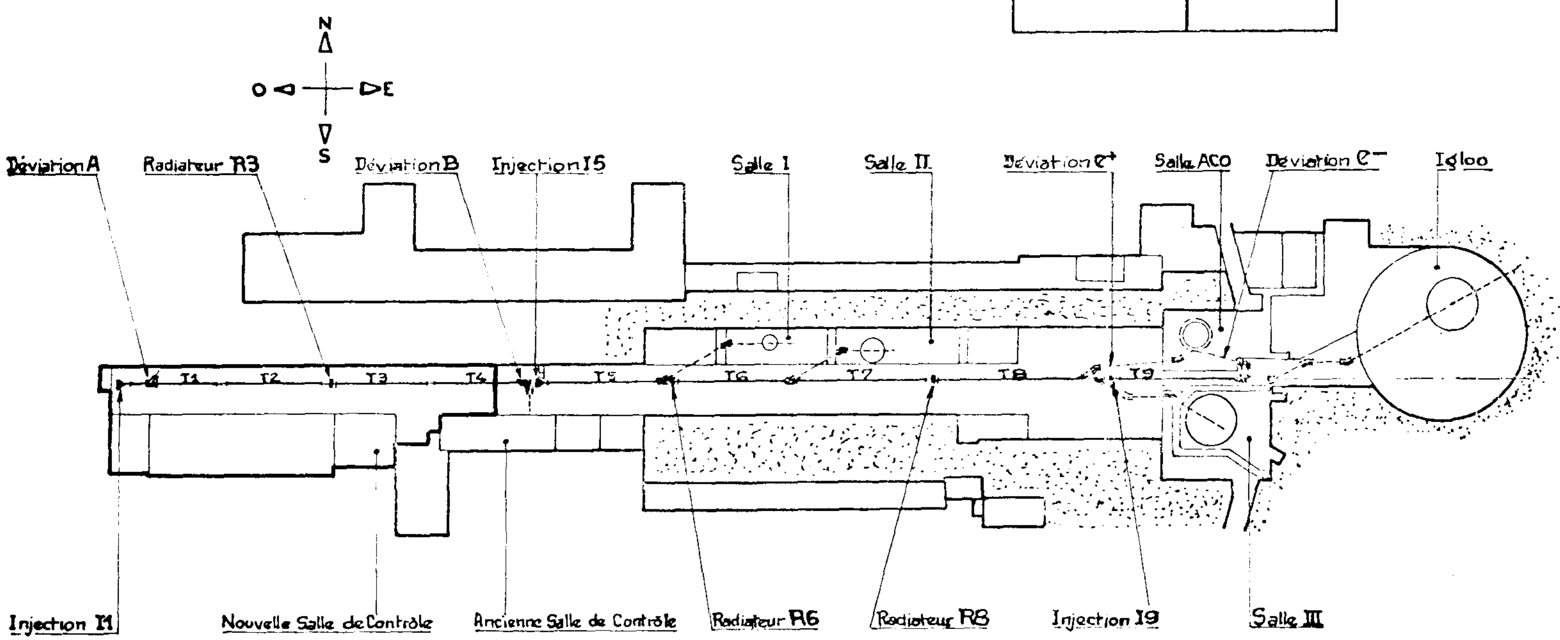

Fig. 2.

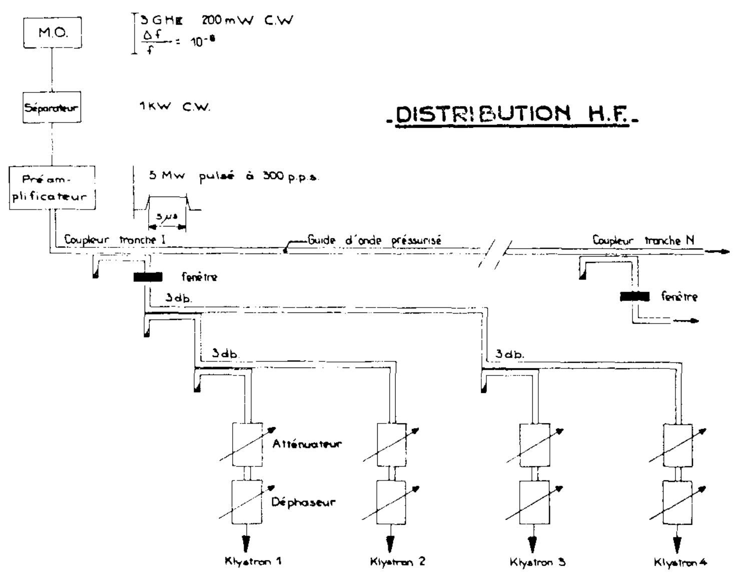

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Fig. 4.

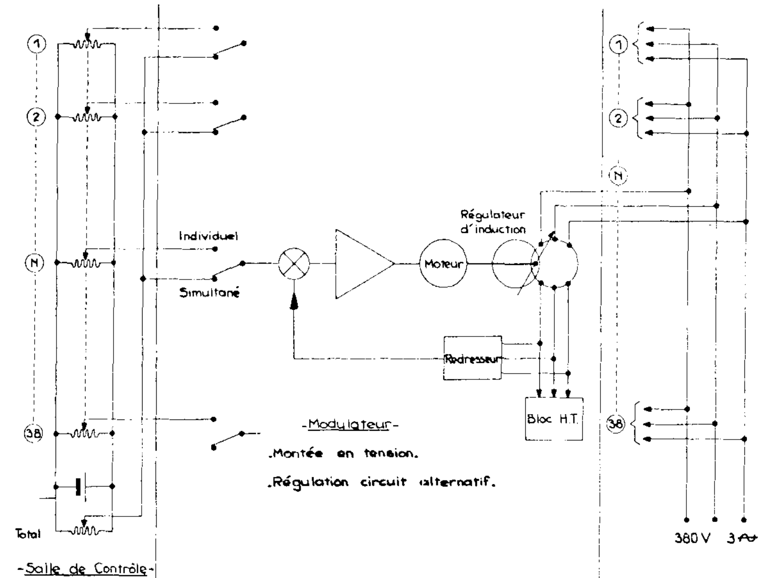

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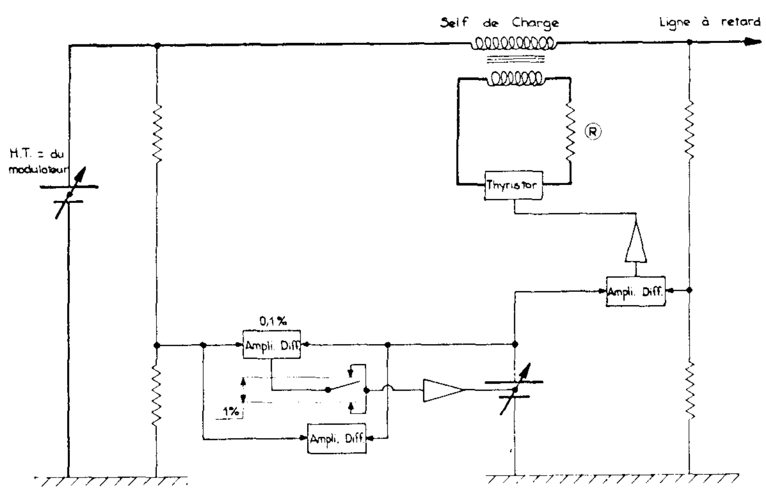
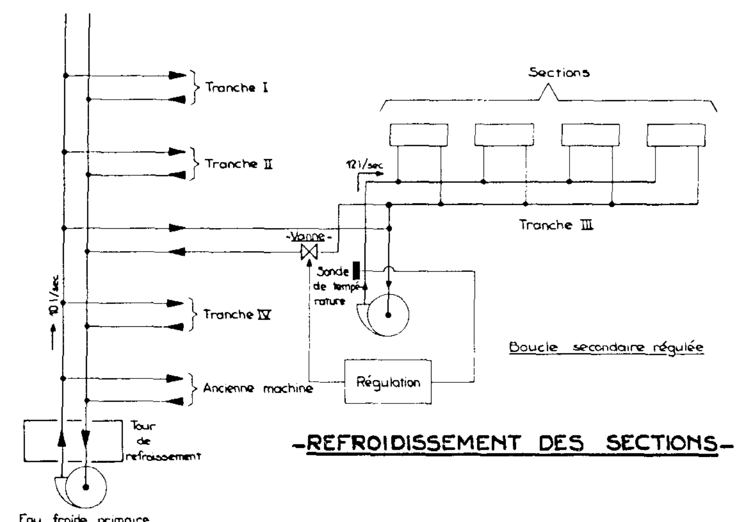
Fig. 5.



.Système de Rabotage des modulateurs à suiveur automatique.

.ACCELERATEUR LINEAIRE. ORSAY.

Fig. 6.



-REFROIDISSEMENT DES SECTIONS-

.ACCELERATEUR LINEAIRE. ORSAY

Fig. 7.

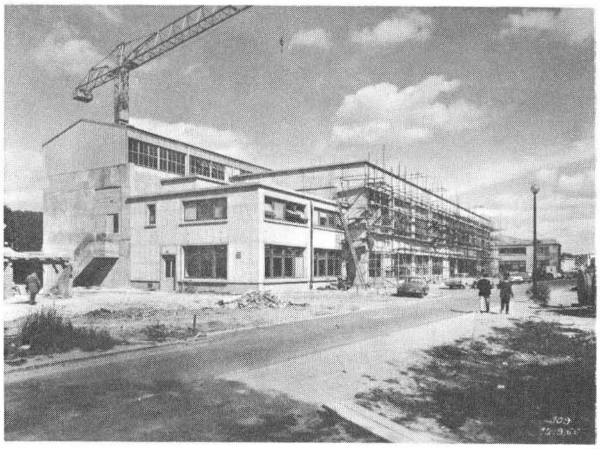


Fig. 8.

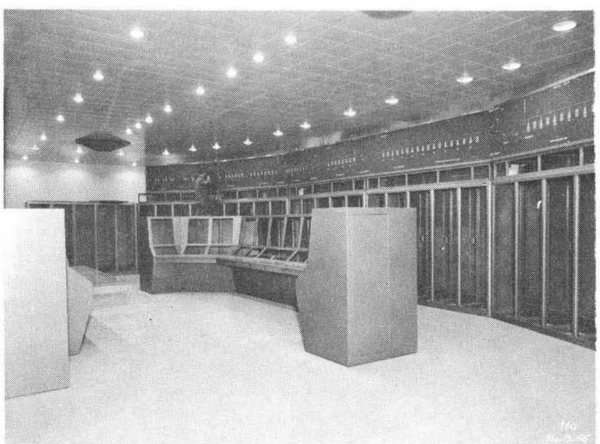


Fig. 9.

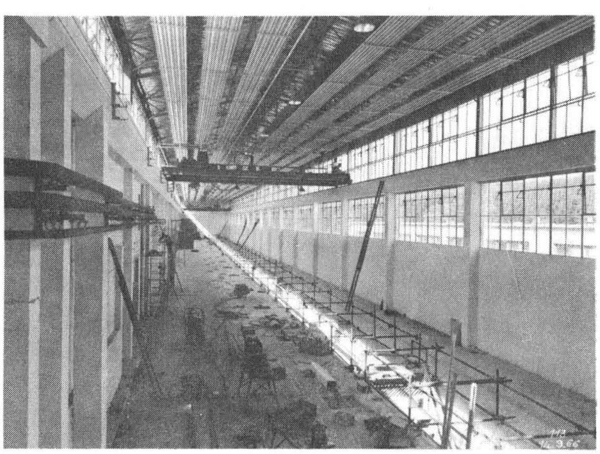
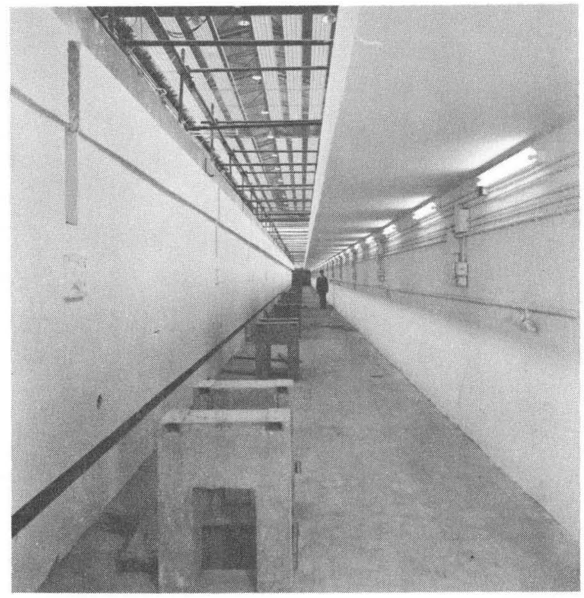


Fig. 10.



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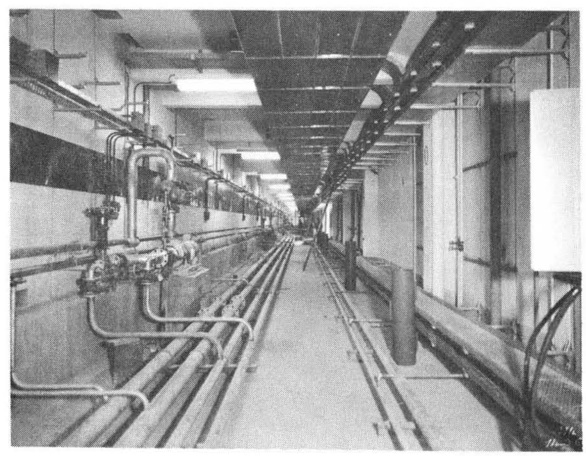

Fig. 12.

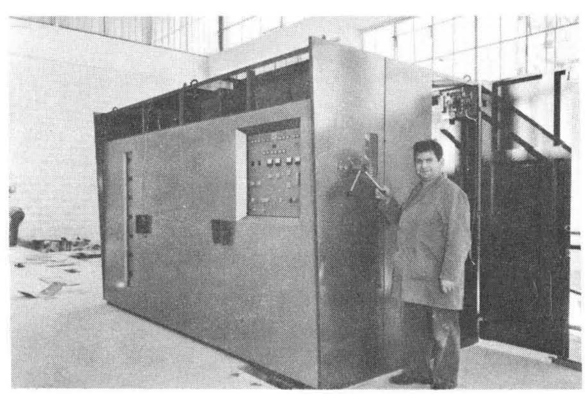

Fig. 13.