II. REVIEW PAPERS

1. Review of the CERN-PS Project.

by O. Dahl, Group Director.

When the Proton-Synchrotron study and planning group was organised, immediately after the conference in Copenhagen in June, 1952, the situation was that a number of European nations were to get together and build a scaled-up version of the Brookhaven Cosmotron.

Since we were to build for the future, a 10-Gev machine looked reasonable as the minimum aim, and seemed to be within the technical and economic resources of Europe.

By July, 1952, a small staff of three people was engaged to begin to look into the physics and technological problems involved, supported by a panel of consultants, and with myself as co-ordinator of the efforts.

We thought of the building of a 10-Gev machine, of the Cosmotron type, chiefly as an engineering project and that it should be possible to arrive at leading machine specifications and fairly reliable cost figures without much development and laboratory work to prove the points of issue. We thought we should be able to give a good overall picture of the project and present this to the Council for approval before November, this year (1953). On the basis of this plan, a permanent organisation would come into being and go on with the work.

We did not think that a great amount of money was required to work out a general but realistic plan, since extensive development work was not anticipated. Therefore, a sum of approximately two hundred thousand Swiss francs was put at our disposal, mainly to cover salaries and travels in the planning period.

Due to the international character of the project, it was not practicable to assemble a staff in one spot for the planning period. Rather, it was the idea that independent workers were to be assigned problems and that they would meet periodically for discussions and co-ordination of the work.

As a central office obviously was necessary, from which to circulate reports and pay out salaries and other expenses, this office was established in Bergen, Norway, in my institute.

With the advent of the alternating-gradient focusing principle, however, our working program had to be changed, drastically. Goward and myself, with Wideröe, visited Brookhaven, U.S.A., in August, 1952. There the new principle, which is now history, was demonstrated to us, and it became clear that it should be investigated and possibly adopted for the CERN machine.

It looked as if a proton synchrotron might be constructed with a very small vacuum-chamber aperture and, consequently, at a relatively small cost. Since we expected to have money for a 10-Gev machine, old style (14 million dollars was indicated to the Council at that time), this money might now build a considerably larger machine. Talking things over in the group, we proposed to the Council that, in our work, we should aim at a 30-Gev machine, constructed as outlined by Livingston et al, and this proposal was adopted by the Council in October.

It was, however, evident that quite a large amount of theoretical work and computations had to be carried out before we would know that the alternating-gradient focusing principle would suit our needs, and before we could begin to think in terms of engineering specifications and cost. Consequently, the group was re-organised with emphasis on orbits investigations.

By the turn of the year (1952-3) the group operated with semi-independent subgroups, established in some of the countries which are members of CERN, and in Great Britain, although G.B. was not, formally, a party to the first agreement between the nations. Thus, we had an orbits subgroup with headquarters in Harwell, where Harwell staff were given permission to work on the problems. Another subgroup was established in Paris at the Radio-Electric Laboratory of the Ecole Normale Supérieure to work on orbits, magnet models, and profiles. A third group was set up at the University of Heidelberg to work out the radio-frequency problems. The group headquarters continued in Bergen at the Chr. Michelsen Institute with further work on orbits and engineering studies also carried on there.

All four groups overlapped in their work to a certain extent. General group meetings were held periodically, in a given country, for co-ordination of the work but individual staff members also circulated in the subgroups to discuss current problems. The discussions at the group meetings were based upon written progress reports by the individual members, and these were circulated before the meetings.

The CERN Theoretical Group, under Professor Bohr in Copenhagen, also has been working on problems of orbits and pole profiles directly related to the work in the PS Group. The results from Copenhagen are co-ordinated into the general picture of the group's work.

We thought we were beginning to see our way with the alternating-gradient focusing principle when the difficulties with azimuthal inhomogeneities were pointed out, and we went through a depressing period, until we began to see our way through these difficulties. This put further emphasis on theoretical work for the planning period, with engineering and cost problems pushed still further into the background.

Our full-time salaried staff was still very small but, to make up for this, contributary work was done by colleagues taking interest in the problems as they developed.

Work cannot very well progress and be co-ordinated effectively under the conditions which I have outlined for you, and it was always felt strongly in the group that we should work together continuously in one place. But there were practical difficulties. The group did not own, and had no money to buy, much equipment of its own but, as it was, we had the advantage of using available equipment in several institutes. Therefore, the conditions were accepted as the best compromise in the circumstances.

But, as the orbits problems cleared, we could establish a better background for work on magnet models and profiles, as well as RF and building problems, and we could foresee that we had to get together in the near future, in order to make co-ordinated use of the collected material.

In the meantime, Geneva was chosen as the site for the future permanent laboratory and, if the group were to be brought together, this was the obvious place.

But there were formal difficulties connected with such a transfer. It would represent a substantial commitment on behalf of the final organisation, or on behalf of present CERN, if the New Convention, for any reason, were not to come into force.

Further, we knew that we could not take full advantage of such a move, since the available money would not permit the purchase of extensive amounts of equipment, or even a general stocking of laboratories.

Fortunate circumstances in Geneva made it possible, however, to have working quarters for the group in the Institut de Physique, where laboratory and shop facilities were available and furnished offices were placed at our disposal. Even if we had to give up the facilities at our disposal in the different subgroups, we felt that it would be a good move to come to Geneva and reorganize into one unit.

When this situation was explained to the Council, arrangements were made, whereby it was made possible for the group to move to Geneva on October 5th. Rules and regulations were worked out for the interim period in Geneva, under the assumption that this initial group organization would form the nucleus for the Proton Synchrotron Project under the final Convention.

Therefore, the group transferred to Geneva, and the total staff today consists of about 20 people.

Of these, the scientific staff responsible for collecting the material and preparing the lectures for this conference were with the group before we moved, and I think it is appropriate to mention the names:

Odd Dahl	Norway	Group Director
F.K. Goward	Great Britain	Deputy Group Director
J.B. Adams	Great Britain	On engineering and orbits
A.. Citron	Germany	On shielding problems
J.A. Geibel	Germany	On radio-frequency problems
M.G.N. Hine	Great Britain	On orbits
K. Johnsen	Norway	On orbits
M.J. Leroux	France	On magnet modelling
G. Lüders	Germany	On orbits
E. Regenstreif	France	On orbits and magnet modelling

A. Sarazin	France	On magnet modelling
Ch. Schmelzer	Germany	On radio-frequency problems
W. Schell	Germany	On radio-frequency problems
J.P. Blewett,	on leave from Brookhaven, U.S.A.	
M.H. Blewett,	also on leave from Brookhaven, U.S.A.	

Professor Pierre Grivet of Paris, Professor W. Gentner of Freiburg, Dr. R. Wideröe of Baden and Dr. S.D. Winter with Dr. H. Bruck of Saclay have been working, part time, closely connected with the group as consultants on specific problems.

Drs. Blewett and Blewett have been with us in the group since this summer, on leave from Brookhaven. They will be with us here in Geneva until the end of the year. It has been of great importance to the work in the group to have direct Cosmotron experience available to us and we are in debt to Dr. Haworth, who made this arrangement possible.

I should like to stress again that, although I think this transfer to Geneva is good, we have very little money for experimental work, and cannot plan to conduct it in the way we would do if we could use money as needed. We are trying to make the best of the situation, and to be prepared to expand our activities as soon as the New Convention money will be available.

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The machine, as it is visualized in the group today, is a 30-Gev alternating-gradient proton synchrotron.

The orbits work calls for a free aperture of 8 cm by 12 cm, based upon a mean orbits radius of 112.1 m, and an n-value of approximately 400, this value to be considered as maximum.

You will, later in the meeting, hear about our views concerning the leading parameters for such a machine. I have, however, circulated a printed table of these parameters for your reference.

Some modelling and electrolytic-tank investigations have been carried out for the indicated pole profile and the model program will be discussed later.

In Figure 1, is shown a scaled diagram for the magnet profile that is indicated in the table of parameters.

The accelerator is to be erected at the site placed at the disposal of CERN, located at Meyrin (on the road to Lyon, France), beside the French border. If we fire the machine into the open air, the protons will pass into France!

There are problems connected with the housing of the machine, mainly because of the close tolerances that must be preserved during the erection of the magnet. We talk in terms of a quarter, or a half, millimetre to which we must know a point in space with reference to the centre of the machine.

Since the machine must also be surrounded by a radiation shield, consisting of about 5 meters in the radial direction of heavy concrete, or the equivalent amount of earth, it seems best to install the magnet ring in a circular, closed, trench sunk into the ground or piled over with earth.

The site has a fair slope to it, and it turns out that we can have the target building at the average ground level, and let the trench building gradually disappear into the slope.

In Figure 2 is shown our most recent building study, which is based upon the following assumptions:

a) The magnet is to be installed in a ring-shaped building with a cross-section, six meters wide by four meters high.

The ring building is to be completely covered with earth, for radiation shielding.

A number of exit openings are to be distributed along the inside wall of the building.

The central area enclosed by the ring building is to be excavated and levelled down to one meter above the orbit plane (for surveying reasons).

The orbit plane is to be 1.5 meters above floor level.

In the centre of the magnet ring a small two-story building is to be located. On the lower floor is to be installed an azimuthal angle-measuring device which gives free sights into the ring for each 36 degrees of azimuth. Radio-frequency equipment is to be installed on the upper floor.

b) The ring building is to be straddled by a target-areas building.

The magnet ring is carried through this building underneath a free-spanning concrete bridge, 5 m wide and 4 m above floor level, which will provide radiation protection in the vertical direction. For protection in the horizontal directions, shielding blocks are to be piled up on the floor on both sides of the bridge.

The target-areas on both sides of magnet ring must be unobstructed by supporting pillars.

Space and facilities for handling the shielding blocks must be provided. The weight of a shielding block is to be 10 metric tons.

It must be possible to observe targets through shield-ports over a wide range of angles.

The shielding in the target areas is to be 5 m of density-4 concrete in the radial direction. The bridge thickness is to be 1.5 meters.

The target-areas building is to be accessible for specified personnel during operation of the machine.

c) Other building facilities must be provided, located as closely as possible to the target building, perhaps under one roof, but arranged in such a way that staff occupying these premises are not exposed to radiation hazards.

d) The total floor space and the grouping of this space must satisfy requirements in the construction period for the machine. It is of special importance to have large areas with crane facilities for the testing and grouping of magnet sections.

Breakdown of total floor space:

The study in Figure 2 shows what is judged to be reasonable floor space requirements for the various functions.

Ring building	4,600 sq m.
Exit areas on ring building	400 sq m.
Central RF building (two floors)	200 sq m.
Target-area, inside the ring, and shielding block storage space	900 sq m.
Target-area, outside the ring, with shielding block storage space (to be used for magnet testing routine in the construction period)	1,800 sq m.
Direct-beam area	400 sq m.
Linac area	750 sq m.
Workshop and equipment assembly space	1,800 sq m.
Control rooms and small laboratories (about 500 sq m.), are to be constructed at a later stage on a partial second floor in the workshop and assembly space	(500)sq m.
Main generator and switch gear	600 sq m.
Experimental generator sets (for bending magnets)	300 sq m.
Offices, laboratories and building services	1,000 sq m.
Total floor area	13,250 sq m.

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I think we can show, in the papers which follow my introduction, that it looks reasonable to build a 30-Gev machine with a fair insurance that it will work, that it is not a gamble.

Then, of course, one will ask how much it will cost, and how long will it take to build it with reasonable efforts and staff.

We have worked out a tentative time and staff schedule, and feel that we are on comparatively firm ground here, even considering the small amount of engineering studies we have made.

It is much more difficult to give cost figures at this stage, and I will give them with reluctance for what they are worth, since I think it is needed for a comprehensive review of our project.

Our cost estimates are based, chiefly, upon Cosmotron figures, and a fairly detailed but very tentative study is contained in a report from the group, which will be available shortly. The summary of this report reads as follows:

Magnet with details and power supply	S.F.	20.5 mill.
R-F System	S.F.	4.0 mill.
Vacuum system	S.F.	0.9 mill.
Injection	S.F.	6.0 mill.
Control, timing, wiring	S.F.	2.6 mill.
Design, assembly, testing and salaries	S.F.	18.0 mill.
Buildings (about 13,500 sq m.)	S.F.	17.2 mill.
Total	S.F.	69.2 mill.

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Now it takes lots of time and work to use this money in a sensible way but, in our planning, we assume that a partial beam will be observed in the 6th year of work under the final Convention, and that it would be difficult to proceed faster.

As to staff buildup, and time and money schedules, there is this to be said: until our engineering studies are further advanced, we can only give a general program. This program will be subject to modifications, as we see better what work can or should be done by industry, and what should be done in our shops. Since time is important, we plan to work through industry as much as is practicable. The rate at which we expect to use money will also be influenced by such considerations.

Again there is no time on our agenda to show you the program in detail, but we expect that the project will require about 700 man-years, distributed over the six construction years as follows:

Man-Power Distribution

1st year	- 53	4th year	- 146
2nd year	- 93	5th year	- 143
3rd year	- 126	6th year	- 131

In the seventh year, operational studies and experiments will begin and the man-power figure for this year is expected to be 120.

Our tentative construction-budget figures, in millions of Swiss francs, for years are: (large orders: 1/3 down, 1/3 half way, 1/3 upon delivery)*.

1st year	9.2
2nd year	14.4
3rd year	17.0
4th year	13.6
5th year	6.8
6th year	4.6
7th year	3.6
Total	69.2

It should be mentioned that this is only a construction budget. Beginning about the 5th year, additional funds for operation, maintenance, and experimental equipment, must come from other funds; thus, the budget for the PS project does not, in effect, shrink to the figures given for the last years.

Concluding my review, I will say that our main effort is still on orbits and basic parameters, but we are now beginning to look into specific technical problems and to produce realistic design studies.

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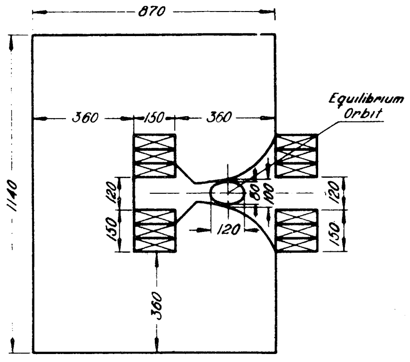
*Note: Later budget estimates, based upon a payment schedule of no payment with the order, $\frac{1}{2}$ at the half-way point in fabrication, and $\frac{1}{2}$ upon delivery, lead to expenditure rates of about S.F. 2.0 million for the first year of building the machine, and S.F. 11.0 million for the second year.

30 Gev magnet and gap profile study



Useful aperture : 8cm vertical x 12cm radial
Weight of steel : 4000 tons
Weight of copper : 250 tons
Stored energy : 14×10^6 joules
Peak current density : 440 amps per sq.cm
Average dissipation : 1200kW
Mean radius of orbit : 112,1m

Fig. 1

BUILDING STUDY NO. 7c

Scale - 1:1000

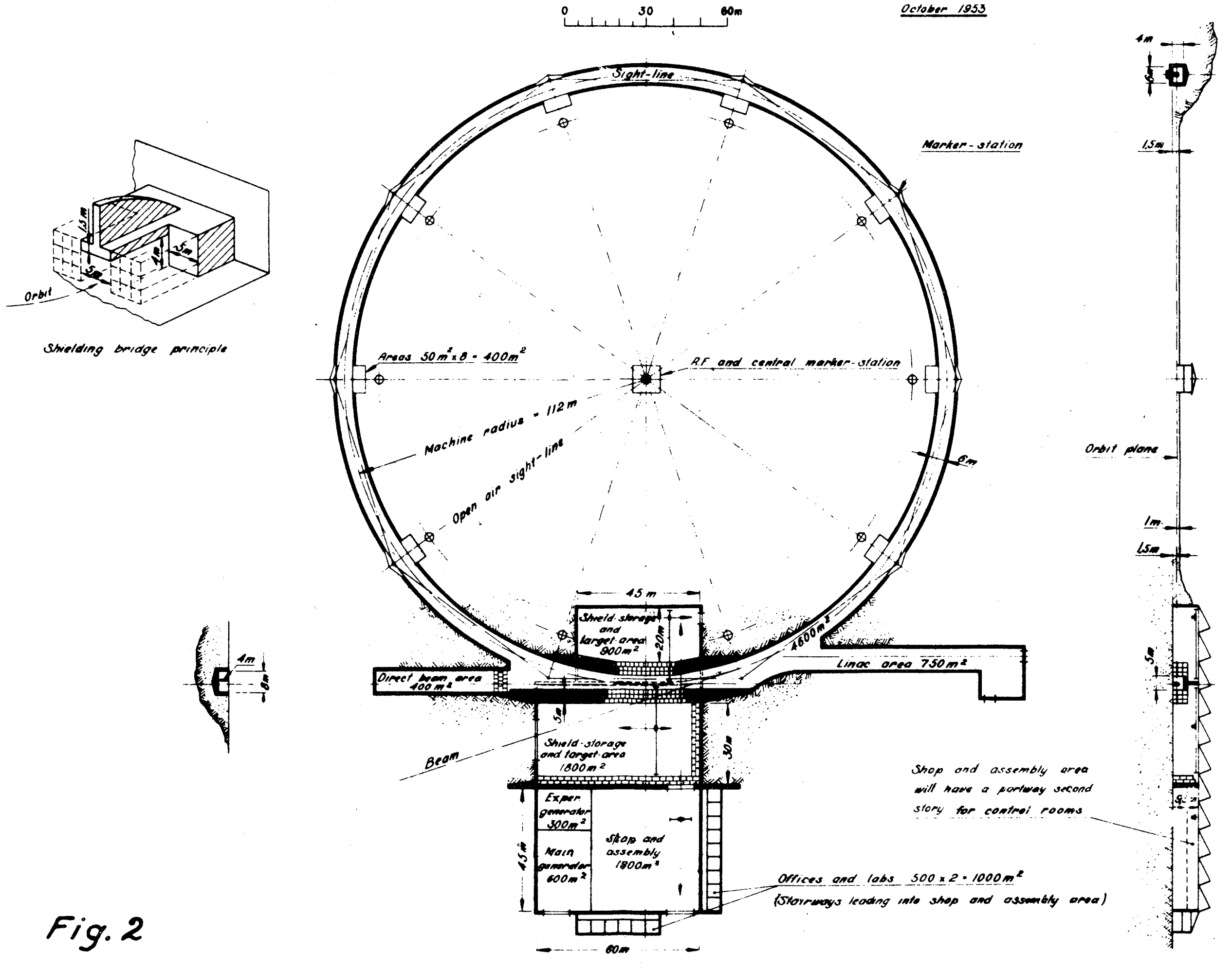


Fig. 2