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ITALIAN ACTIVITIES IN THE FIELD OF URANIUM ENRICHMENT

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I- INTRODUCTION

Following a ten-year period of fundamental research and related studies, Italy's National Nuclear Energy Committee (CNEN) started up, in 1967, jointly with The National Electricity Agency (ENEL) and the main industrial companies, both privately and State-owned, a series of research and development activities of a more ambitious nature. For this purpose a coordinating Committee (the Italian Group for Uranium Enrichment - GIAU) was set up with the participation of representatives of Government agencies, the principal industrial groups and the associations engaged in this sector (fig. 1).

The research and development programme in question concerned chiefly gaseous diffusion and ultrecentrifuges.

The aim with both methods was first and foremost to test capacity for isotope separation work. This was achieved by 1973 in the case of the ultracentrifuges and by 1974 in that of gaseous diffusion. In this way, Italy could be certain of having acquired an overall grasp of the problem, even it this did not imply a completely in-depth understanding of that problem in all its aspects. Efforts here also served to demonstrate that there were no unsurmontable problems for Italy' technological capacity in the enrichment field.

As to the question of meeting short-term demand for uranium, ever since 1967 Italy had advocated within the various organisms of the European Community the desirability of having an internationally-run gaseous diffusion plant in Europe. CNEN has accordingly promoted among manufacturing firms a programme for the development of components for large-scale gaseous diffusion plants. These efforts have led on to the production of natural-size prototypes.

Following the Eurodif decision to build its own plant (another course strongly advocated by Italy) these efforts in the way of industrial promotion took on added strength. With the technical and financial support of CNEN, activities were directed first to the manufacturing of first specimens for series production and to the building of a pilot-scale plant for the qualification of both components and associated production technology.

In addition to these research and development activities on the more established methods - gaseous diffusion and centrifugation - a start was made in 1975 on a research programme on uranium isotope separation by means of laser photoexcitation.

2 - SUPPLY OF ENRICHED URANIUM AS GOVERNED BY ITALY'S ENERGY PROGRAMME

In 1975 the Interministerial Committee for Economic Planning (CIPE) approved the National Energy Programme (PEN). This programme contains forecasts for enriched uranium demand up to 1990.

The programme is currently under review in Parliament, following upon developments occurring in the meantime in the implementation of nuclear power programmes in the larger countries of the world and in Italy. The forecasts (up to 1990) speak of:

	Min.	Max.
Installed nuclear capacity (MWe)	46,000	62,000
Cumulative enriched uranium needs (TSW)	37,000	48,000

Given the coverage of Italy's requirement for enriched uranium, CIPE in 1973 authorized the country's participation in the Eurodif company, so that CNEN and AGIP Nucleare are now equal shareholders in Eurodif to a total of 25%. Initiative in this direction was taken in Italy several years before the official setting up (in 1973) of the working party that preceded the actual establishment of the Eurodif company.

Against this background, enriched uranium supply up to 1990 to-day shows the following pattern:

	Contracted (TSW)	
	Finalized	Not finalized
Supply contracts (firm)	6,291	
(option)		13,765
Share in Eurodif production (CNEN + AGIP Nucleare)	23,454	
Share in Coredif production 1/		6,000
	29,745	19,765

From this table it will be clear that supply contracts already finalized cover, respectively, 80% of the maximum and 60% of the minimum requirements

1/ Not finalized at the time of compiling this report.

forecast by PEN up to 1990. In this way, with our share of the Coredif output practically the entire cumulative requirement up to that year could be covered. Beyond 1990 annual requirements as extrapolated by PEN may be put at some 5-7 million kgsw/yr - i.e. greater than the share in Eurodif and Coredif output to which Italy can lay claim (approx. 3.5 million kgsw/yr).

According to the most recent estimates, PEN is likely to be postponed a further two years or so, for the reasons given, though this will not substantially change the situation.

3 - RESEARCH AND DEVELOPMENT

Against the background described in what precedes, an examination will now be made of reasearch and development activities going forward in Italy under close collaboration between CNEN and the country's industry.

These activities are pursued along three main lines:

(1) Gaseous diffusion
(2) Ultracentrifuges
(3) Laser and related methods

3.1 Gaseous diffusion

During an initial period (1968-73) the research programme extended to all plant components. Activities comprised both laboratory experiments and studies for the design and manufacture of the component prototypes most promising of qualification - barriers, compressors, valves, etc. The aim of the programme was to acquire an understanding, at least at the experimental level, of the entire range of problems associated with the gaseous diffusion process.

As a result of this work it was possible to achieve in particular:

(a) a prototype transonic axial compressor of a 40 kg UF_6/sec rating (fig. 2);
(b) a batch of ceramic barriers. With these it was possible to carry out UF_6 isotope separation experiments. The latter yielded positive and encouraging results.

Where industrial scale development is concerned, as early as 1968 a survey on the structure of Italian firms was also put in hand in order to ascertain what industrial contribution the country might be able to make to the building of a gaseous diffusion uranium enrichment plant. The matter was discussed several times within the Italian Group for Uranium Enrichment (GIAU), and technical delegations visited firms and installations in other countries.

Following the decision in 1973 to build the Tricastin plant, CNEN's research and development programme (itself oriented along lines indicated by GIAU, where qualification of the country's industry was concerned) was gradually brought into gear with the industrial promotion effort calling for first product and then producer qualification.

Development work accordingly has in principle gone forward at three levels in the production in successive stages for the various components of a number of prototypes, first specimens for series production, and pre-series production of specially built pilot plant.

The components were divided into three classes:

(a) special components (e.g. barriers, compressors) which called for the use of special techniques requiring testing at the three levels just referred to;

(b) quasi-conventional components (e.g. valves, heat-exchangers) for which all that was needed were tests on one or two prototypes or experimental demonstration of one or other particular solution;

(c) conventional components, for which no special qualification was required.

<u>Barriers</u>

The research done on barriers envisaged several alternative solutions. Two studies were made on ceramic and metallic supports and on ultrafine metal powders for the microporous layer.

Efforts to produce complete barriers encountered serious difficulties both as regards the deposition of the microporous layer on the support and as regards the mounting of the barriers on the diffusors of the experimental pilot plant. These difficulties were overcome by 1974 where the ceramic barrier was concerned. Separation trials were then carried out with this type.

Subsequent research produced improvements in characteristics, notably in the matter of structural efficiency (fig. 3).

However, the barrier research and development programme had to be slowed down due to the fact that there was not even the minimum time necessary for qualifying the barriers themselves with a view to assembling them on the Tricastin plant. Following the Eurodif agreement, Italian effort has focussed on the manufacture of supports, since the production of barriers was an integral part of the supplies covered by CEA guarantees.

Given the industrial situation at the time, it seemed more appropriate to follow the metal supports line of approach. Prototypes were already to hand largely complying with Eurodif specifications. These had been made in the laboratory but in sufficient quantity for batches of hundreds of specimens to be put through the first qualification tests.

The results of these tests were positive, and multilateral agreements were drawn up whereby an Italian firm would build, with CNEN and Eurodif, a first pilot plant for the manufacture of barrier supports (fig. 4). The plant was subjected to qualification tests and proved to comply with specifications. However, as a result of technical decisions - of a generic nature and having nothing to do with the quality or price of the product - supply to Eurodif could not be actually concluded.

Meanwhile, however, research and development work continued, with promising results, in the research departments of the Italian firm engaged on ceramic supports.

Compressors

Research and development on compressors for large-size gaseous diffusion plant began, where Italy was concerned, as part of research activities promoted by CNEN in 1969. A first prototype was built to the specifications agreed between CNEN and the manufacturing firm concerned. This had a flowrate of approx. 40 kg UF_6/sec, and was of the axial transonic type.

By means of freon testing, first with a full-scale model of the first three rotors and then on the prototype itself, it was possible to verify the entire suitability of the design tools.

In 1974 following the Eurodif agreement, the same prototype was tested with UF_6 on the CEA test facilities at Pierrelatte (France). The results were entirely positive, and the Italian firm was thus able to obtain recognition as qualified to tender.

Accordingly, with CNEN support, the firm in question developed a design conforming to Eurodif specifications for large-size compressors (approx. 160 kg UF_6/sec) and also manufactured two specimens for series production. One of these was tested at Pierrelatte, with entirely satisfactory results (fig. 5).

In the meantime, industrial negotiations for the Eurodif tender came to a positive conclusion. The Italian firm obtained 50% of the supply of the 732 large-size engine-driven compressors in association with the French Gercos Company (made up of Snecma and Rateau). Subsequently, the same Italian firm, pursuing its own development work, was able with Eurodif support to produce two further prototypes, this time of intermediate size and characterized by highly advanced aerodynamic performance. It was not possible for these to be considered for supplying Eurodif, since the time-limit for the tender had already expired in 1974, but since they, too, passed the qualification test successfully, they are eligible for tendering for further plant of the same type.

Valves

The need to avoid UF_6 contamination and the problems of compatibility of materials and corrosion resistance make it necessary to have UF_6 valves designed specially.

Two Italian firms produced two prototypes up to 1973. These were two specifications developed by CNEN, calling for various diameters up to a maximum of 1.2 m.

Subsequent to the publication of Eurodif specifications two prototypes, of original design were built and tested both in air and in UF_6. Thanks to an agreement with a French firm, one of the Italian firms has been able to obtain a contract for the supply of over 500 valves, 40% of wich have a diameter in excess of 400 m.

Heat exchangers

A heat exchanger, as with other types of plant where two chemically incompatible fluids are involved, cannot be produced according to conventional standars. Tests on a full-scale exchanger - the only truly valid tests -

call for the availability of a test facility possessing all the necessary apparatus, in particular a compressor of an adequate power rating. Since no such facility was available in Italy up to 1973, efforts were directed to design studies and experimental work on finned tubing.

The heat exchanger was accordingly proposed to Eurodif in terms of specifications established by the firm in question and of information supplied by the French architect engineer (USSI Company). Being without moving parts and of a largely conventional technology, this component was a kind where product qualification was unnecessary. For this reason no tests were required on prototypes but only technological testing of tube bending and connection characteristics.

Nevertheless, the Italian firm was able to obtain, in association with a Belgian firm, the contract for the supply of several hundred heat exchangers.

Conventional components

Italian firms have competed with varying degrees of success according to the particular case, for the supply of other components, this time of a more conventional kind.

From what precedes, it will be clear that Eurodif has constituted one of the first examples of the production of an industrial-scale enrichment plant on an international basis and provides a useful fund of experience for the future. One conclusion may be drawn from this even now, namely that the broadening of the market has sharpened the competitiveness of the various suppliers, thus encouraging the development of improved technology and a reduction in costs for the production of separation plant. It is to be hoped that further experience will be addedd to that so far gained and will lead to even better results. This will certainly be possible if it is also possible to strengthen that same climate of collaboration between Government agencies and industrial firms in the countries concerned as has prevailed in the development of a number of components involving highly demanding technology.

The record would be incomplete without acknowledgement of the help afforded by CEA (France). The Commissariat made test facilities available so that qualification of Italian-built compressors could be completed in time, where otherwise this might not have been possible.

Experimental activities and related facilities

In addition to affording technical and financial support to industry, CNEN has devoted effort to creating a complex of laboratories for research and development work on gaseous diffusion and for components qualification.

The laboratories in question have:

(a) a pilot plant for testing barrier characteristics, with 8 stages mounted in series. This is the former PC4 of CEA (France);

(b) plant for testing valves, including large diameter valves, in UF_6 and under temperature and pressure conditions similar to operational conditions (fig. 6);

(c) UF_6 permeameters;

(d) barrier test apparatus with Argon separators;

(e) UF_6 corrosion test apparatus;

(f) also available a central analysis service equipped with high quality mass spectrometers.

Side by side with the foregoing, process and optimization studies have been developed.

The laboratory complex described is thus able at the present time to undertake the qualification of components developed by Italian manufacturers up to the pre-industrial stage. The basic facilities and services have also been provided for completing the qualification process up to the product-marketing stage (test halls, for example, equipped with complete services for the surface treatment of large-size components).

The activities listed here can be intensified in view of the construction of the Coredif plant and according to the requirements of Italian industry.

3.2 Ultrancentrifugation

The ultracentrifuge development programme has been marked by two quite distinct phases.

Up to 1974 there was no practical certainty that the Eurodif plant would be finalized. Accordingly, the aim of the programme was to demonstrate the feasibility of machines which, despite their low unit capacity, might allow of producing enriched uranium at prices not too different from those obtaining on the market, with a view to an international solution and, solely as an extreme expedient, an Italian - only one. The objective has been attained in part with the tests on separation in UF_6 of machines with small-size steel rotors, thus making it possible, also, to test theoretical forecasts and acquire an understanding of the process as a whole.

Since 1974, the construction of the Tricastin Eurodif plant has made it possible to gear the programme to a longer term. Consideration has therefore been given to machines offering a higher unit capacity for separative work and thus a more competitive performance.

Studies have accordingly been divided into two parts:

(a) mechanical problems, with a view to achieving:
   - rotors having a greater effective length (fig. 7);
   - machines that can be built at less cost in series production (fig. 8), and

(b) theoretic problems of fluid dynamics and separative potential of these machines.

In both fields considerable progress has been made so that to-day it is possible to establish characteristics and specifications of machines offering a high unit capacity.

Worth noting in particular are:

- experiments on rotors making it possible to achieve effective lengths of 2 m or so;

- development of a finite-difference computer code. With this it is possible to achieve a high degree of definition in the resolution of the fluid dynamic field within the ultracentrifuge. In this way, too, it is possible to reveal influences on the fluid dynamic field and thus on the separative capacity offered by the constructional solutions actually adopted (fig. 9).

Side by side with the research and development activity where machines are concerned, work has also been done on the design of a pilot cascade plant for a few hundred machines. The purpose here has been to identify interface problems between machine and plant (fig. 10).

As regards experimental work, in addition to the test loops on single existing machines, equipped as these were, with in-line mass spectrometers, there is now in construction a more complex test loop, with which it will be possible to test machines connected in series and in parallel.

Further effort in this field is governed, therefore, not so much by technical or research considerations as by the size of Italy's requirements in the way of enriched uranium around 1990 and, in particular, by the possibility of demand being in excess of Italy's share in the Eurodif and Coredif production capacity.

In view of the uncertainty of the situation in such a long term and of the burden implicit in a programme for the development of high performance ultracentrifuges, an attempt will be made to secure international collaboration which should make possible a sharing of costs and improved probabilities of success.

3.3 Laser and related methods

Among the most advanced methods of isotope separation those based on the use of laser techniques have received particular attention.

A thorough-going survey was initiated in 1974 using as starting point the know-how acquired independently by CNEN's and the Universities' research laboratories.

As a follow-up to this survey, the decision was taken to put in hand a specific research programme in which all the know-how, hitherto dispersed, in Italy might be concentrated.

The programme is still in the process of being organized, though numerous experiments of a fundamental nature have begun already.

As regards other methods, among them gas dynamic methods, several laboratories have shown interest here and have already undertaken experimental work to corroborate the theoretical studies done earlier. But at the moment Italy has no programme in this sector at the national level.

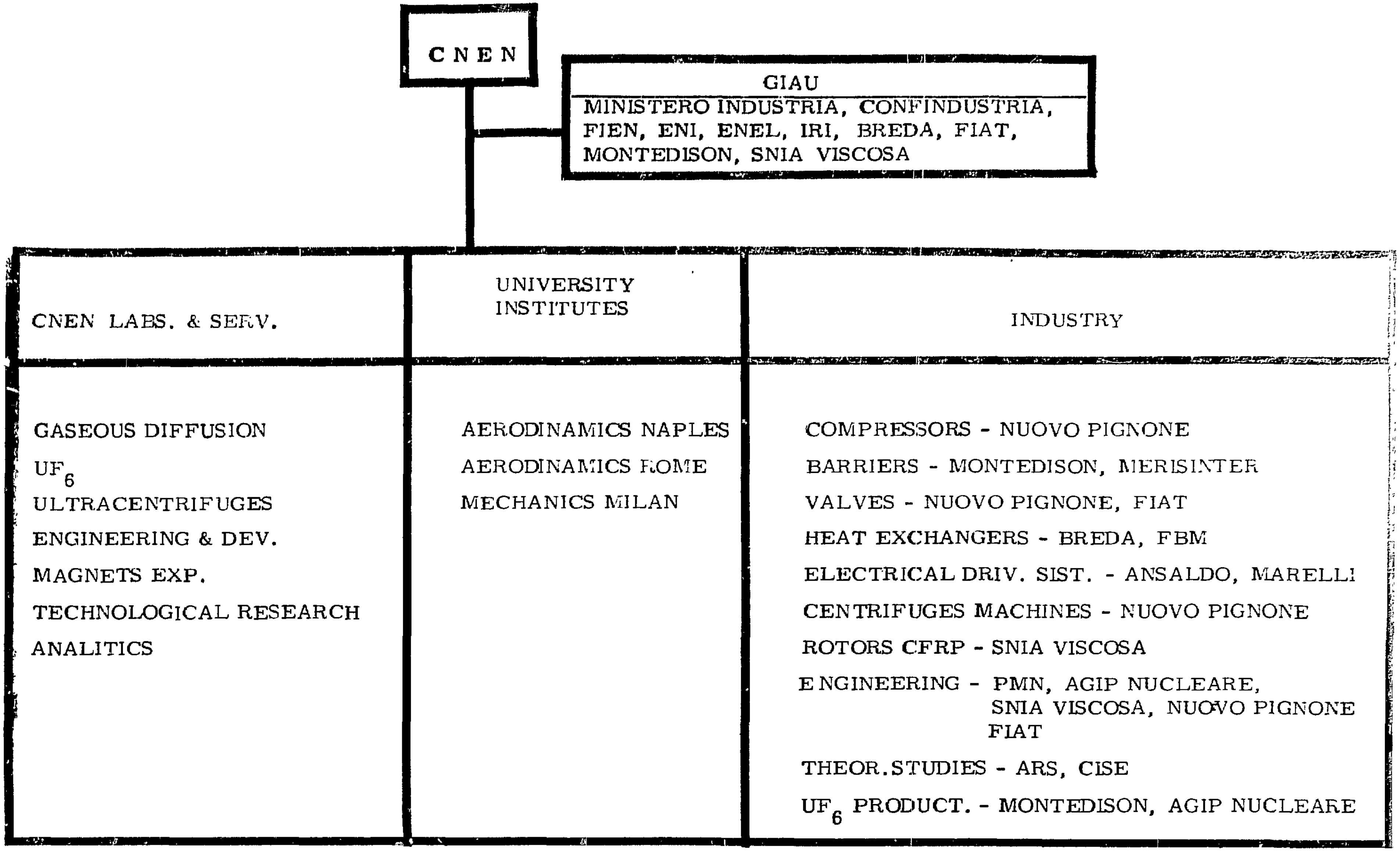

Fig 1 - URANIUM ENRICHMENT R & D ORGANIZATION IN ITALY

FIG. 2 - PROTOTYPE OF A TRANSONIC AXIAL COMPRESSOR (45 kg UF_6/sec)

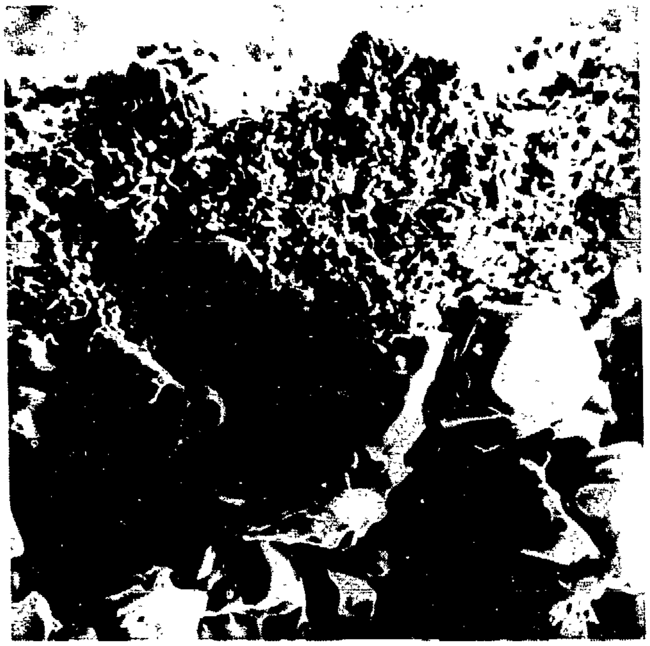

FIG. 3 - CERAMIC BARRIER FRACTURE (620x)

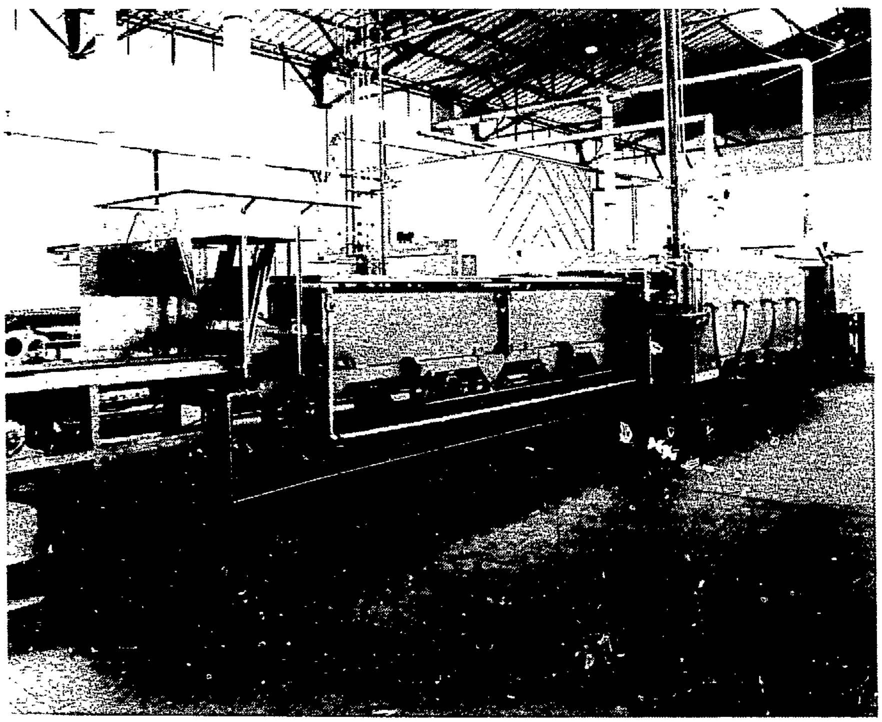

FIG. 4 - ONE OF THE FURNACES OF THE METALLIC BARRIER SUPPORTS PILOT PLANT

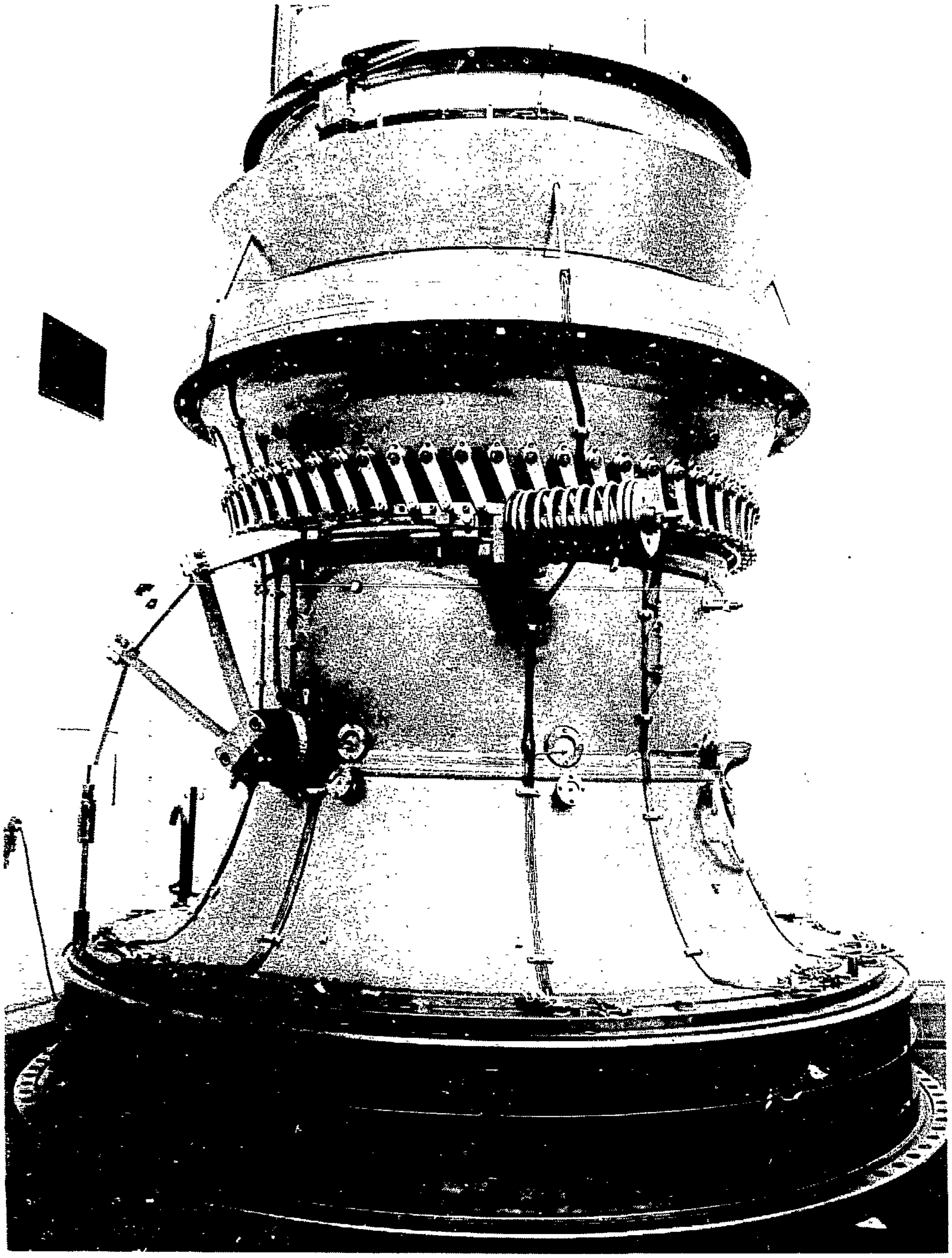

FIG. 5 - FIRST OF THE SERIES COMPRESSOR (160 kg UF_6/sec)

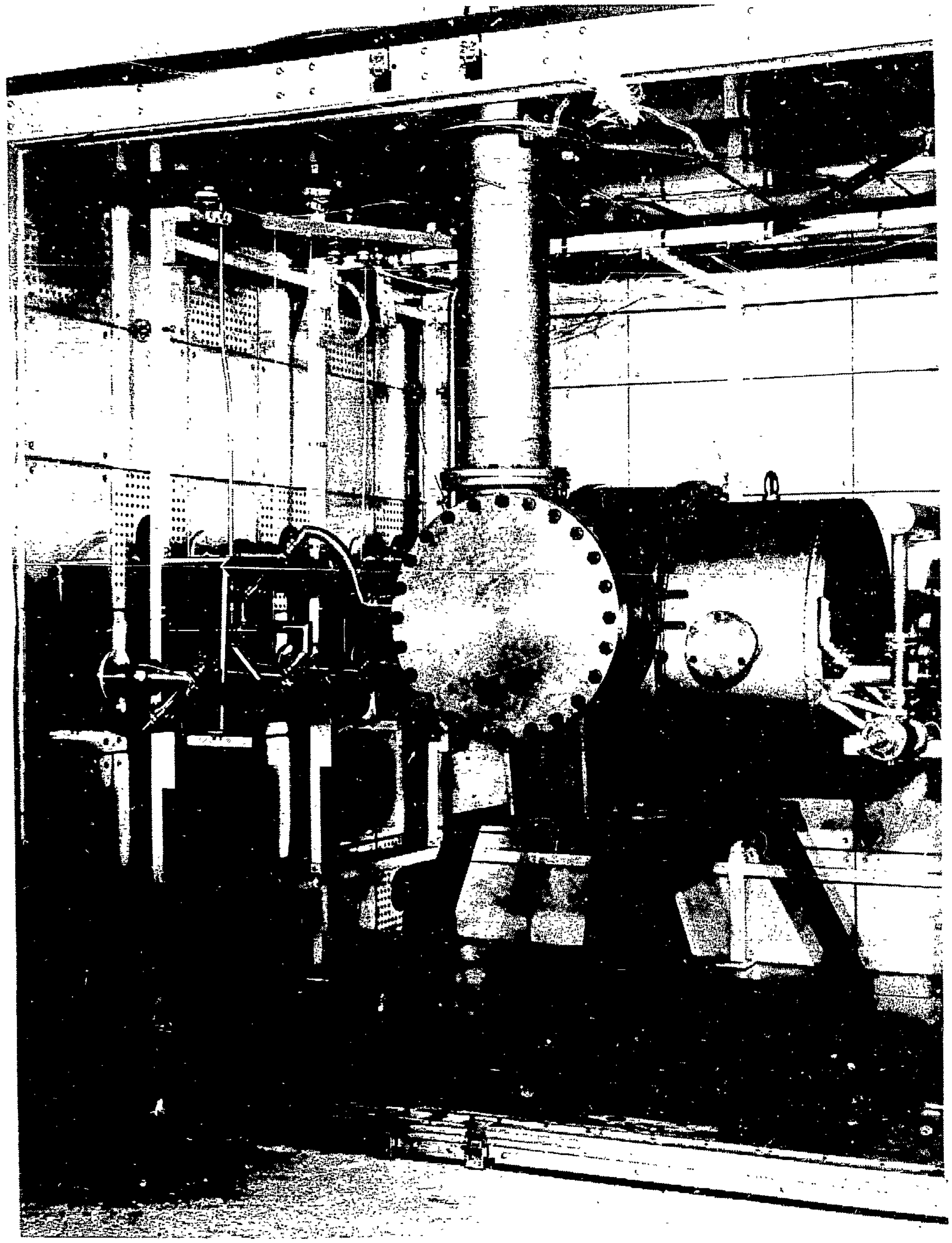

FIG. 6 - A VALVE UNDER TEST IN UF_6

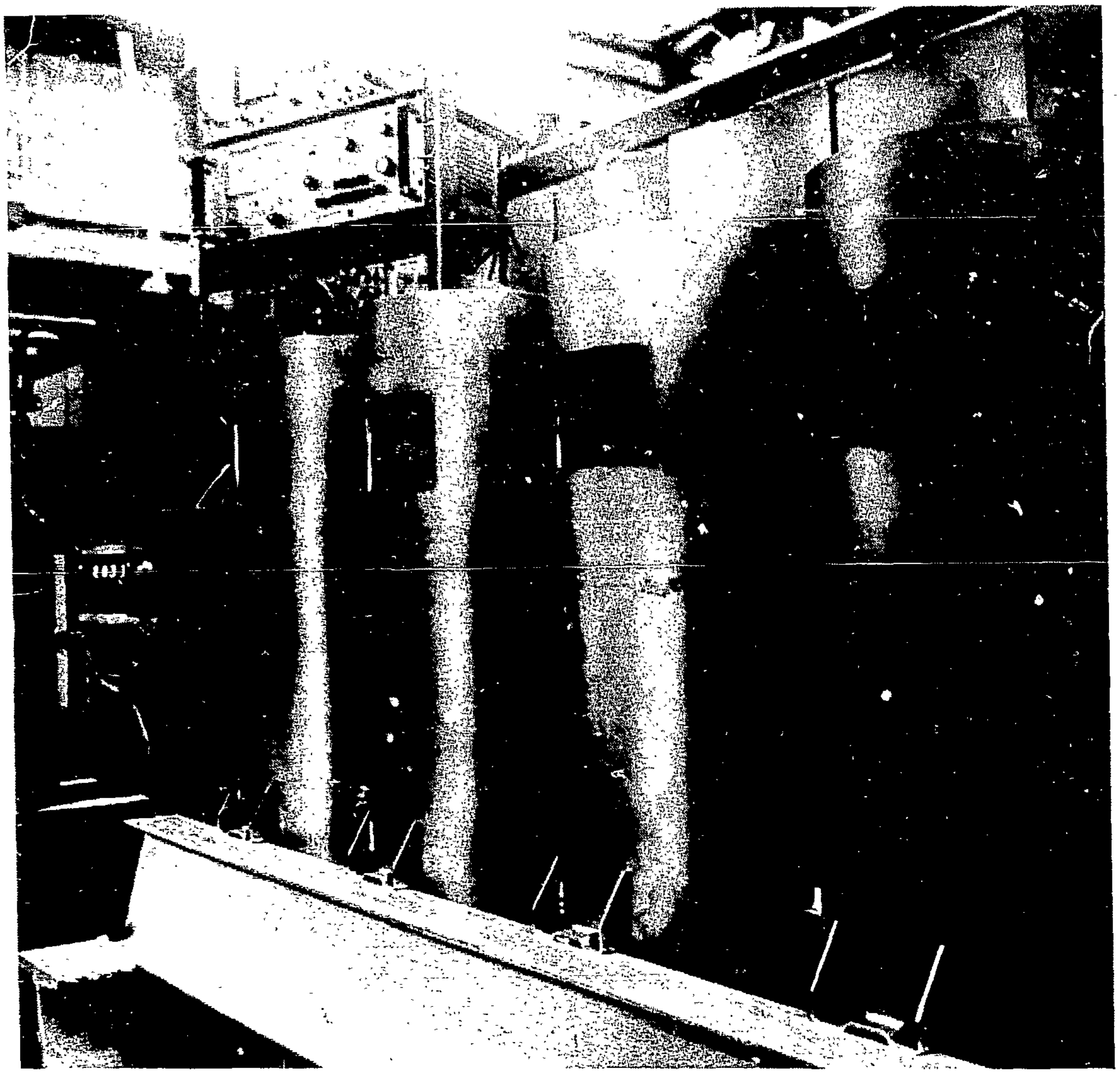

FIG. 7 - PROTOTYPES OF CENTRIFUGES OF LOW PRODUCTION COST

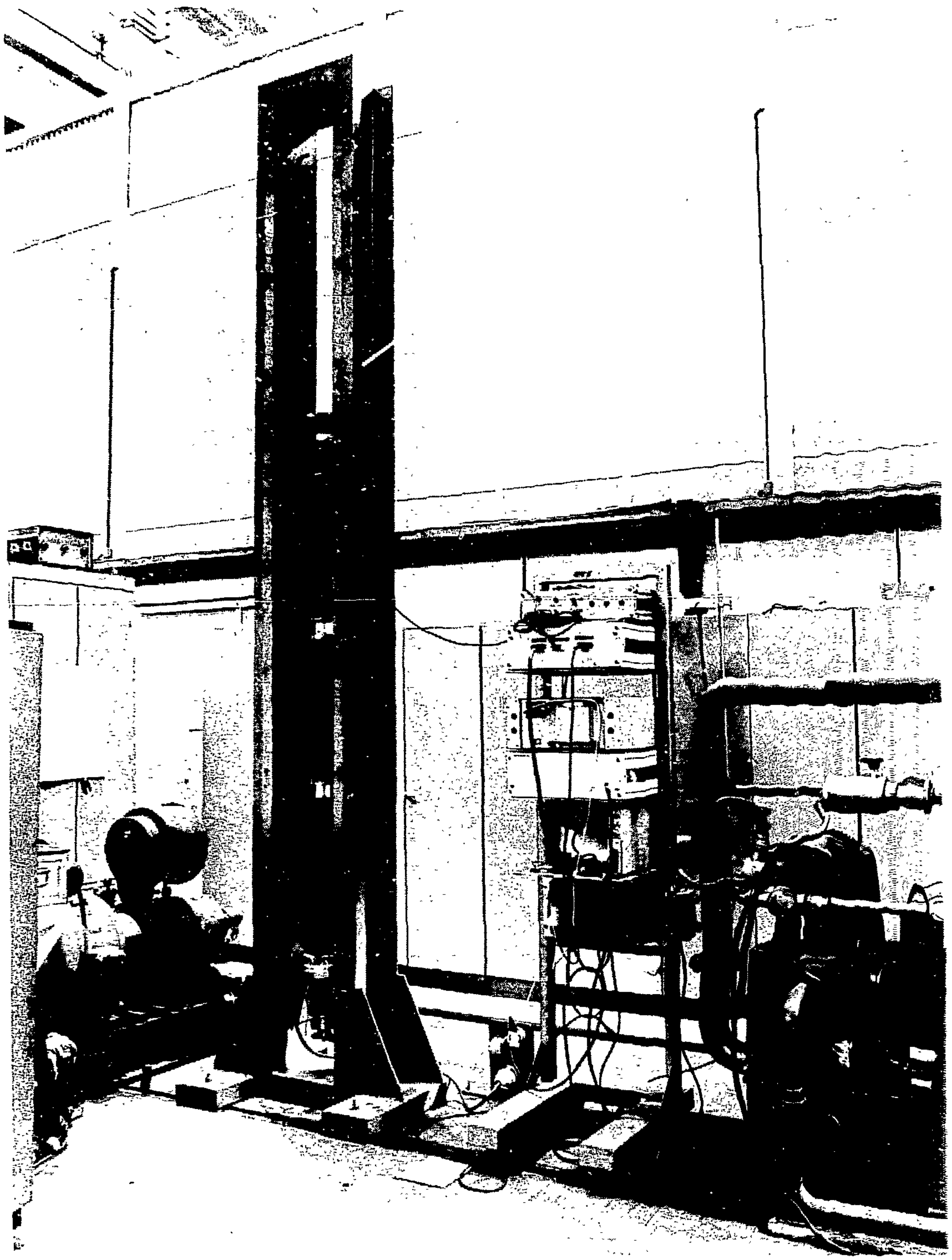

FIG. 8 - TEST APPARATUS FOR A HIGH EFFECTIVE LENGTH MACHINE

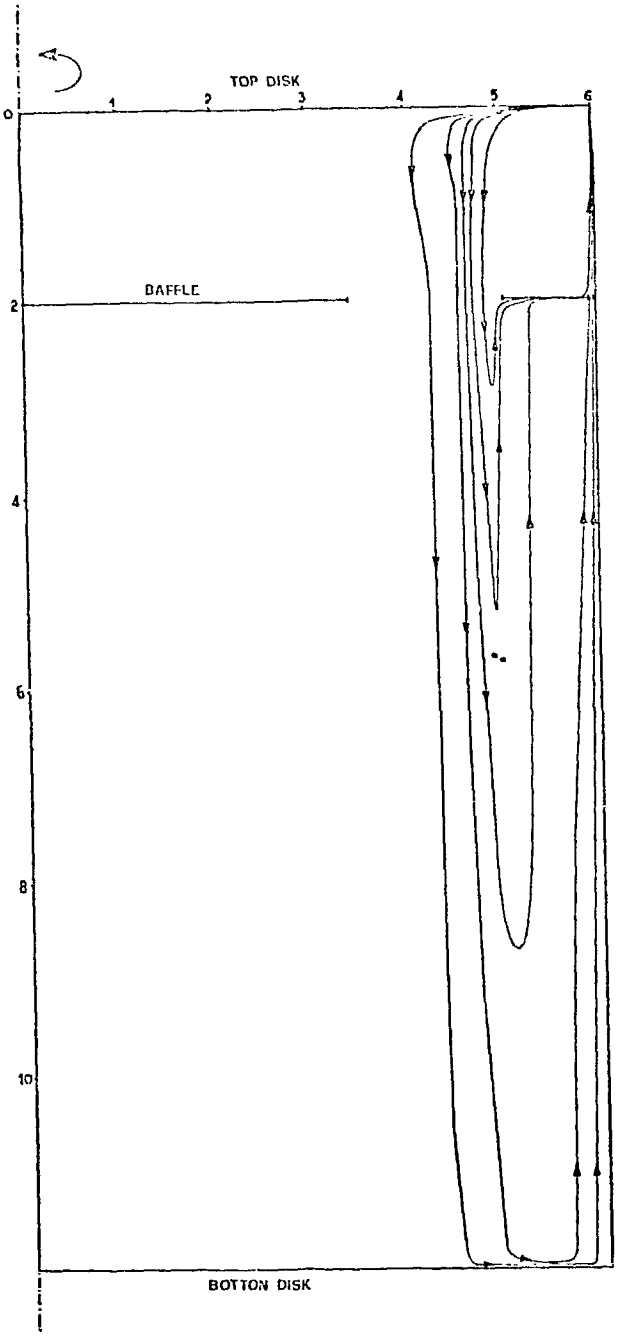

FIG. 9 - FLOW PATTERN IN A CENTRIFUGE; THE TOP DISK ROTATES AT LOWER SPEED ($\Delta\Omega$ = - 3, 3%)

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LAY OUT STUDY OF A CENTRIFUGE PLANT

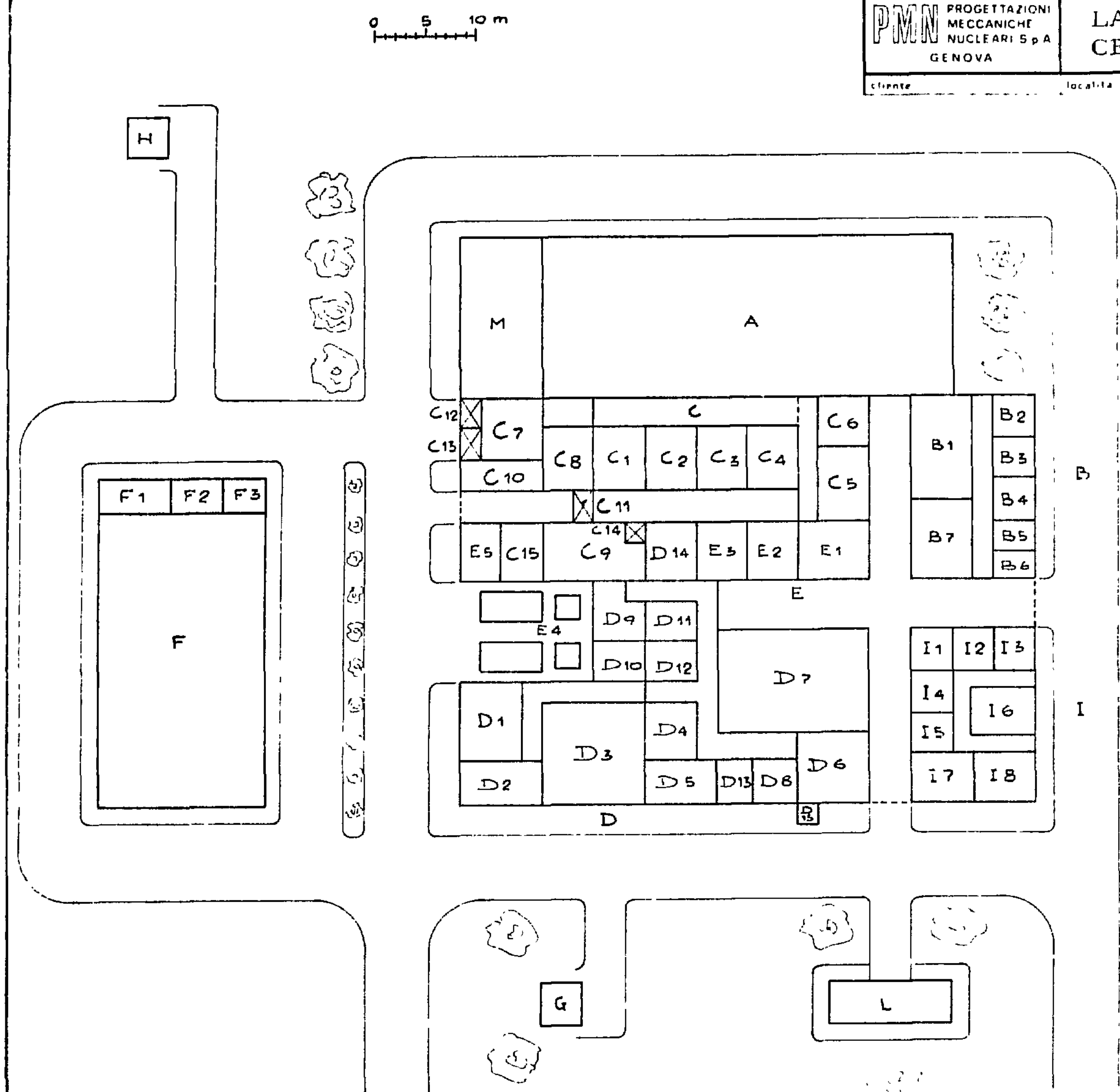

Fig 10

A - CASCADE HALL
B - CONTROL AREA
- 1 - Control Room
- 2-6 Offices
- 7 - Infirmary

C - U F_6 HANDLING
- 1-4 Auxiliary systems
- 5 - Contaminated Workshop
- 6-7 Decontamination Halls
- 8-9 Showers and Change Rooms
- 10- First Aid
- 11-13 Materials Input and Output
- 14- Personnel Entrance
- 15- Offices

D - CENTRIFUGE TREATING AREA
- 1 - Storehouse for Components to be Treated
- 2 - Non Contaminated Workshop
- 3 - Pickling
- 4 - Treated Components Storehouse
- 5 - Clean Condition Workshop
- 6 - Passivation Hall
- 7 - Passivated Centrifuges Storehouse
- 8 - Local Control Room
- 9-10 Areas D_1-D_3 Showers and Change Rooms
- 11-12 Areas D_4-D_8 Showers and Change Rooms
- 13- First Aid
- 14- Offices
- 15- Fluorine Bottles

E - AUXILIARY SYSTEMS
- 1 - Sampling
- 2 - Centrifuge Cooling System
- 3 - Handling Ventilation System
- 4 - Scrubbers and Stacks
- 5 - Nitrogen Station

F - U F_6 STOCKS
- 1 - Weighing
- 2 - Decontamination
- 3 - Offices

G - SOLVENT STOCKS
H - INCENERATOR
I - OFFICES AND LABORATORIES