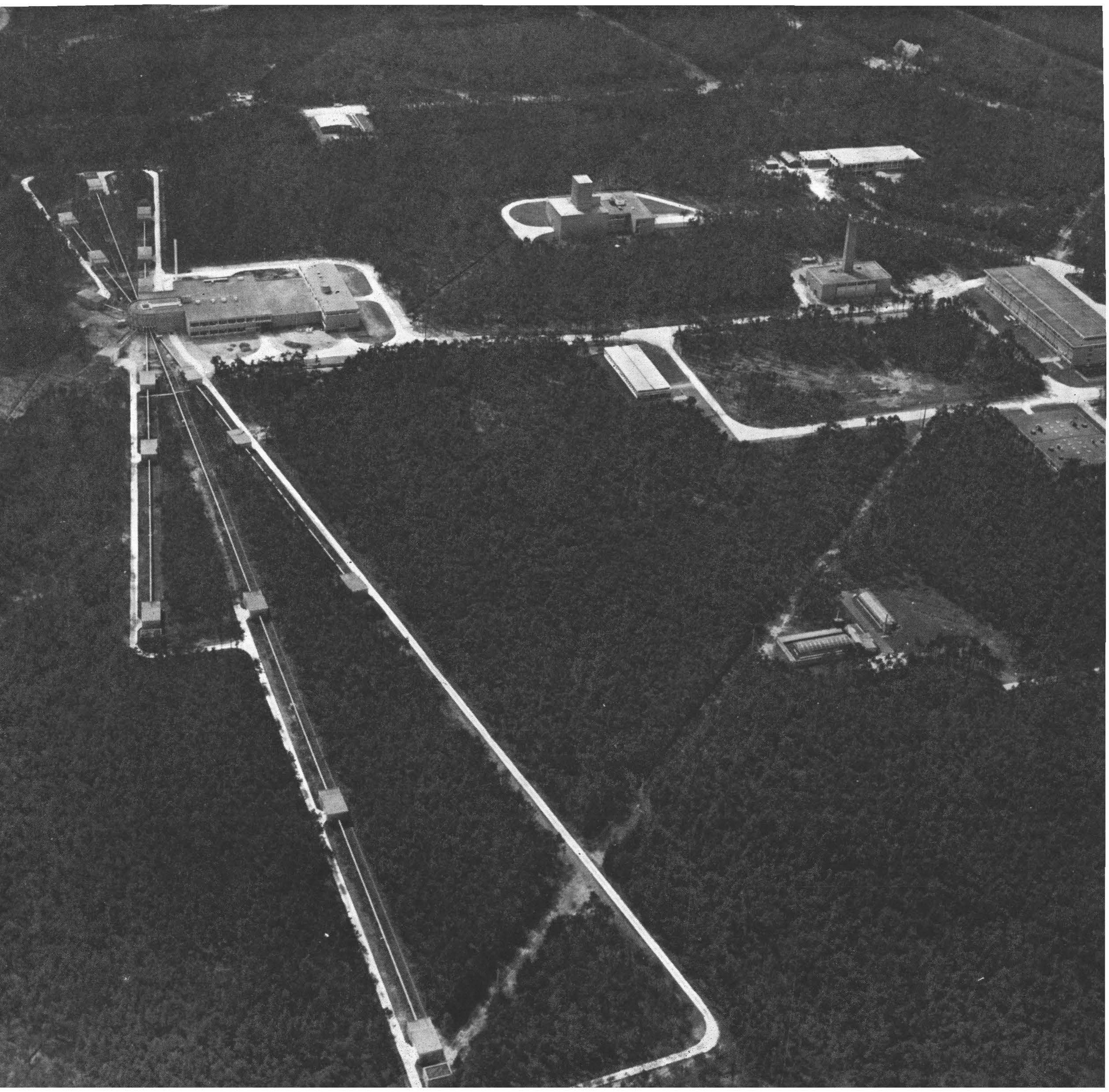
central bureau for nuclear measurements

euratom



introduction

The Treaty of Rome (1957) setting up the European Atomic Energy Community (Euratom) provided for the foundation of a Central Bureau for Nuclear Measurements (CBNM). Work commenced on its establishment at the present site in 1960.

CBNM as a Nuclear Standards Bureau, is primarily concerned with the promotion of the science of nuclear measurements. This means the preparation of the necessary basic standards, which in turn demands continuous efforts to improve measuring instruments and methods and high-precision measurements of nuclear data.

CBNM devotes an important part of its activity to standards needed for neutron data measurements and to the determination of neutron parameters required by the nuclear industry. The other fields of activity pertain to radioactivity, isotopic composition and the preparation of well-defined samples. Specialized laboratories for chemistry, classical metrology and electronics support the nuclear activities mentioned.

On request, CBNM also supplies other laboratories, especially inside the European Community, with special samples (assayed if necessary), standards and measuring services, mainly in the nuclear energy field.

In the following pages a brief description is given of the main equipment available and the current programmes.

J. Spaepen

Geel, 1968

electron linear accelerator

The electron linac of the CBNM (constructed by CSF) is of the travelling-wave type and has two sections. Electron bursts of durations between 10 ns (at 70 MV and 3.6 A beam current) and 2 μs (at 42 MeV and 0.5 A beam current) impinge on a mercury-cooled uranium target. The resultant bremsstrahlung produces neutrons with a maximum intensity between 1 and 2 MV neutron energy. Neutron moderators are used for measurements in the resonance region (some eV to about one hundred keV).

main characteristics of the CBNM electron linac

Burst width (ns)	*Max. repet. freq.* (Hz)	*Peak current* (A)	*Neutrons in the burst per sec.* (neutron/s)
10	1000	3.6	1.10^{18}
100	880	1.8	3.10^{17}
1000	380	0.5	6.10^{16}
2000	250	0.5	6.10^{16}

The linac, which is constantly being improved as far as neutron output is concerned, is used for neutron time-of-flight experiments in a fan-shaped system of eight evacuated flight tubes of 30 to 400 m length (see front cover). Detector and sample stations are inserted at several distances. Three further flight paths of 7 to 10 m length are installed inside an annex of the linac building.

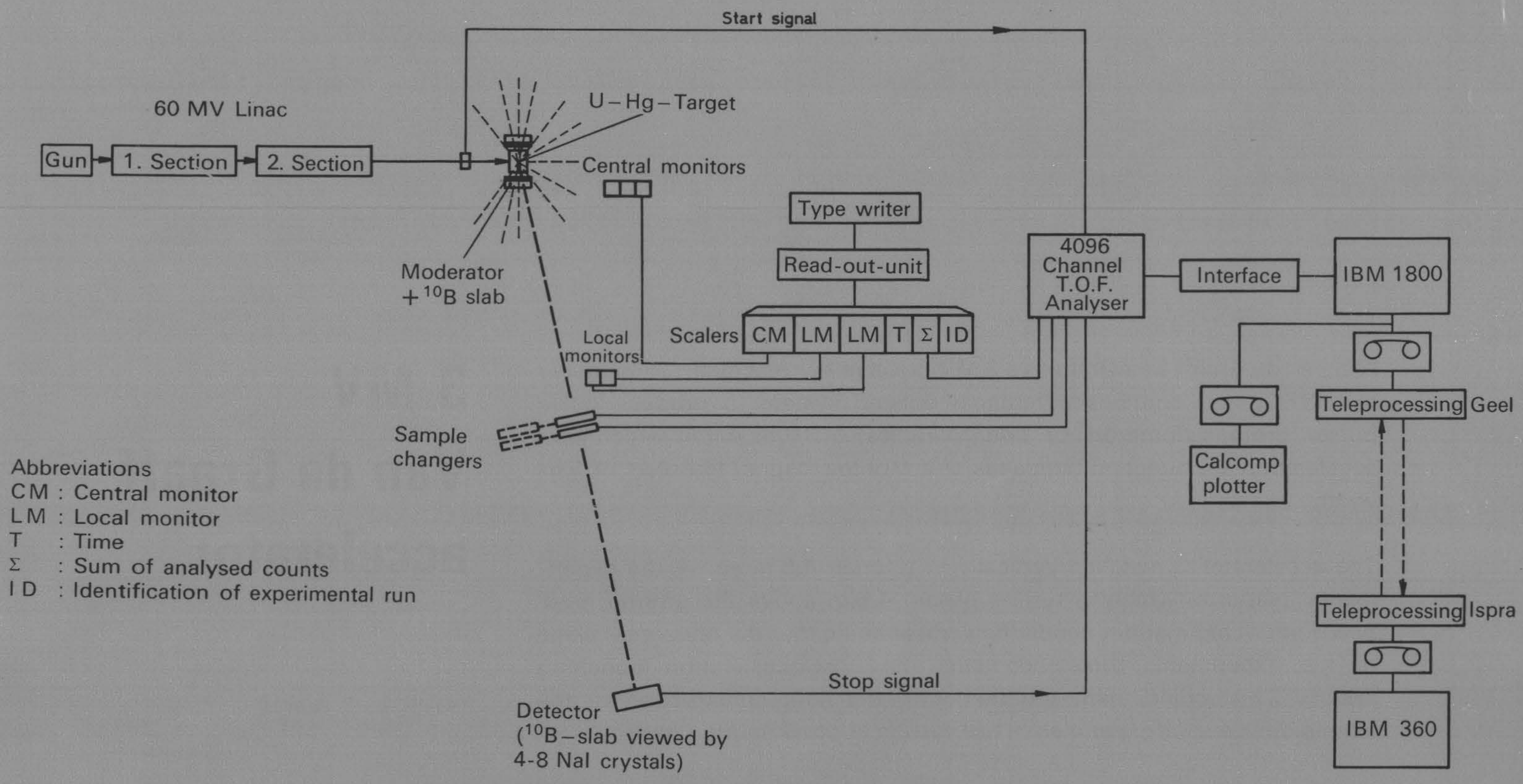
Measurements of total, scattering, fission and capture cross-sections are carried out, neutron reference cross-sections and nuclear resonance parameters being given special emphasis. Experimental results are accumulated in four 4096-channel time-of-flight analysers and in a home-made time-analysing system with a maximum capacity of 10^6 timing channels.

A small computer (IBM 1800) reduces the raw data. Final evaluation of the results is performed via a teleprocessing system (IBM 7702) at CETIS, Euratom's Computer Centre at Ispra.

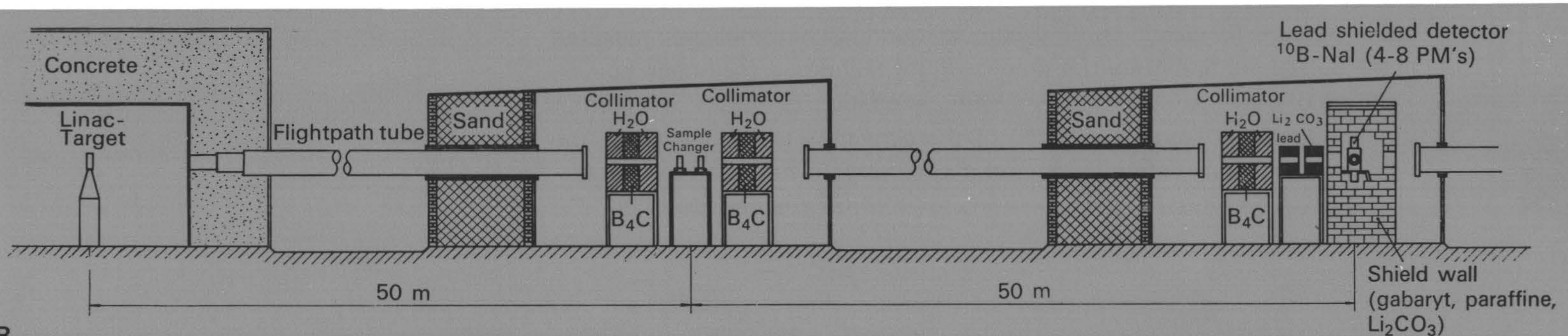
Linac neutron time-of-flight spectrometer as used for a total cross-section experiment

A schematic arrangement

B neutron flight path



A



B

3 MV Van de Graaff accelerator

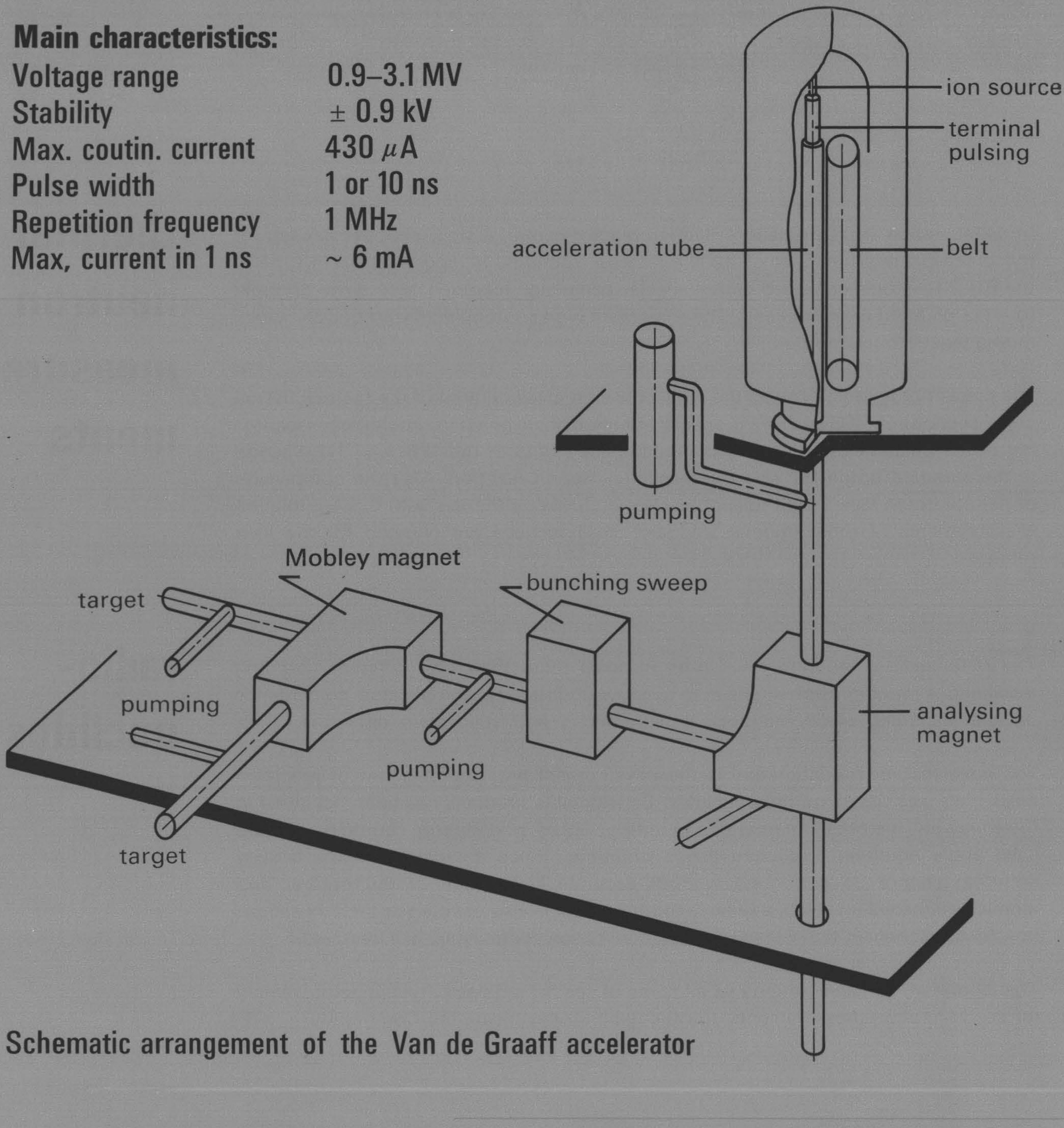
The Van de Graaff accelerator is a 3 MV positive ion machine (constructed by HVEC) and contains a terminal pulsing system to produce beam bursts (protons, deuterons or alpha-particles) of 10 ns width which after acceleration are bunched by means of a Mobley magnet to bursts of 1 ns width.

The accelerator is installed vertically in a tower 4.5 m above the experimental platform, which in turn is placed 4.5 m above the ground level. A 90° analyzing magnet bends the vertical beam into the horizontal plane of the experiments which contains the post-acceleration bunching system. This arrangement, together with the light construction of the aluminium-covered experimental hall, results in a low neutron background.

The Van de Graaff accelerator is exclusively used for measurements in the field of neutron physics. The maximum energy of 3 MV for protons and deuterons limits the production of monoenergetic neutron beams to the energy regions 0.03 to 6.2 MV and 12.6 to 19.6 MV. Mainly differential cross-sections for elastic and inelastic scattering of neutrons are measured in the pulsed mode by neutron time-of-flight technique (see back cover). Furthermore, in the direct current mode, excitation functions for neutron threshold reactions are determined by the activation technique. Also, the problem of accurate determinations of monoenergetic neutron fluxes is studied by different independent methods for neutron energies up to 20 MV.

Main characteristics:

Voltage range	0.9–3.1 MV
Stability	± 0.9 kV
Max. coutin. current	430 μA
Pulse width	1 or 10 ns
Repetition frequency	1 MHz
Max, current in 1 ns	~ 6 mA



Schematic arrangement of the Van de Graaff accelerator

thermal neutron measurements

In collaboration with the nearby Belgian reactor centre, a slow chopper is used for the precision measurement of 2200 m/s cross-sections. A tangential beam tube in the BR-2 reactor is equipped with a special collimator followed by a slow chopper for time-of-flight measurements. The equipment works automatically around the clock during reactor operation.

The present programme covers the high-precision measurement of the thermal fission cross-sections of ^{235}U and ^{239}Pu, special attention being given to simultaneous recording of the pulse height and time-of-flight spectra of both the $^{10}B(n, \alpha)\,^{7}Li$ reaction in the standard boron foil and the respective fission reaction. Also the comparison of natural boron layers with foils of fissile material is performed with this equipment. Measurements of other thermal standard cross-sections are planned for the near future.

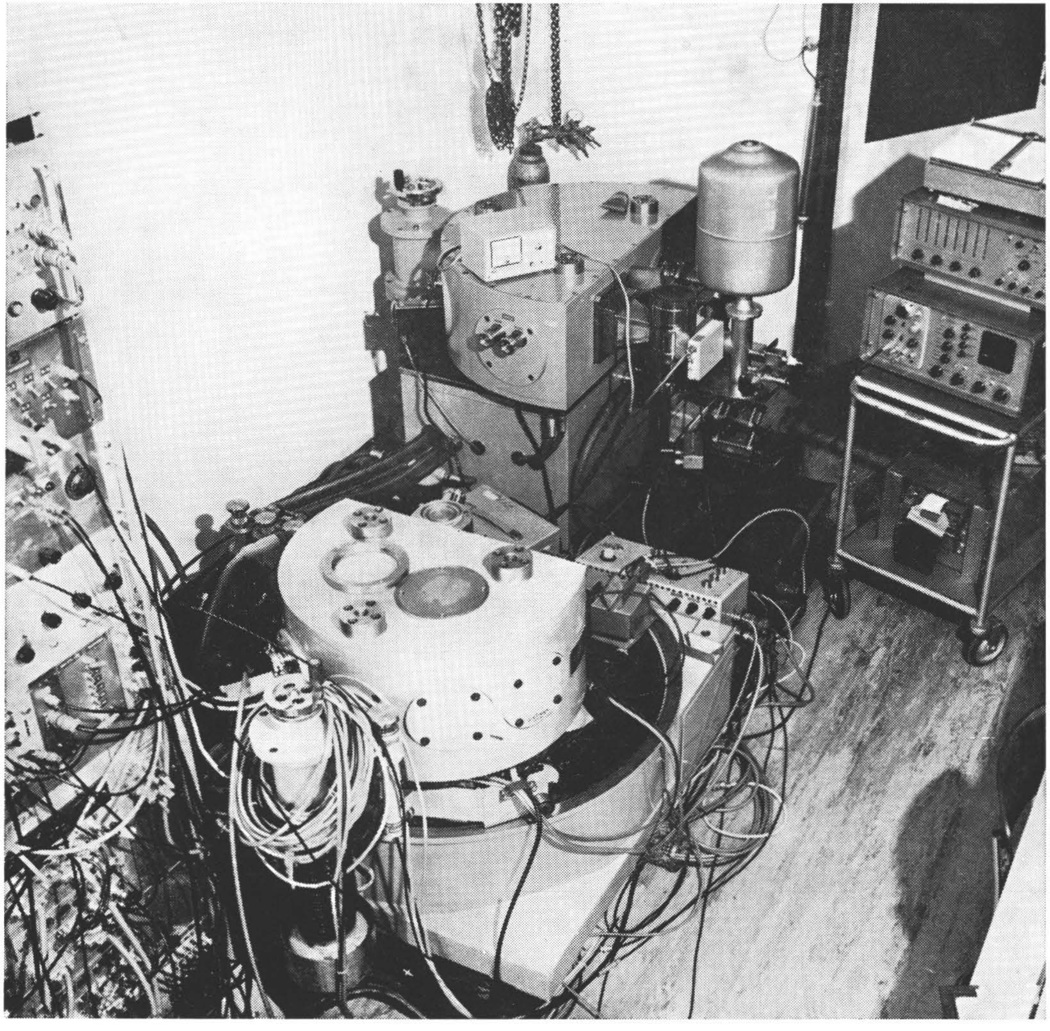
radio-nuclides

The radionuclides laboratory has at its disposal more than fifty different counting installations ranging from simple end-window counters to complicated coincidence devices including electromagnetic spectrometers and solid-state detectors.

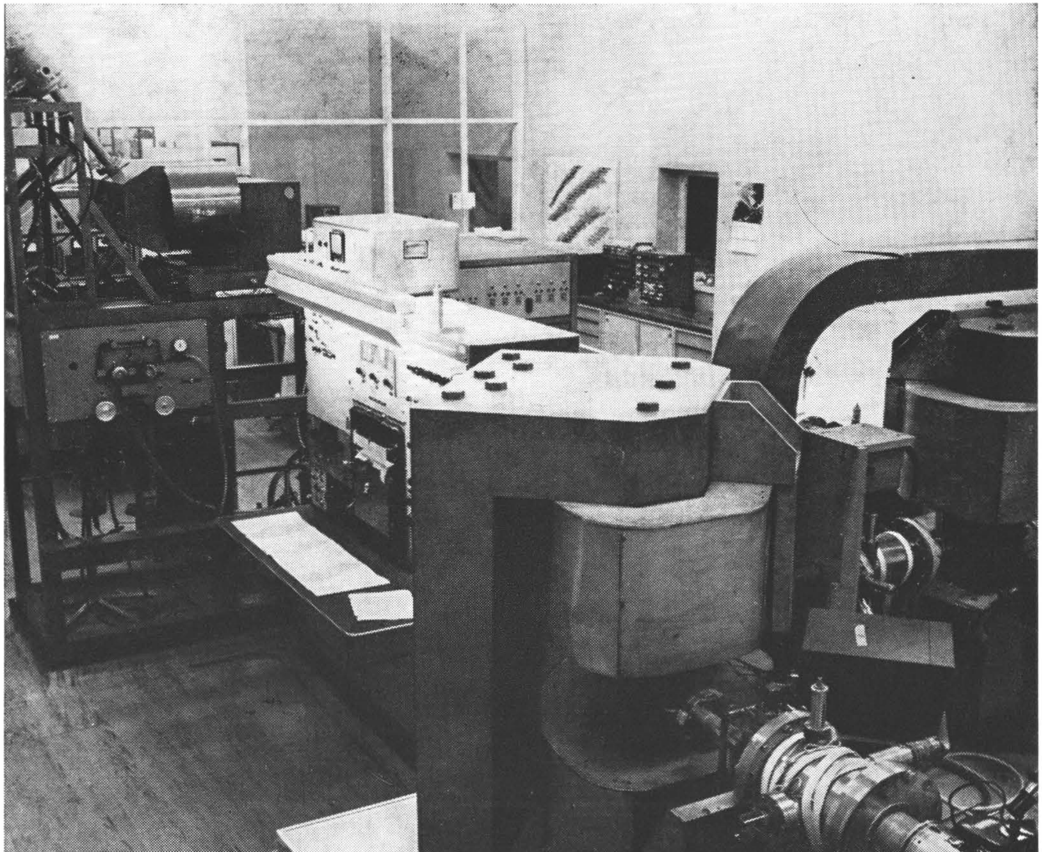
The main task of the laboratory is the development and improvement of precision measuring techniques on radionuclides. Considerable progress has been achieved in the following methods: internal gas counting, liquid scintillation counting, defined solid angle counting and coincidence counting. Since accurate absolute activity counting cannot be performed without accurate knowledge of the nuclear and atomic parameters involved, a great amount of work is also devoted to their investigation (decay schemes, fluorescence yields, conversion coefficients, half lives, etc.).

The laboratory supplies on request all kinds of special radioactivity standards, mainly for use in neutron measurements, to other laboratories inside the Community.

Electromagnetic β-spectrometer and high resolution Si(Li) X-ray detector used for *e-x* coincidence measurements of conversion coefficients



Tandem mass spectrometer



mass spectrometry

Seven mass spectrometers, all of the magnetic type, form the basic instrumentation of the mass spectrometry laboratory.

The laboratory performs accurate analyses of the isotopic composition of solids and gases ($A < 125$ for the latter). The mass spectrometers are also used for chemical analyses of gases and for quantitative determinations of solids by means of isotope dilution. Mainly materials of interest in the nuclear energy field are analyzed, e.g., standard materials such as lithium and boron and fissile materials such as uranium and plutonium. The laboratory is also concerned with instrumental development, compilations in connection with atomic weights, intercomparisons of the results and analytical methods used for the absolute determination of the isotopic composition of heavy water samples, and with studies on mass discrimination and isotopic dilution.

On request the mass spectrometry laboratory provides other institutes with analyses of nuclear fuel, burn-up determinations, isotopic assaying of reference samples, quantitative analyses of gases including fission gases, and high-precision isotope ratio determinations (e.g., H, Li, B, O, U, Pu).

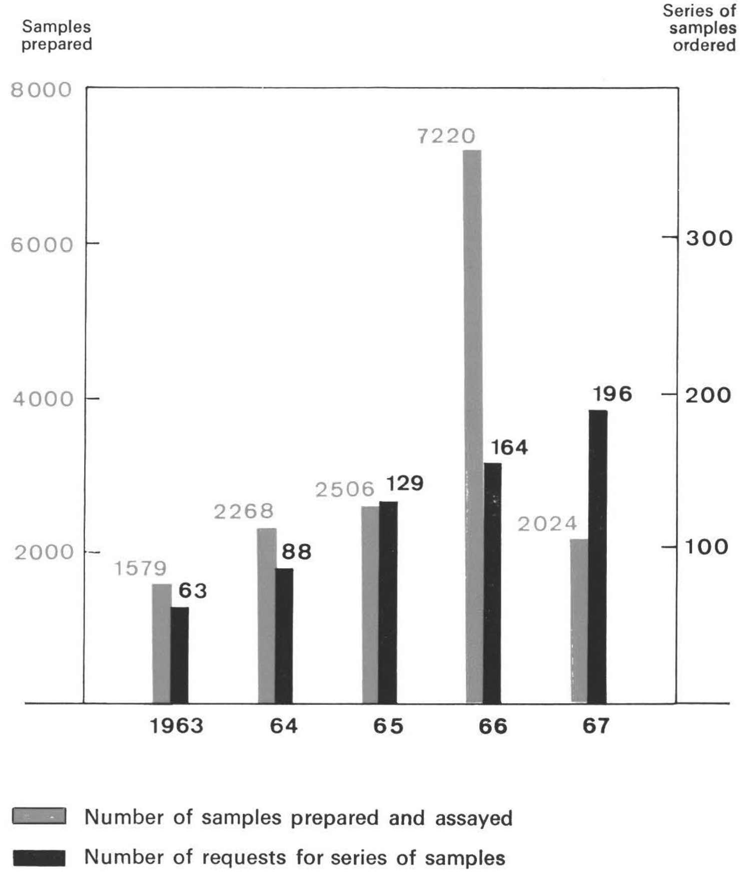
sample preparation and assaying

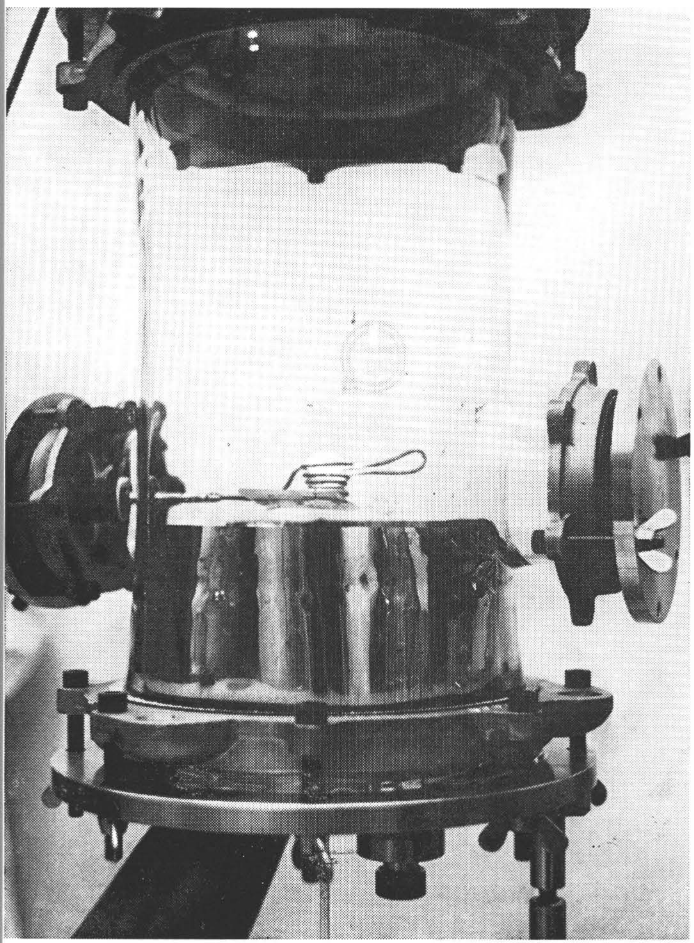
Various facilities are available for the preparation of well-defined samples to be used in nuclear research, in particular those which are not fabricated commercially. The main techniques used for preparation are alloying (especially by levitation melting), electrolysis, electrophoresis, electrospraying, vacuum deposition and precision machining.

The assay of the samples requires usually very precise determinations of sample material data. The most versatile methods used consist of dimensional and weight control, chemical, isotopic and X-ray analysis, counting of radioactivity, and metallographic techniques.

Some typical samples provided by the CBNM were thin layers (e.g. of fissile material), rolled foils (e.g., of metals for neutron flux measurements), reference alloys and solutions, canned Li and Na samples, and powder samples.

Number of samples prepared and
assayed and number of requests for series of samples
in the last years

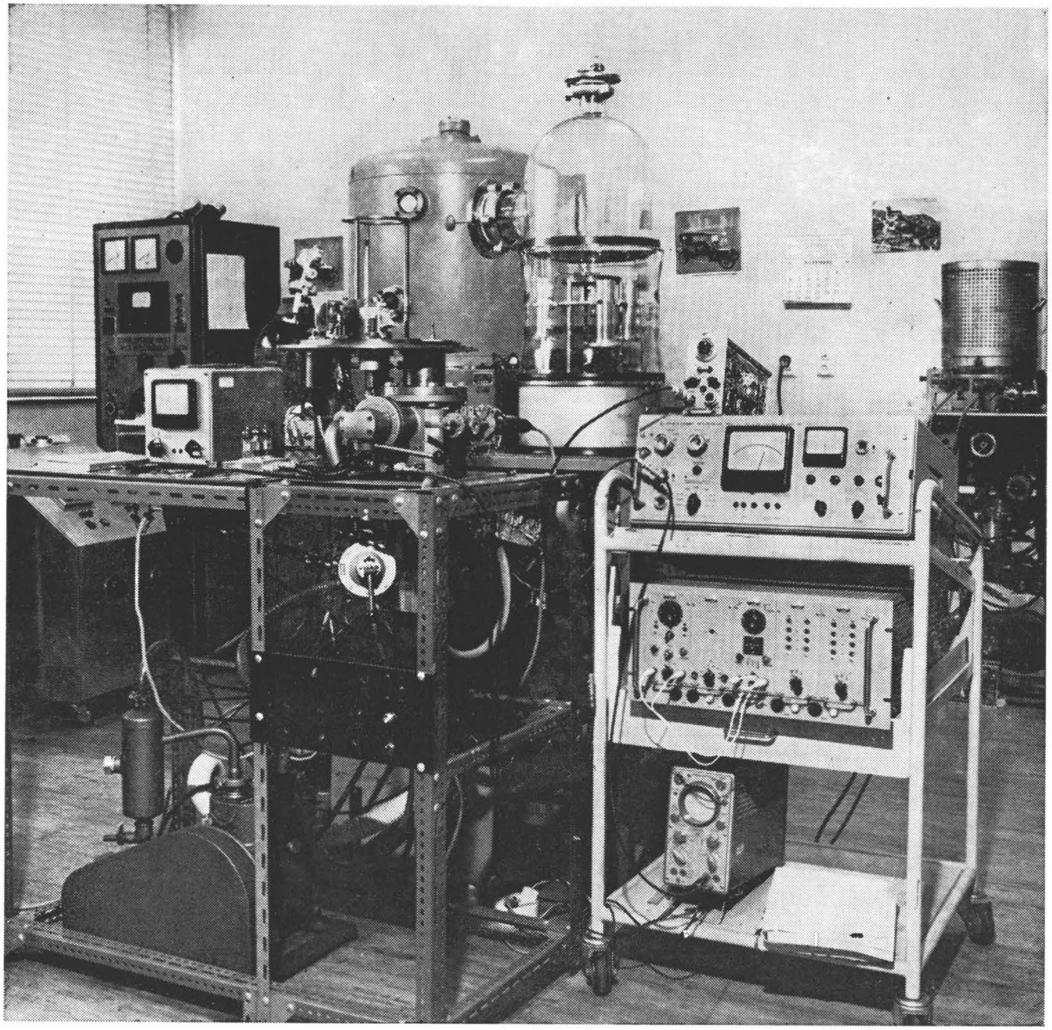




The levitation technique allows the preparation of very homogeneous alloys of different metals

supporting laboratories

Laboratories for classical metrology, analytical chemistry and electronics provide the necessary support for the above-mentioned nuclear laboratories.



Some of the evaporation units used for the fabrication of nuclear targets and standards. The possibilities of heating the different metals and compounds to be evaporated *in vacuo* range from resistance heating to electron bombardment, r.f. heating and sputtering.

metrology

The metrology laboratory has at its disposal all the facilities for precision measurements of classical quantities such as mass, density, length, angle, thickness, temperature, pressure and electrical data. The main equipment is provided for weighing (many precision balances, also for the submicrogram range and for weighing in vacuum) and for vacuum deposition (about ten installations, also under ultra-high vacuum).

Some special applications of this instrumentation are density measurements on heavy water and on alloys made by levitation melting, vacuum deposition of thin layers of Li, B or U as standards for nuclear measurements, encapsulation of semiconductor counters, development of an ultra-high vacuum balance, evaporation in ultra-high vacuum and determination of thickness, homogeneity and structure of thin layers by X-rays.

chemistry

The chemical activities are primarily concentrated on aiming at the accurate chemical analysis of substances of interest to nuclear industry and research (U, Pu, B, Li, transplutonic elements). Classical high-precision chemical methods are used together with physico-chemical methods such as coulometry, polarography, emission spectrography and spectrophotometry, especially for the accurate analysis of small quantities of elements or purified sotopes.

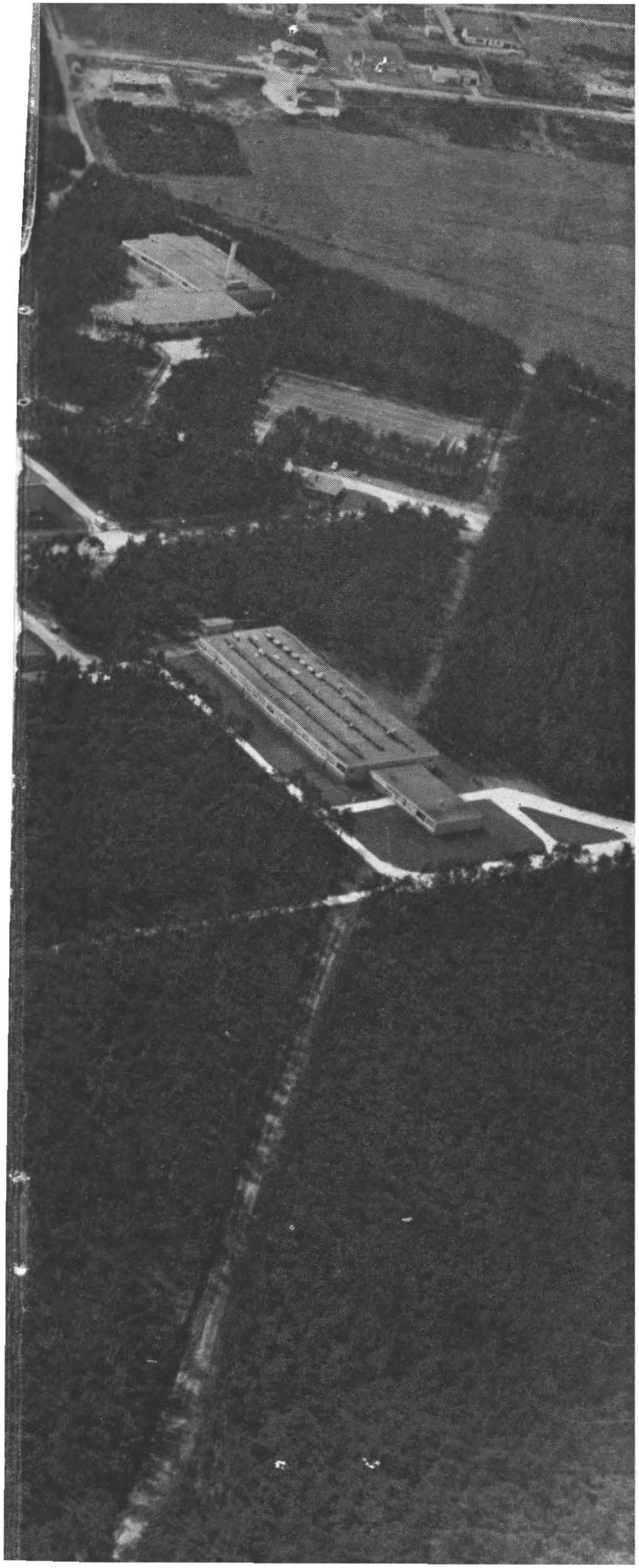
Some typical work performed was the fabrication of highly alpha-active sources of actinides using specia preparative techniques, the preparation of standard solutions of many elements or isotopes for oscillation measurements in reactors, the precise analysis of impurity traces in materials used for neutron measurements, and the precise quantitative determination of uranium and plutonium samples.

electronics

There is a special laboratory to handle the electronic instrumentation at CBNM. It develops suitable electronic instrumentation, particularly, when characteristics and performances are required which are not offered by industry. It is equipped with the most recent electronic instrumentation.

Some examples of electronic developments performed are: equipment for handling and converting analog signals for high-precision γ-spectroscopy and neutron cross-section measurements (e.g., 1 ns time analyser); instruments for the storage and handling of digital data, including multiparameter spectra units, also with computing functions; standard nuclear electronic equipment with adaptation of the system layout to modern electronic elements and automation of measurement procedures.

Also special semiconductor detectors are made, such as silicon detectors with large sensitive surfaces, with high energy or time resolution, or for the detection of heavy particles, and Ge(Li) detectors up to large volumes for high-resolution γ-spectroscopy.



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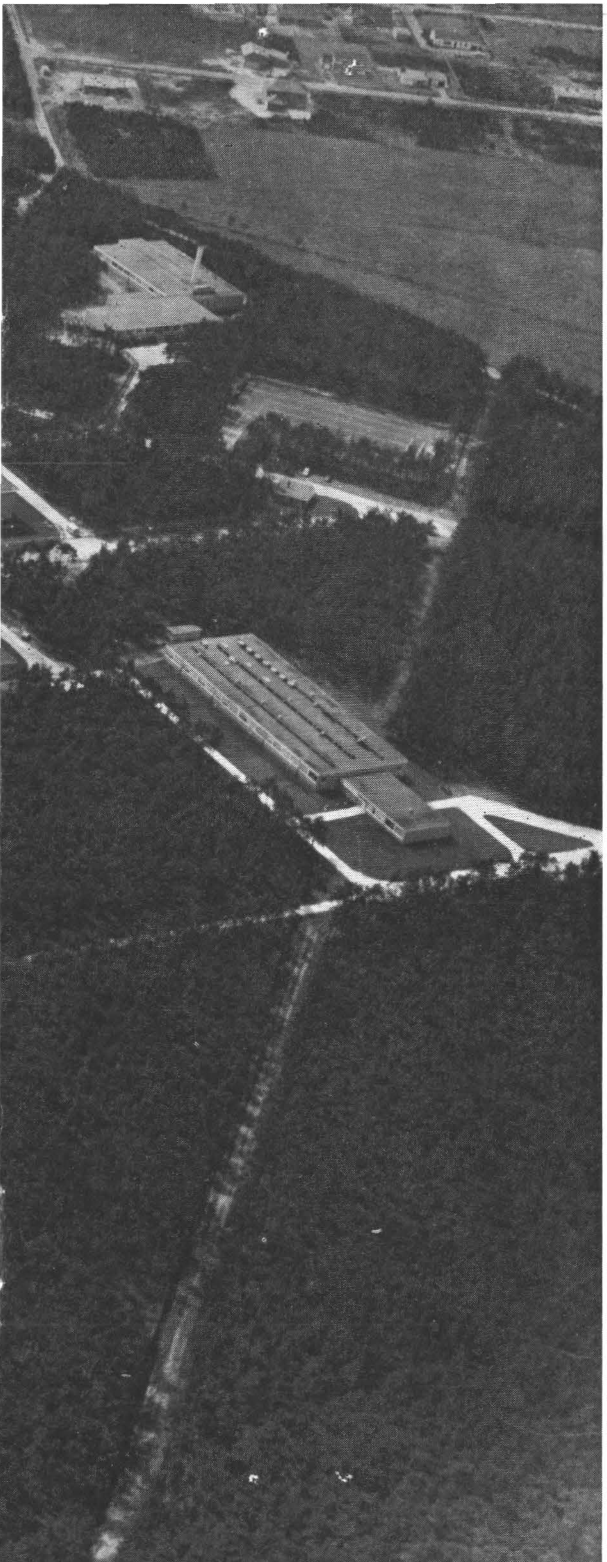

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