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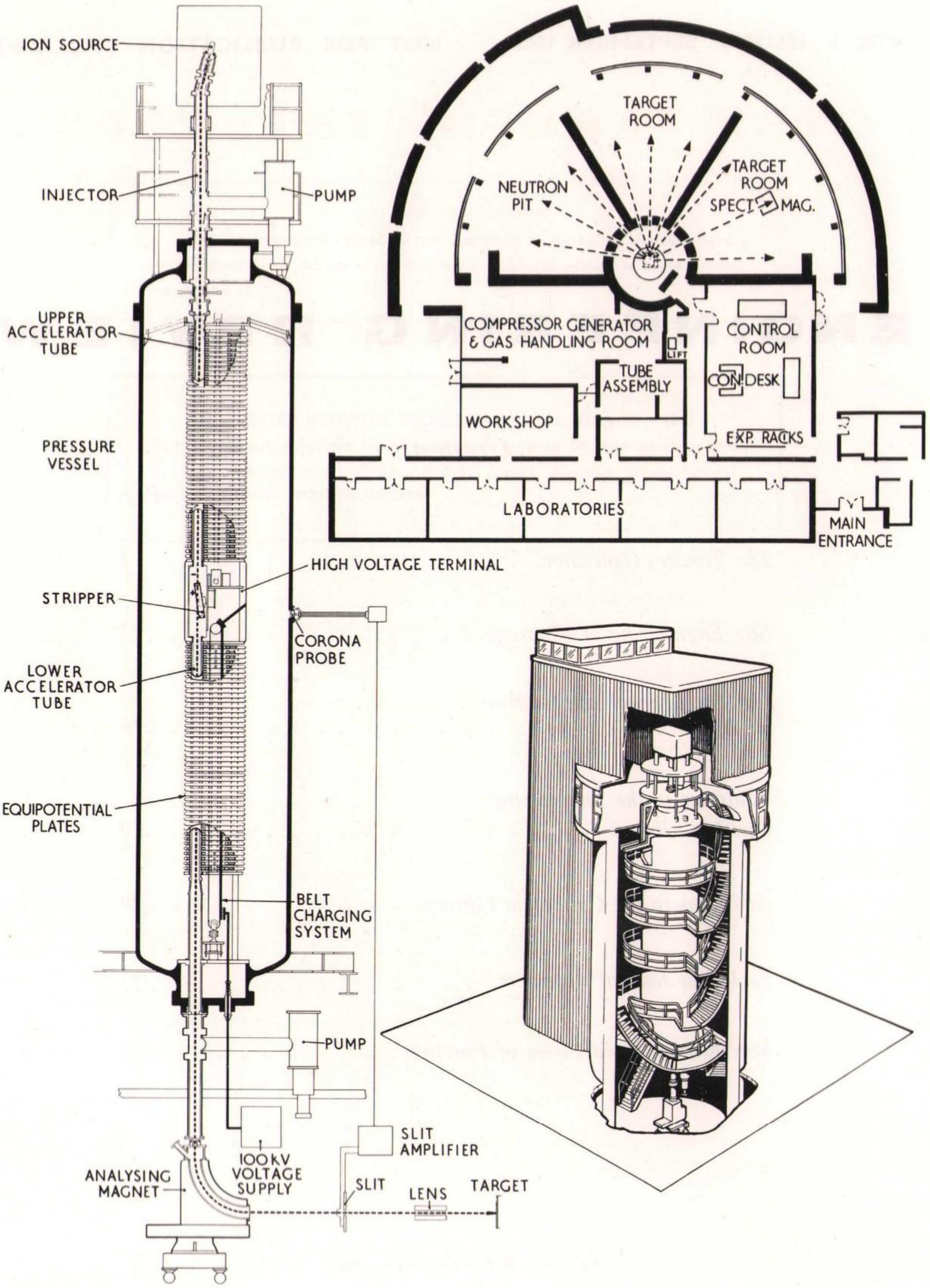


Fig. 1 *Illustration Studio, No. 217747*

THE TANDEM GENERATOR

by

P. Humphries

Physics & Electronics Support Group

The Tandem Generator, at A.E.R.E. Harwell, has been developed for the Nuclear Physics Division, the requirement being for a generator which would produce particles with energies in excess of five or six million electron volts. This generator was required for basic nuclear research and, in particular, for a thorough investigation of the nuclei of the elements having a higher charge, and requiring a penetration energy in excess of 5 or 6 MeV. The conventional Van de Graff electrostatic generator had been used in the past for investigating the properties of the nuclei, but unfortunately energies in excess of this machine's practical limit were required. This limitation was due mainly to the difficulty experienced in maintaining higher voltages across the vacuum path of the accelerator tubes.

The conventional Van de Graff machine accelerates a beam of positively charged particles from a positively charged high voltage terminal, to earth. This type of machine has proved exceptionally useful as it is capable of producing a tightly collimated beam of charged particles. In addition, the voltages can be varied continuously from zero to five or six million volts and at any given voltage, stability can be maintained to within one part in a thousand, or better. Furthermore, the machine can be readily and accurately calibrated for voltage, against known thresholds. (A typical experiment of this type is described at the end of the article.)

A generator was required which would produce a higher energy particle beam having the same resolution as that of the conventional Van de Graff machine, without exceeding the terminal voltage of five or six million volts. The direct result was the Tandem Generator, in which double acceleration of the particles occurs. The Tandem Generator accelerates negatively charged particles from earth to the positively charged high voltage terminal, and then converts them by means of an electron stripping device to positively charged particles which are further accelerated to earth. The prime difficulty was the development of an ion-source that would produce a beam of negative ions.

The basic components of the Tandem Generator, shown in Figure 1, are the ion-source assembly, the particle accelerator enclosed in a pressure vessel, the main analysing magnet and the focussing system. The ion-source assembly shown in Figure 2, is situated at the upper end of the pressure vessel. At the discharge end of the ion-source shown in Figure 3, is a glass bottle with a R.F. coil around it. Gas is fed into this bottle and is ionised by the radio frequency field from the coil. The positive particles are focussed into the charge exchange canal where they may pick up first one and then a second electron, to become negative ions. A voltage accelerates the particles which are then focussed through a differential pumping tube into a 20° analysing magnet. After passing through adjustable magnetic deflectors, the particles pass into the injector which operates at about 80 kV, this being the accelerating voltage that is required to give the particle its initial acceleration. All controls for the ion-source are operated via a multiple remote control unit. These controls are duplicated, one set being located in the vicinity of the ion-source at the top of the tower, and the other set on the control desk which is shown in Figure 4. Closed circuit television, which can be seen either locally or on the control desk, is used to view the metering panel, thus overcoming the problem of viewing meters that are normally operating at 80 kV above earth. The pressure vessel is made of steel, is ten feet in diameter and forty feet long. Three adjustable jacks support the vessel which weighs forty tons. The removable lid of the vessel weighs ten tons and carries the ion-source assembly which weighs a further four tons. Normal access to the

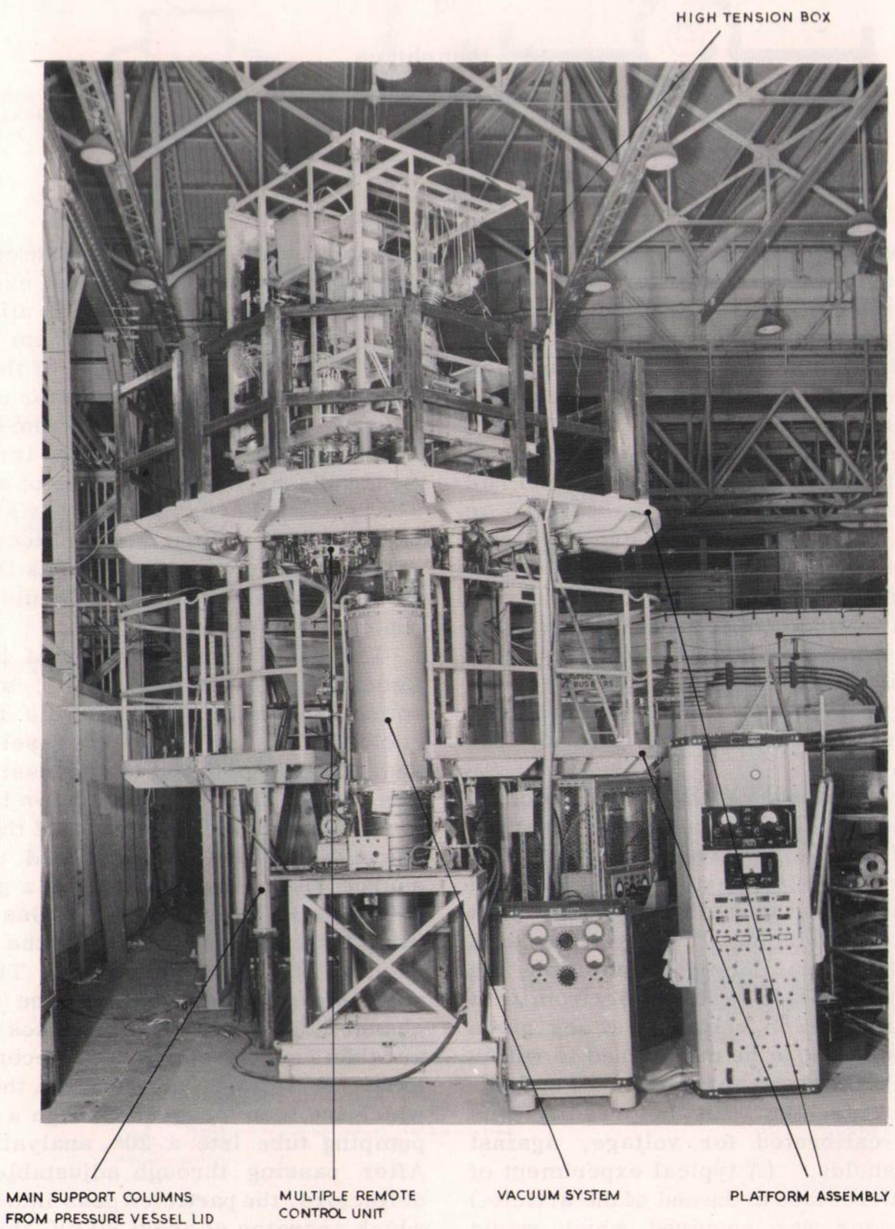


Fig. 2 Ion Source Assembly prior to installation on the Pressure Vessel lid.

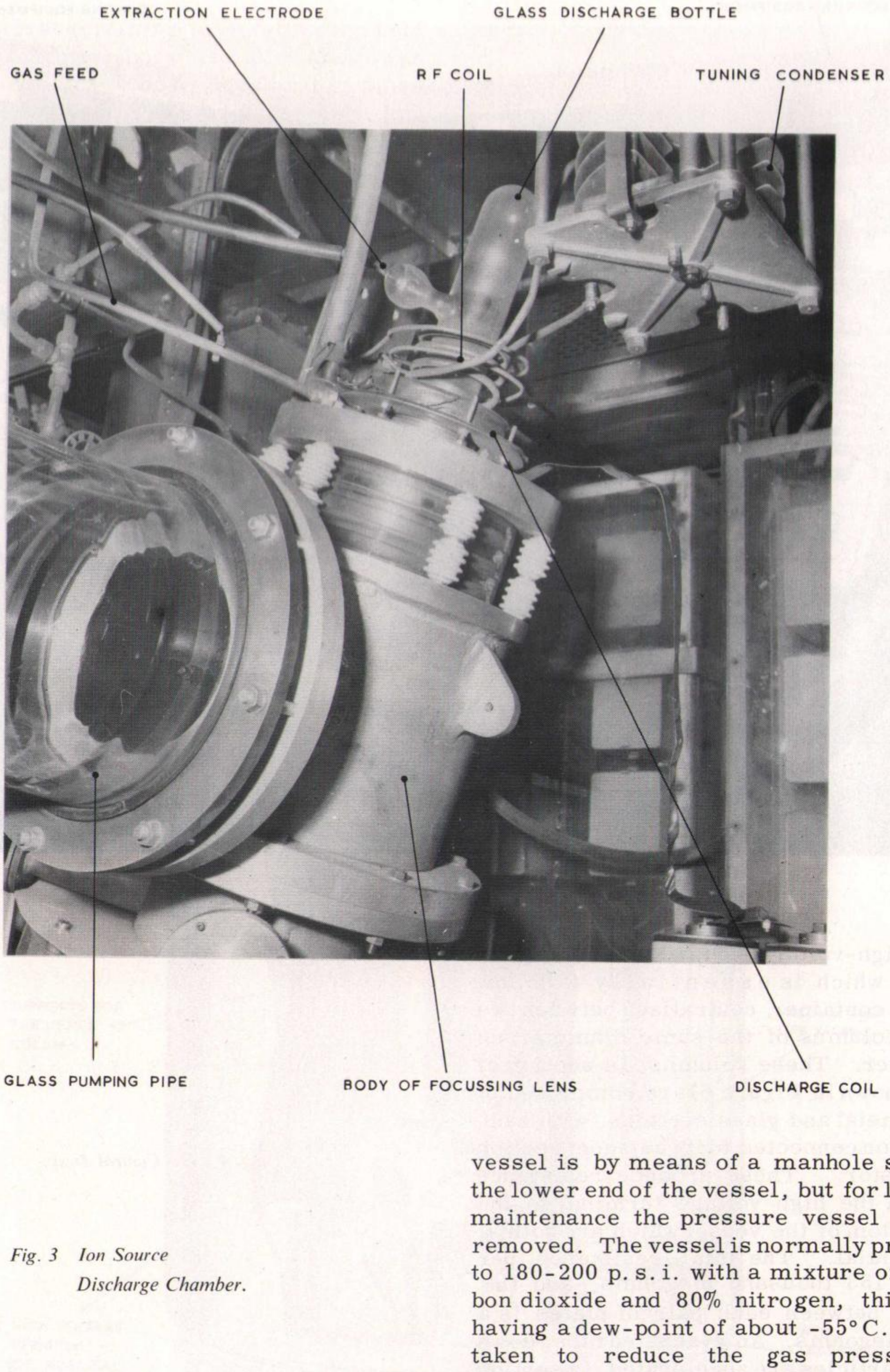
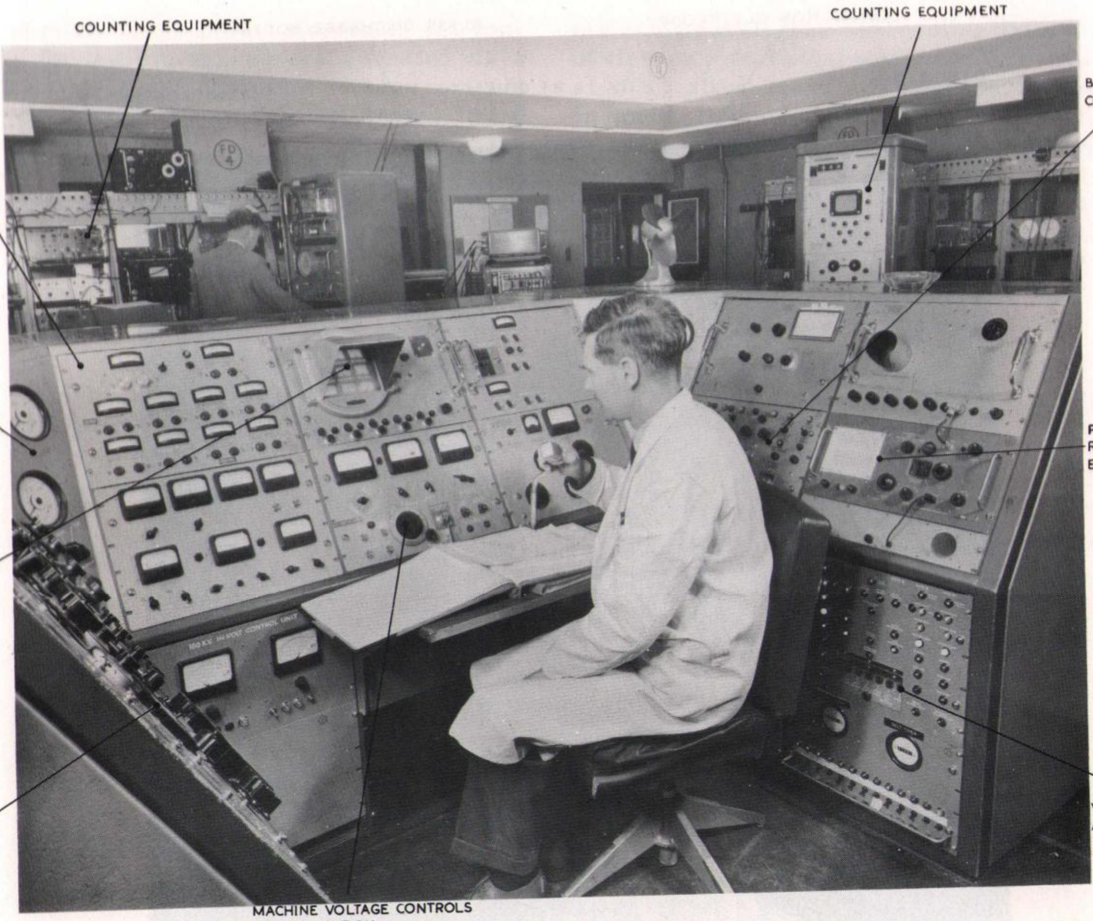


Fig. 3 Ion Source Discharge Chamber.

vessel is by means of a manhole situated at the lower end of the vessel, but for large scale maintenance the pressure vessel lid can be removed. The vessel is normally pressurised to 180-200 p. s. i. with a mixture of 20% carbon dioxide and 80% nitrogen, this mixture having a dew-point of about -55° C. The time taken to reduce the gas pressure from 200 p. s. i. to 20 in. of mercury is about three and a half hours, and a further hour reduces it from 20 in. of mercury to 1 m. m. of mercury.

At the centre of the vessel there is a



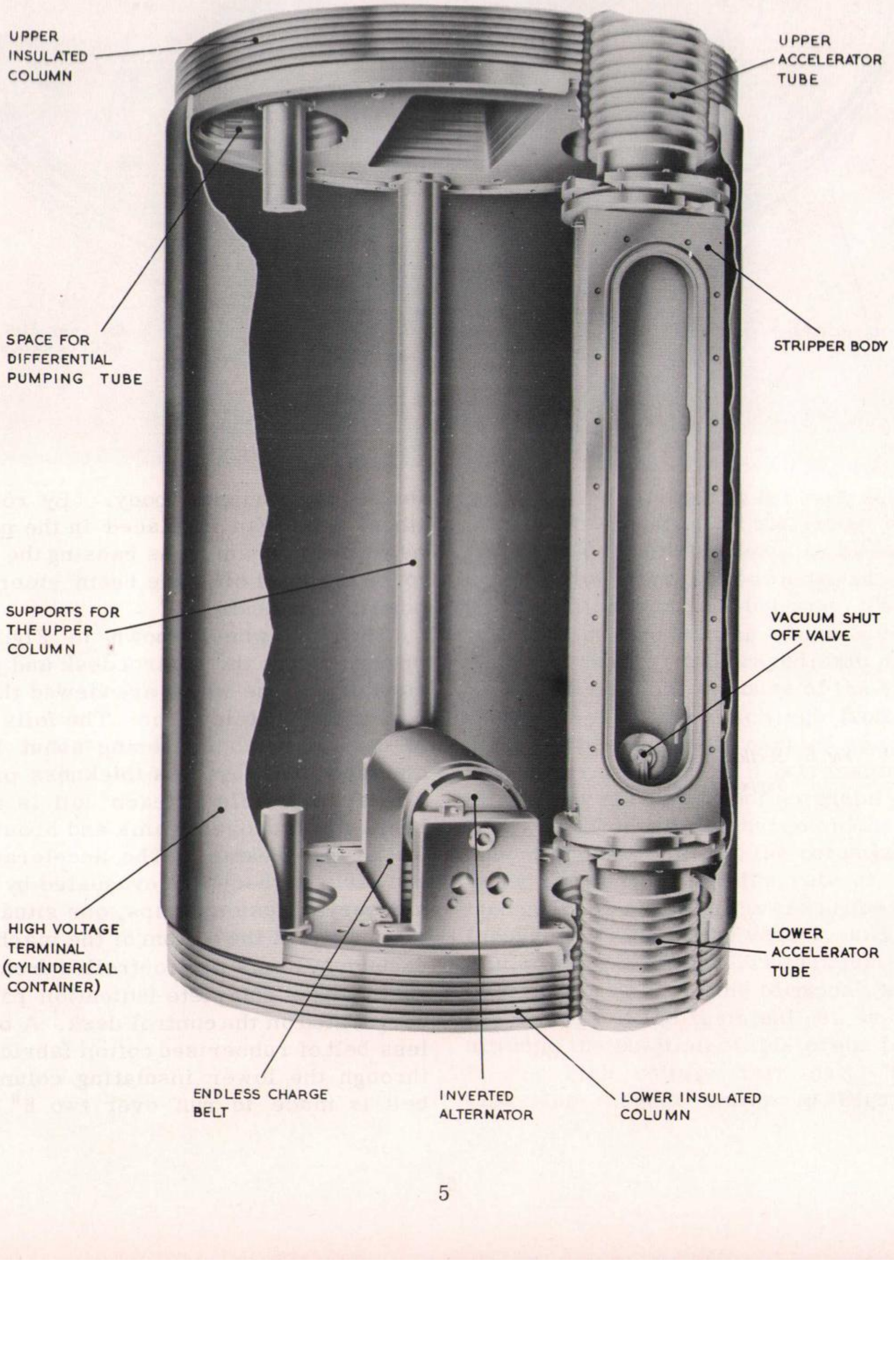
positive high-voltage terminal shown in Figure 5, which is essentially a hollow cylindrical container, centralised between two insulated columns of the same diameter as the container. These columns, (a section of which is shown in Figure 6) are comprised of alternate metal and glass sections, with each metal section connected to its adjacent section via a resistor. These produce resistance paths from the high voltage terminal to the top and bottom of the vessel which are both at earth potential. The total resistance per column is 153 thousand megohms, and the resistance between each pair of plates is a thousand megohms. An evacuated tube, down which the particles are accelerated, (a section of which is shown in Figure 7) runs through the insulated columns. This tube is not continuous but is broken inside the high voltage terminal by a "stripper body" which is also evacuated. The top end of this tube is known

Fig. 4 The Control Desk.

as the upper accelerator tube, while the part below the "stripper body" is called the lower accelerator tube. These accelerator tubes are comprised of alternate glass rings and aluminium electrodes, the components being joined together with vinyl acetate. Each of the metal sections of the tubes is connected to the adjacent metal sections of the insulating columns, providing an even voltage gradient over the whole length of the tube.

The beam stripping device is made up of thirty-six foils contained in a wheel, positioned

Fig. 5 The Positive High Voltage terminal.



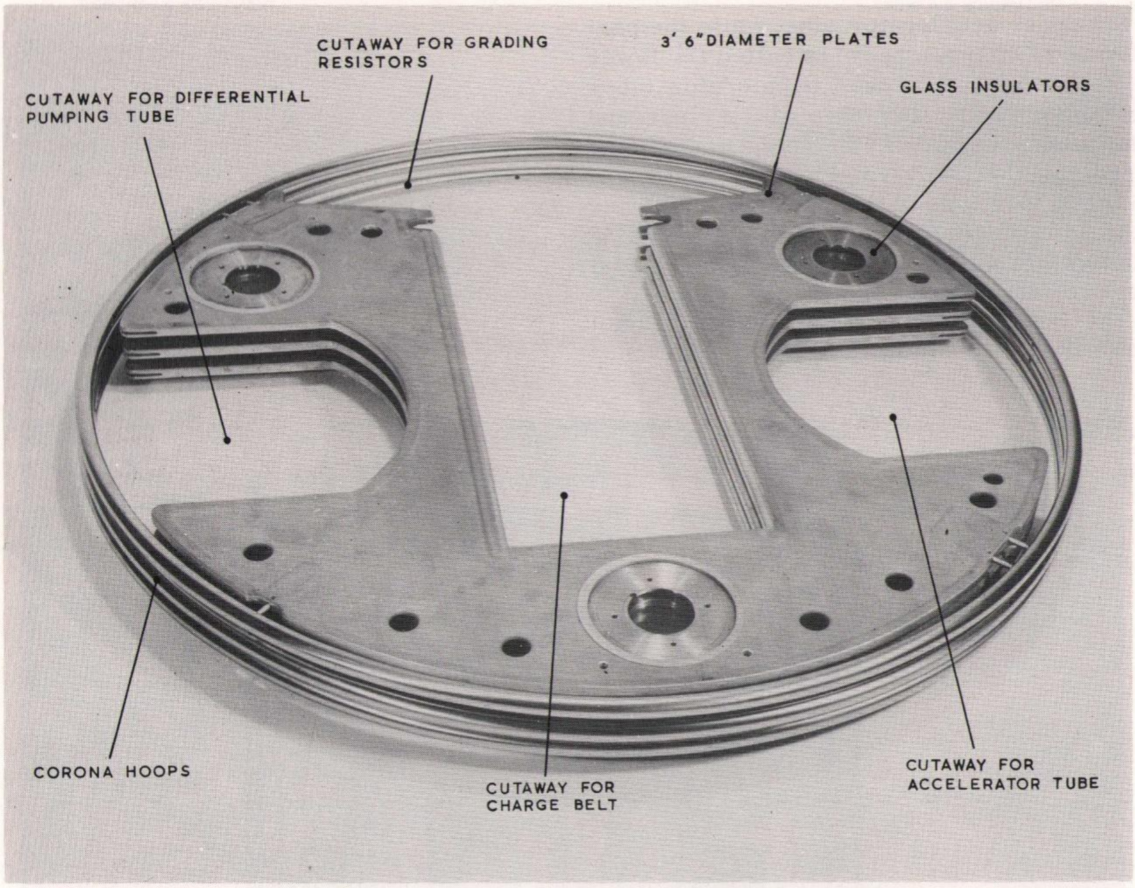


Fig. 6 Section of insulated Support Column.

inside the stripper body. By rotating the wheel a foil can be placed in the path of the negative ion beam, thus causing the electrons to be stripped off; the beam emerging as a positive ion beam.

The foil wheel shown in Figure 8, is operated from the control desk and positional counters on the wheel are viewed through the closed circuit television. The foils are made of carbon, each foil being about 1 c.m. in diameter and having a thickness of 10^{-6} in. The average life of each foil is about 150 hours for hydrogen beams and about 10 hours for oxygen beams. The accelerator tubes and stripper body are evacuated by means of mercury diffusion pumps, one situated at the top and one at the bottom of the machine. The vacuum systems are controlled from adjacent racks and a complete indication panel is incorporated on the control desk. A broad endless belt of rubberised cotton fabric also runs through the lower insulating column. This belt is made to run over two 8" diameter

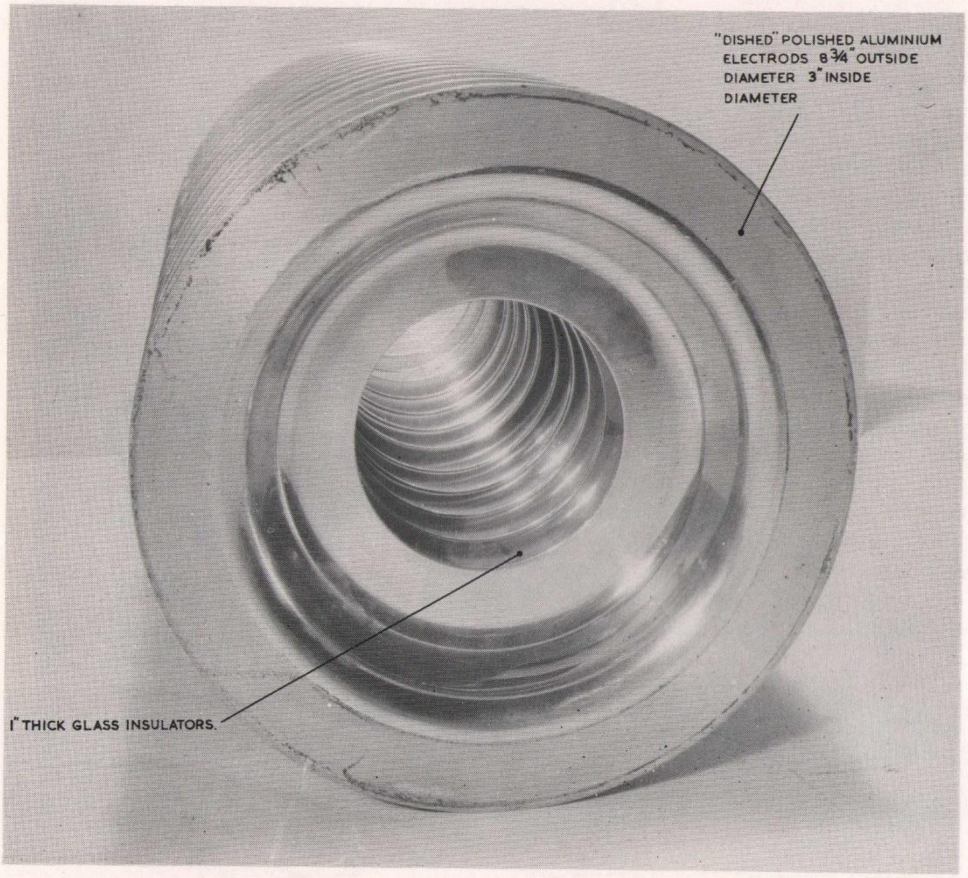


Fig. 7 Section of Accelerator Tube.

pulleys, one situated in the high voltage terminal and the other at the lower end of the vessel. The belt is twenty inches wide, has a peripheral length of four hundred inches and travels at a velocity of 50 ft/sec. The average life of a charge belt is about 3,000 hours. Electric charge is sprayed onto the rising end of the belt, at the base of the vessel, by means of a corona discharge from a metal comb. This charge is carried up to the high voltage terminal where it is transferred from the belt by means of another metal comb. In this way the positive charge on the terminal is continuously built up, the potential obtained being limited only by the rate at which the charge leaks away. A corona probe protrudes through the side of the vessel, and faces the high voltage terminal. The amount of corona current drawn from the terminal, and hence, the voltage of the terminal can be varied by altering the position of this probe in relation to the high voltage terminal. The main analysing magnet shown in Figure 9, is

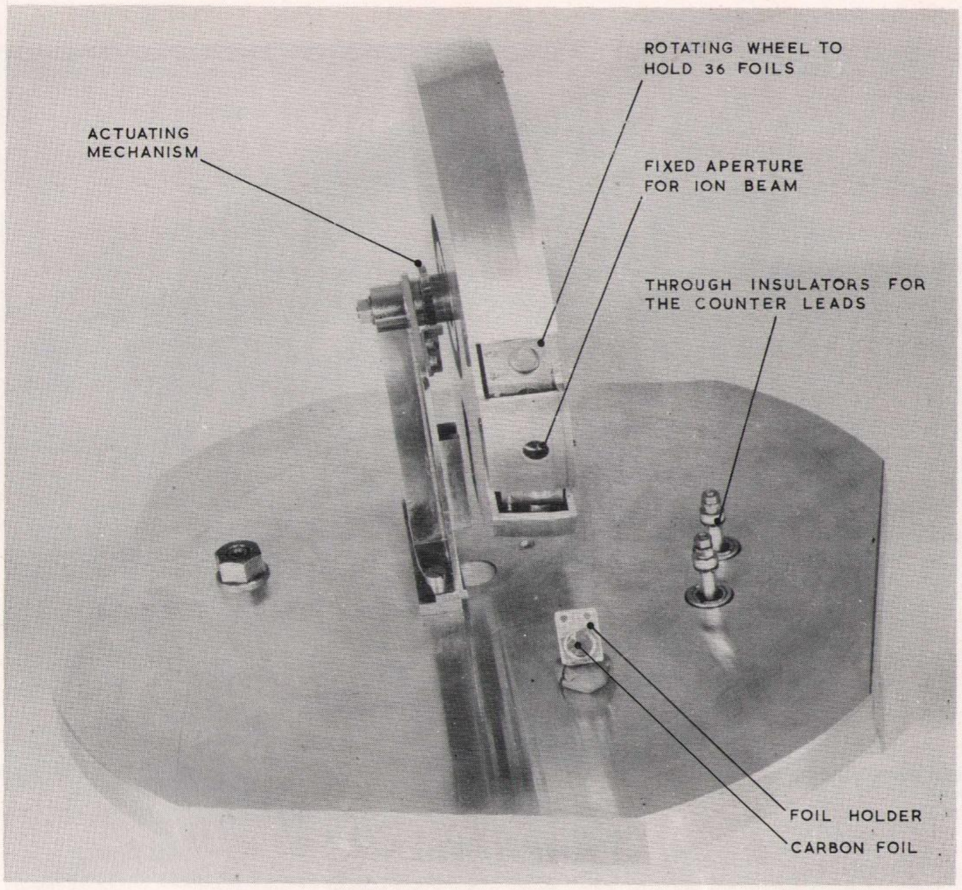


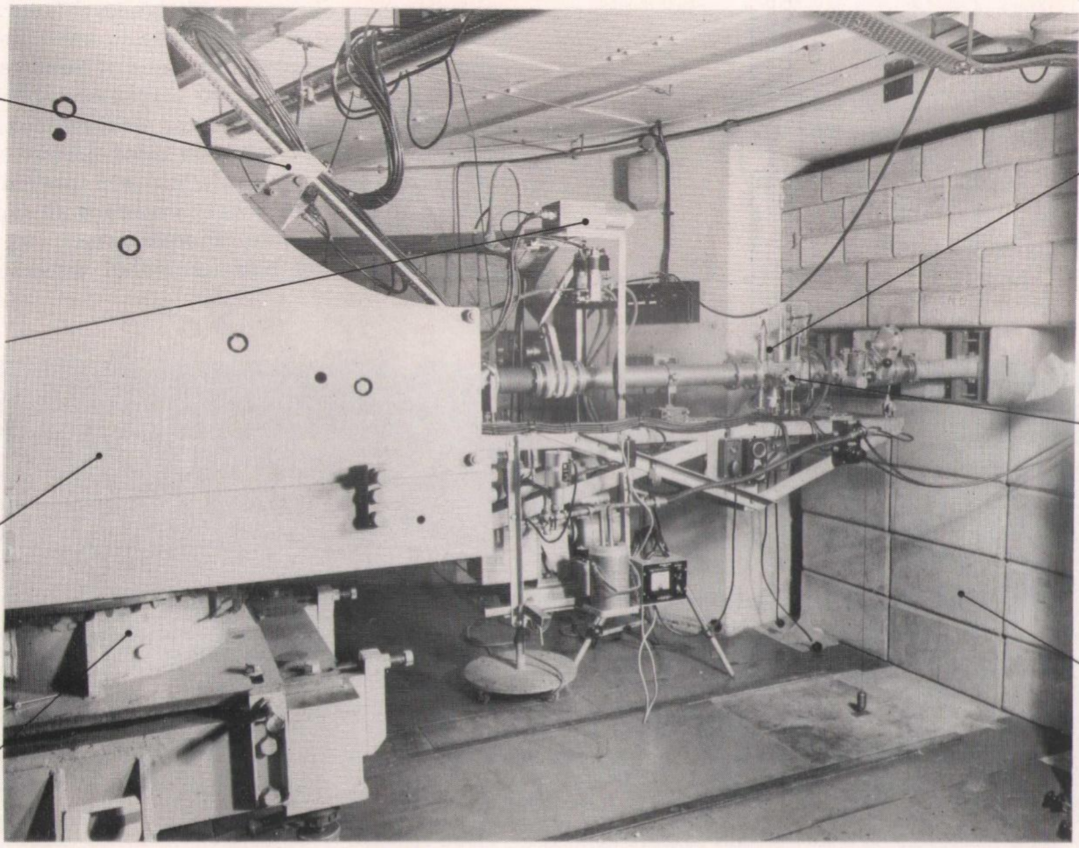
Fig. 8 The Stripper Foil Wheel.

situated directly below the base of the pressure vessel. This magnet which is stabilised to 1 part in 10^4 provides a very precise means of analysing and maintaining the energy of the ion-beam. Passing through the magnet the path of the beam is deflected through 90°, transferring the beam from a vertical to a horizontal direction. Two adjustable stabilising slits are situated next to the analysing magnet, and form part of the stabilising circuit for the high voltage terminal. If more of the particles strike one slit than the other, a signal from a differential amplifier is transmitted back to the grid of a triode valve. This signal will vary the amount of current drawn from the high voltage terminal by the corona needles, and hence the terminal voltage is adjusted. Finally there is a focussing lens assembly which can be adjusted to focus the beam onto the target, situated further along the flight tube.

The ion-optical system is shown in Figure 10. One of the operating conditions of the machine, is that the point of focus just inside the machine may be varied by as much as two feet by the einzel lens and injector. This is necessary in order to counteract the variation in lens strength of the upper accelerator tube with variations in machine energy, at the same time maintaining a focus at the stripper foil. After passing through the analysing magnet, the beam refocusses at the stabilising slits. On leaving the slits, the beam again diverges until the final lens system in the target rooms refocusses the beam onto the target. The beam has seven focal points along its path which is approximately 120 feet long. The position of these points can be altered by the lens and deflector systems at the ion-source, the lower end of the machine, and along the target lines.

Radiation is only present when the machine is running, and then only in certain parts of the building, i.e. halfway up the tower adjacent to the high voltage terminal, in the analysing magnet room and in the target room in use.

Fig. 9 The Main Analysing Magnet.



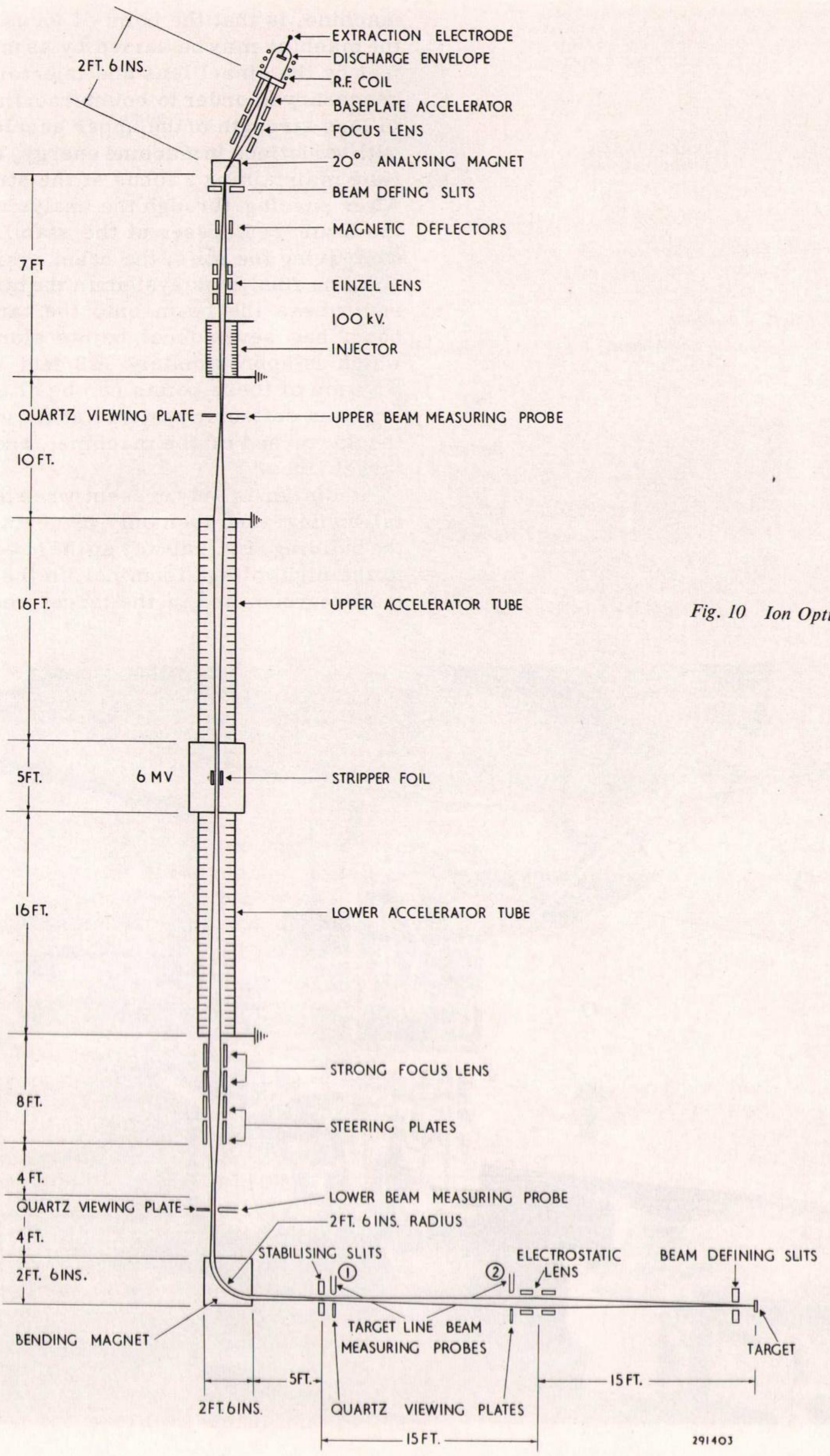


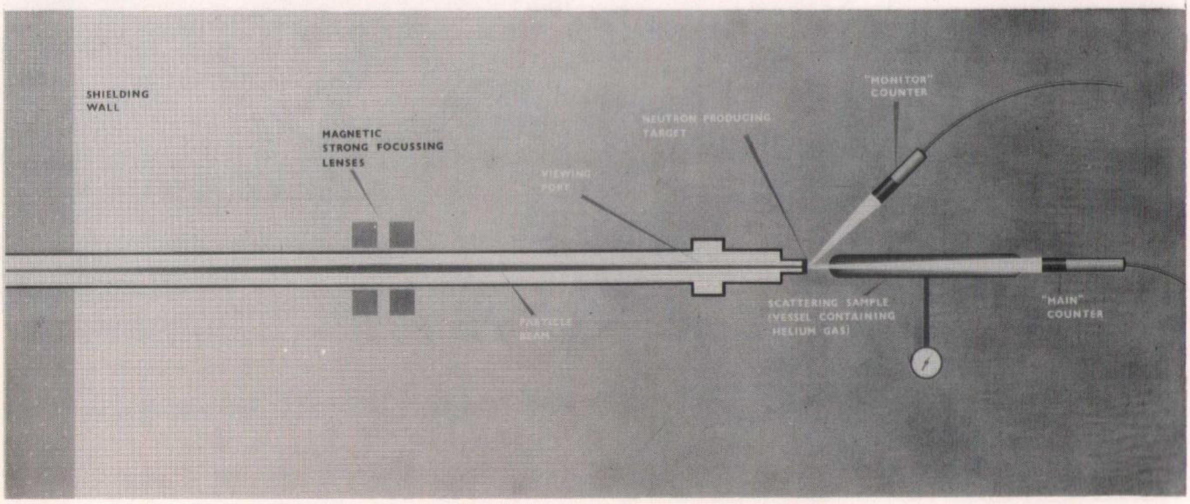
Fig. 10 Ion Optics.

The Harwell Tandem Generator has proved extremely useful to the Nuclear Physics Division. The greater part of the machine's time has been given to basic nuclear research, while other experiments carried out have been concerned with materials used in reactors. One particular fundamental experiment was concerned with the polarization (spin properties) of protons. The polarization was produced by scattering the beam from a carbon target and was measured in a selected direction by scattering from a second carbon target and observing the ratio of the counts in two counters mounted at equal angles on either side of this second target. A left-right asymmetry indicated that the proton spins had been frequentially lined up in one direction.

Another experiment was to measure the proton energy threshold for neutron production following the proton bombardment of aluminium, nickel and other nuclei. The onset of such a threshold is very well defined and provides a means of determining the beam energy very precisely. It also gives quantative information about the particular reaction involved; this can be used to determine nuclear masses and in some cases beta decay properties of fundamental interest.

Experiments have also been carried out involving total neutron cross-section measurements, in which the absorption in a sample is measured as a function of neutron energy. Such experiments have been made for reactor materials and for helium gas in a cylinder. Figure 11 illustrates the method adopted for the latter case. A deuteron beam from the machine, directed onto a deuteron target produced an abundance of neutrons. This beam of neutrons is directed into a gas cylinder to which a counter is fitted at the far end. Various absorption factors can be determined by varying both the gas and the pressure.

Fig. 11 Gas Absorption Experiment.



SITE ENGINEERING AT WANTAGE

From the one-time USAF Base, known as Grove Air-Field, Wantage has graduated through an RAF Station to its present status as a wing of the Research Establishment. At the time of the acquisition the aerodrome was in the hands of a resident caretaker staff of the Air Ministry Works Department. The property taken over by the Authority consisted of two sites about half a mile apart together with part of the perimeter track which links the two. The two groups of buildings involved were the old RAF Communal Area (now the South Site) and the original West Technical Area (now the West Site).

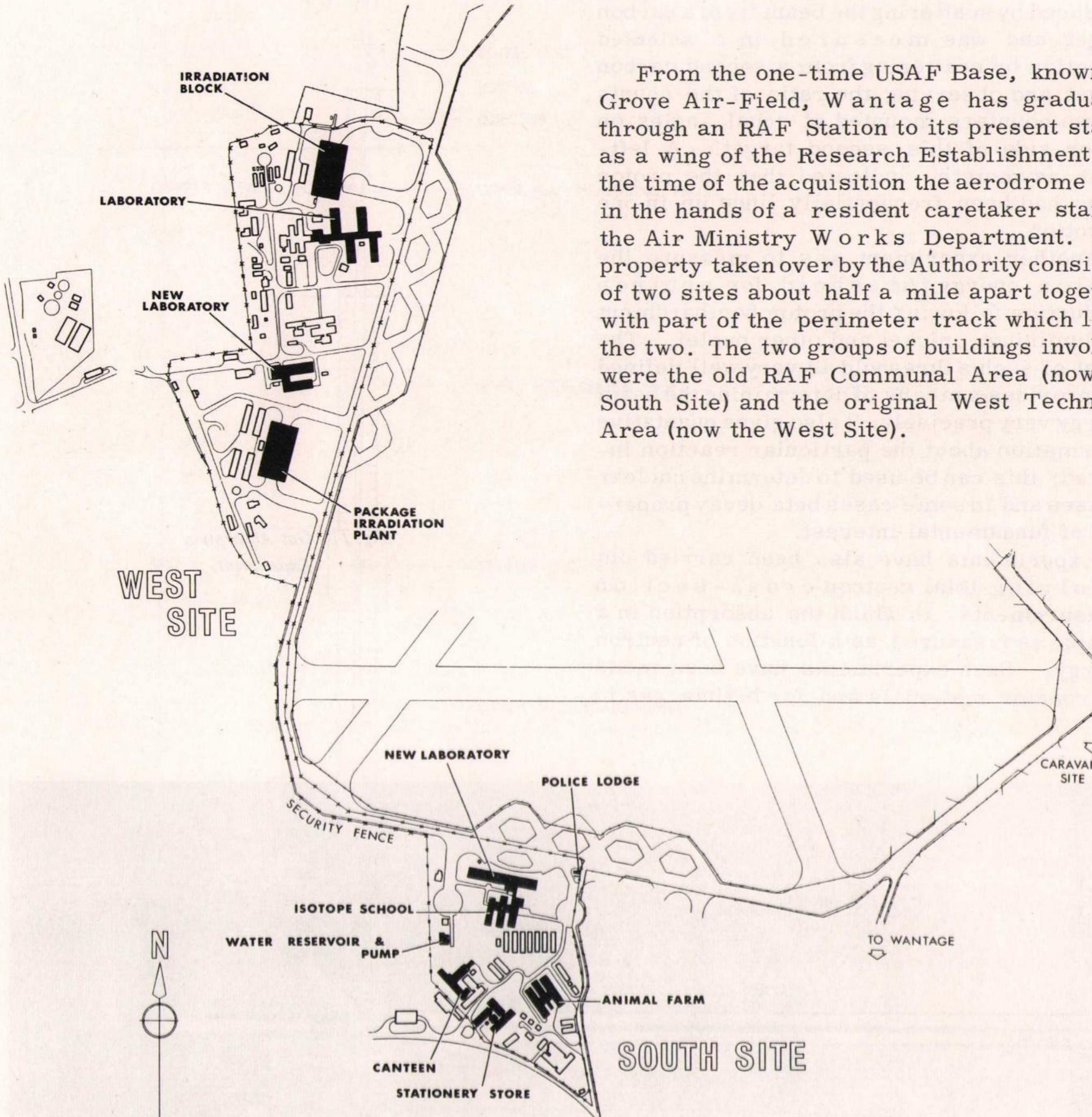


Illustration Studio. No. 315314

By

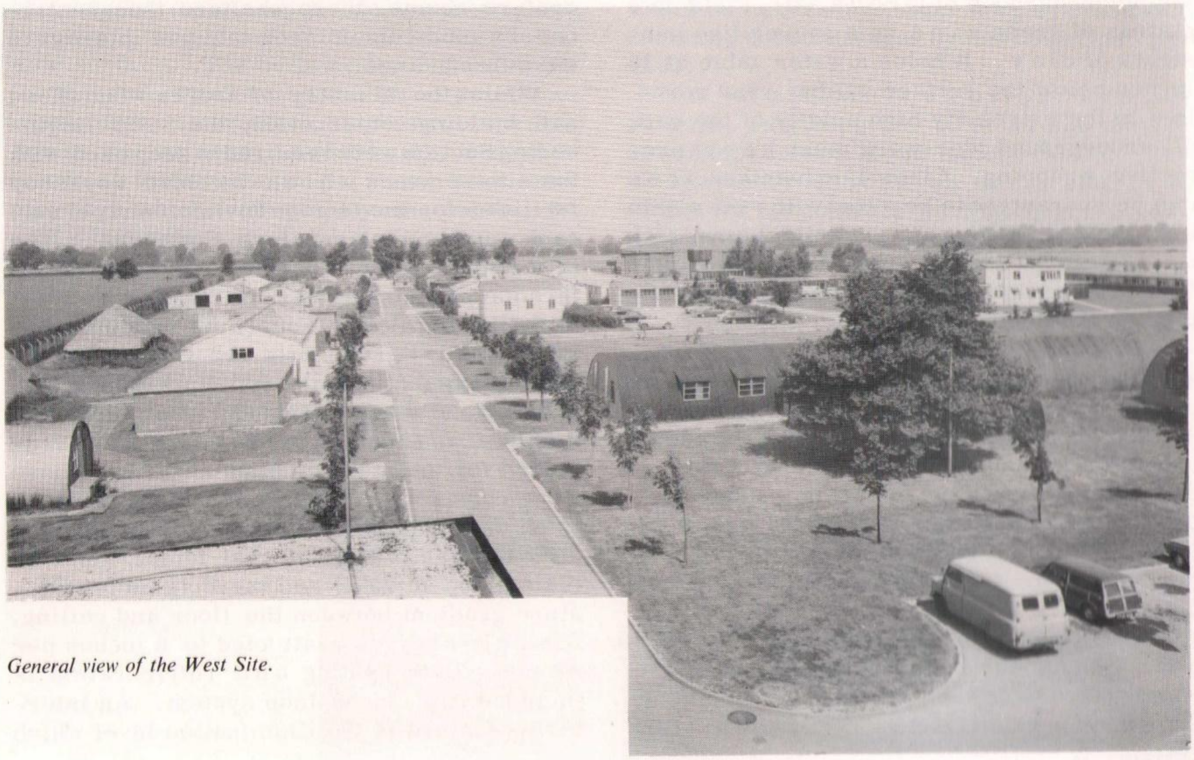
A. M. McIntyre.

The purpose of the acquisition was to provide laboratory and office facilities for the Isotope Research Division and perhaps a permanent home for the nomadic Stationery Store.

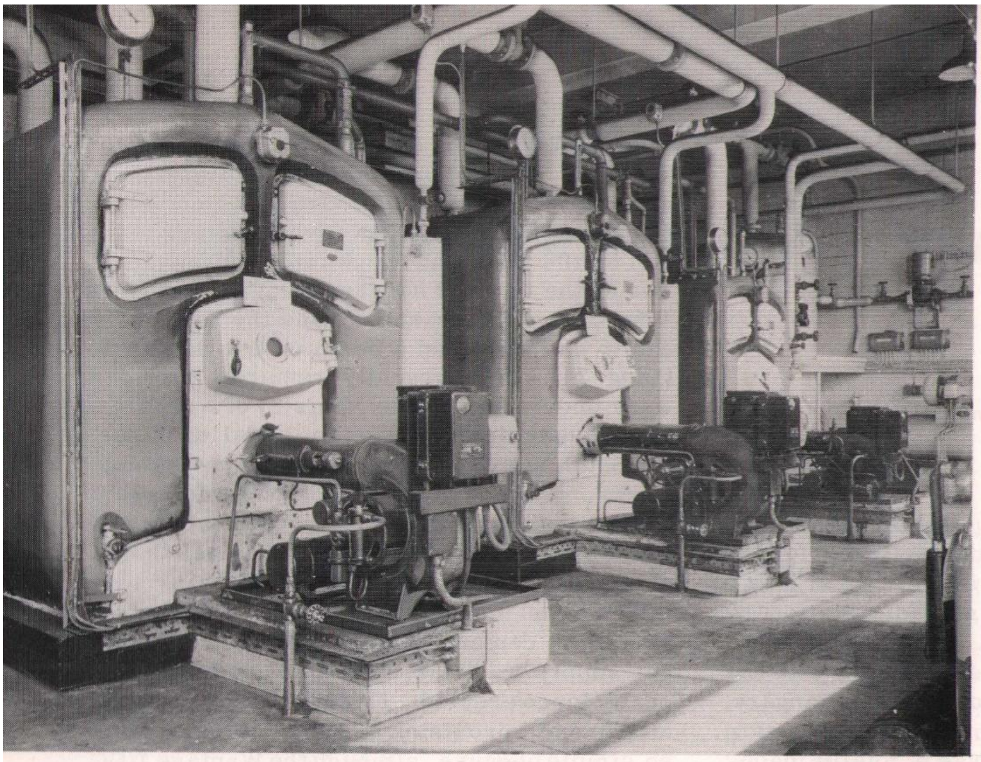
The basic structures inherited with the take-over were a couple of type T2 hangars, an assortment of Nissen huts and single-skin brick buildings. There was a totally inadequate water supply, very little drainage and, it follows, no proper sanitation.

Commissioning began in 1956, under various sections responsible for individual items of work, and using existing buildings wherever possible. Phase 1 of the operation called for the provision of laboratory and irradiation cell accommodation. For use as the former the old RAF Headquarters (Bldg 221 on the map) was chosen and, for the latter, one of the type T2 hangars (Bldg 241), both on West Site. At the same time the Stationery Store was allocated a berth on the South Site (Bldg 24). The urgently required services were undertaken by the Ministry of Works and an adequate drainage system installed linking the South and West Sites with the sewage works. A modern sanitary system followed.

The estimated power requirements exceeded the capabilities of the original 3·3kV electrical system and a new 11kV/415V ring main was therefore installed. This has a maximum demand rate of 600kVA. The town gas supply was laid on and an enclosing security fence erected. This left a water supply, an adequate provision of which was not quite so simple because, although the Wantage UDC could supply the required quantity of water, they could not meet the demand rate. A satisfactory solution to the problem was found by building a 100,000 gallon reservoir and pumping station from which the whole out-



General view of the West Site.



Boiler house.
Building 2

station is supplied during the normal working hours. The reservoir is replenished from the town supply between the hours of midnight and 4 am each night.

It is interesting to note that, geologically, the neighbourhood of Grove Air-Field is a plateau of green sand in a saucer like substrata of clay. It holds a water table at 18 inches below the surface all the year round. Due to the extremely high acidity of the soil, all underground pipe-work must have protective wrapping. Class 1 galvanised iron can be guaranteed to be pitted with rust within six months. Fitting out the animal farm with its 12 animal rooms, laboratory, office and food preparation room, together with a canteen on the South Site completed Phase 1.

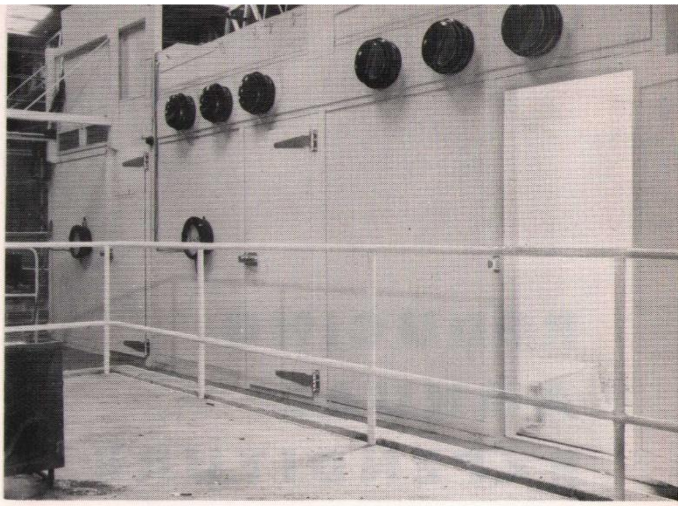
At about this time began the transition from work by the various maintenance sections to the formation of a separate Site Engineering Section. Phase 2 of the operation was one of consolidation and expansion. The programme called for the building of two new laboratory blocks, an isotope school, a package irradiation plant and workshops for the Isotope Division. (These may all be identified on the map.)

In addition, more irradiation cells were being demanded and constant temperature rooms were becoming an urgent requirement. Indeed, so pressing was the need for the latter that a temporary solution had to be found. Two old air-raid shelters were turned to good use by thermally insulating the walls with bales of straw and thatching the roofs. In addition to their efficiency as constant temperature rooms, these shelters thus contributed a modicum of architectural interest to the surroundings.

Whilst the Ministry of Works went ahead with building construction, the Site Engineering Section were required to keep pace with the site services which included workshop facilities for the Isotope Division and permanent constant temperature chambers. The latter were granted tenure of part of the irradiation block. This old hangar on West Site (Bldg 214) now houses 22 experimental medium activity cells and a 4MeV linear accelerator. Since the building is unheated by artificial means, it appeared an ideal site for the two constant temperature units, required for the study of plant growth. These were constructed above the line of cells. Each unit consists of a room measuring 8ft x 8ft x 6ft high. The internal temperature is maintained at 25°C and there is no temperature gradient between the floor and ceiling. Air velocity is restricted to 6 inches per second. Both heating and refrigeration is included in a closed loop system. An interesting feature is the illumination level which is maintained at 2,000 lumens/foot, measured at any point 2 feet from the ceiling. This level is achieved by the use of 52 5ft 80W fluorescent lamps built into a cavity extending over the whole area of the ceiling and with an aluminium (foil) reflector. The cavity is isolated from the constant temperature area and cooled by a separate air extractor.

The second hangar on West Site (Bldg 106) was the only possible place for the erection of the Package Irradiation Plant. In this case internal heating was essential. The capacity of the building is well over a million cubic feet and, to get things going, six oil-fired hot-air blowers were installed, each with a rated output of 4·2 million BTU/hour. It will be realised that these old hangars were constructed of galvanised iron sheet on a light frame and it will not be necessary to enlarge upon the heat conductivity of the walls and roof, or upon the size of the fuel bill resulting from the use of such a system. Something had to be done about it.

The galvanised iron sheets had been replaced during the initial preparation of the building by sheets in which the iron is sandwiched between two skins of bituminous asbestos. This gives a finish free from the need of frequent maintenance. In these circumstances it was permissible to cover the inside surface. The building was found to be inadequately stressed so that the only material it was possible to attach to the structure was foam polystyrene. Accordingly, a method known as the Grecon In-fill Panel was employed in which foam polystyrene panels, 6ft x 2ft x 1 inch thick are supported on the lightest possible frame-work and attached to the walls and roof with a 4 inch intervening cavity. In addition, transverse tie-rods were installed at each roof girder to support any additional roof load such as snow. When completed, the installation was one of the largest single units of its type ever attempted in this country and



Controlled Temperature room. Building 241.

halved the cost of heating the hangar. The other buildings on the sites, consisting of a number of well dispersed medium and small structures are heated by small individual oil-fired hot-water installations, each with its own fuel storage. There are ten such installations, all of which are automatic in operation. It is thus possible for all to be looked after by one boilerman per shift. The alternative is a large steam raising plant of relatively low overall efficiency due to the inherent losses over the long distribution lines which would be necessary. Such a system could certainly not be attended by one boilerman per shift.

The out-station now employs some 300 persons, excluding the 30 or so who may be attending courses at the Isotope School. The Site Engineering Section has a staff of 30 supported by contract men whenever necessary. Because it is a small establishment, the Section undertakes much work beyond the strictly engineering support sense, such as the site cleaning services, the operation of the sewage works and the discharge of trade waste effluents. Activities such as these add variety to the work of the staff in providing a comprehensive Engineering Support Service.

General view of South Site.