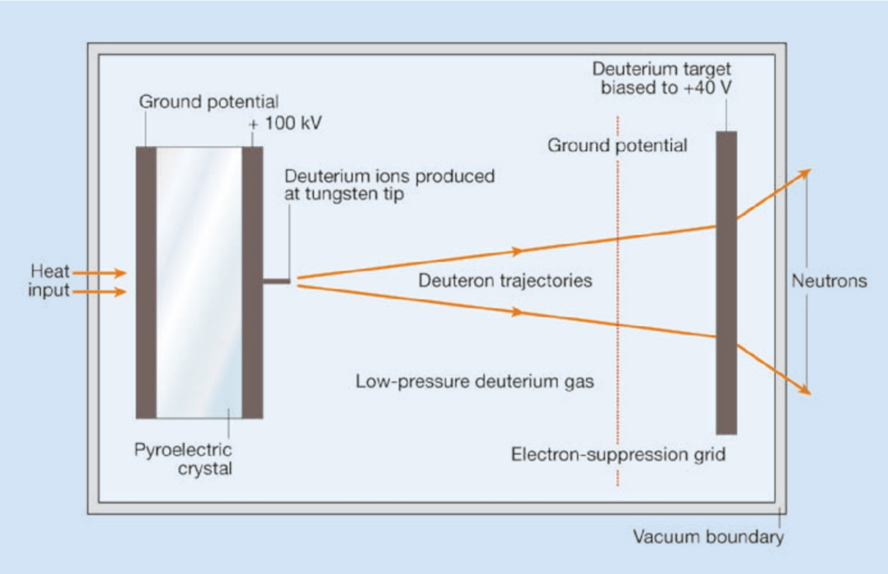

Figure 1 **Naranjo and colleagues' apparatus for neutron generation[1]. The chamber is filled with deuterium gas at low pressure (0.7 pascals). As the crystal is heated, the potential builds across the crystal. Deuterium ions (deuterons) are generated at the tungsten tip, and accelerated towards the target; the electrons fall back to the crystal electrode. The ions strike the deuterium target (ErD_3), and some generate 2.5-MeV neutrons. Electrons knocked from the target surface are repelled by the suppression grid and fall back on to the target rather than being accelerated back to the crystal.**

heat (around 2 watts). A minute or two after the heat is applied, neutron emission starts, reaching a peak of about 1,000 per second; once the heat source is removed, the device gradually switches itself off. The key to the device's simplicity lies in the replacement of the miniature ion-source and accelerator in existing generators by a system based on a combination of two well-known phenomena — the pyroelectric effect and field ionization.

The pyroelectric effect — the fact that some materials become charged when heated — was probably first recorded in 314 BC by Theophrastus[2], Aristotle's student and successor, from his studies of the gemstone tourmaline. More recently, various man-made materials have been investigated, and potentials of around 100,000 volts reported for crystals such as lithium tantalate ($LiTaO_3$), with the emission of energetic electrons under suitable conditions. This effect was used by Brownridge[3,4] to produce a small pyroelectric X-ray generator, of which a commercial version, powered by a 9-volt battery, is now available[5].

Field ionization of gases occurs when a potential difference of a few volts exists over atomic distances — equivalent to a field greater than 10 gigavolts (1×10^{10} volts) per metre. The effect is widely used as the basis of field-ion microscopy. Modest voltages applied to electrodes of very small radius can produce these extremely high fields near the electrode tips, ensuring the ionization of essentially all gas molecules entering the high-field region.

Figure 1 shows how Naranjo *et al.* combined these effects to generate fusion neutrons. The authors grounded one face of a 1-cm-thick pyroelectric crystal to the inside of a vacuum chamber containing deuterium gas at a pressure of 0.7 pascals (for comparison, Earth's atmospheric pressure is around 10^5 pascals). They then attached a tiny tungsten electrode to a plate on the positive face of the crystal. A solid target containing deuterium in the form of erbium deuteride (ErD_3) was placed a few centimetres in front of this electrode.

Raising the temperature of the crystal at a rate of 12.4 °C per minute changed the spontaneous polarization of the crystal, and raised the potential of the positive electrode at a rate of about 50 kilovolts per minute. As the potential rose, the field near the tungsten electrode increased to a value — around 25 gigavolts per metre — sufficient to produce field ionization of the deuterium gas. The positively charged ions (deuterium nuclei, or 'deuterons') produced in this process were accelerated towards the target across essentially the full potential generated by the crystal; the electrons stripped from the deuterium atoms by the ionization experienced a potential drop of only a few volts as they fell back to the crystal. On hitting the target on the opposite wall of the device, the energetic deuterons interacted with the deuterium target to produce 2.5-MeV neutrons via the D + D reaction.

The maximum current obtained in this experiment was about 4 nanoamperes, leading to a maximum neutron production rate of around 1,000 neutrons each second. The accelerating potential can be maintained only while the crystal temperature is changing; thus, the duration of the pulse

NATURE

100 YEARS AGO

The water-supply for the occupants of our huge prehistoric "camps" has always been somewhat of a mystery, and it has been suggested that they were only temporary refuges… But the watering of men and animals on the scale indicated by the areas enclosed would be a formidable task even for a day, and other explanations must be sought. The late General Pitt-Rivers, for example, held that the water-level of the combes was higher then than now, and streams would have been plentiful on the slopes; but, feeling the inadequacy of this view, he also had recourse to the dew-pond theory… An exposed position innocent of springs was selected, and straw or some other non-conductor of heat spread over the hollowed surface. This was next covered with a thick layer of well puddled clay, which was closely strewn with stones. The pond would gradually fill, and provide a constant supply of pure water, due to condensation during the night of the warm, moist air from the ground on the surface of the cold clay… Some ponds of this kind, no doubt of very early and perhaps of Neolithic date, may still be seen in working order.

From *Nature* 27 April 1905.

50 YEARS AGO

In 1949 Burnet and Fenner postulated that antibody production against a particular antigen can be specifically suppressed by exposure to the same antigen during embryonic life… The decisive step which brought the principle of immunological tolerance from the sphere of Nature's eccentricity into the domain of an experimental method of possibly very wide applicability was the artificial production of a similar type of tolerance... The present investigations were carried out on birds by the method devised by Billingham, Brent and Medawar, and had a threefold purpose: (1) investigation of whether tolerance could be acquired to cells of foreign species; (2) if so, whether the tolerance would also extend to a virus from the donor animal to which the recipient was not normally susceptible; (3) whether a sexual cross between species which is not normally possible could be made so by means of acquired tolerance. Positive answers to the first two questions have been obtained; the answer to the third awaits the sexual maturation of the treated birds.

Morten Simonsen

From *Nature* 30 April 1955.