



apdas

applied physics division analytical services

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Applied Physics Division Analytical Services (APDAS) is a new initiative within the Australian Nuclear Science and Technology Organisation. This government-funded organisation, ANSTO, is fully committed to building and maintaining strong links with industry through the provision of a range of scientific and technical goods and services.

Because of its background and achievements in high-tech research, APDAS can provide solutions to many of the problems that arise in Australian industries.

APDAS operates the 100 kW nuclear reactor Moata which commenced neutron production in 1961 and has since been used for a wide variety of nuclear research and applications. The operating characteristics of the reactor are well known and the reactor is managed by experienced scientific and technical staff.

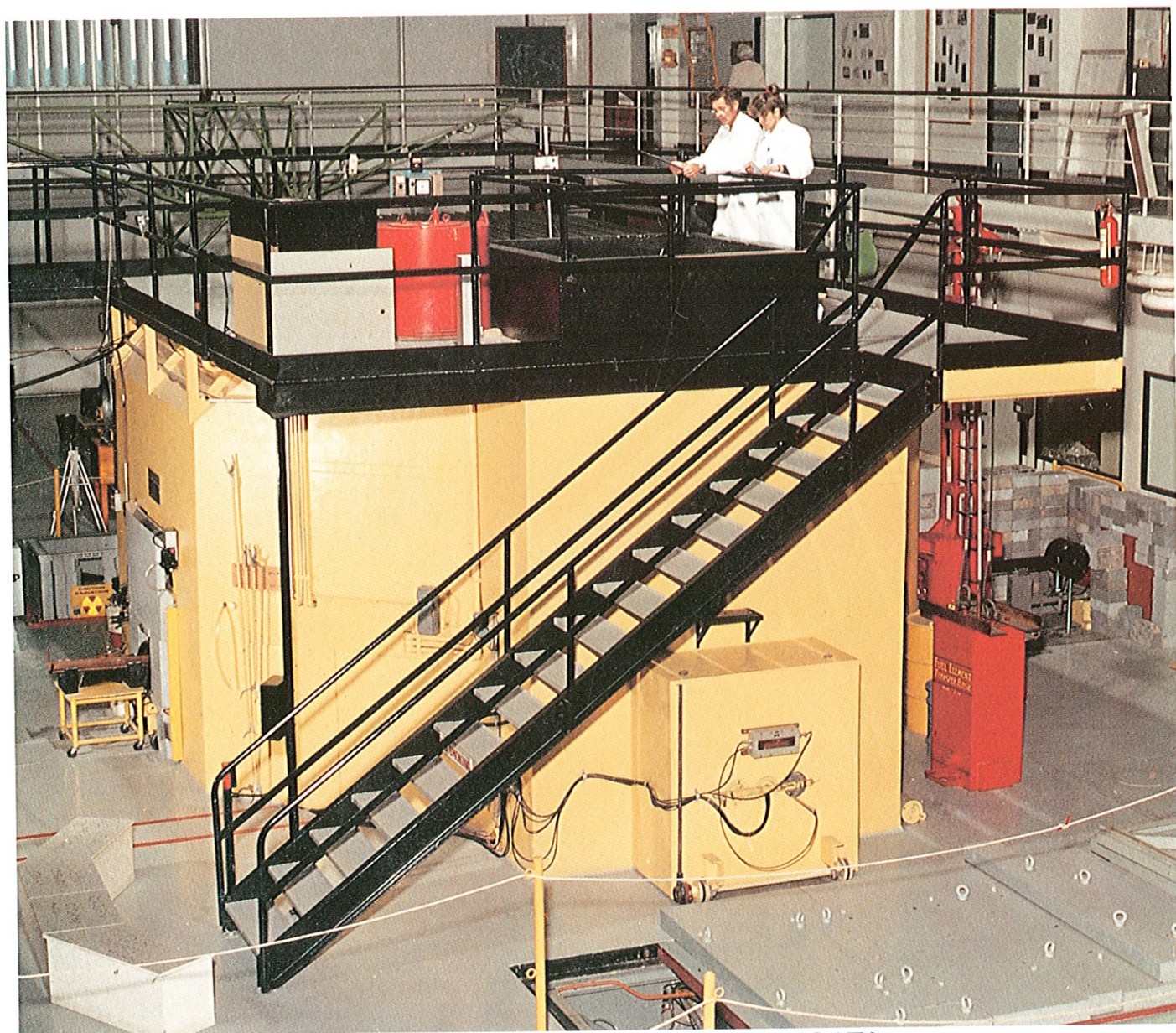
The reactor provides steady thermal neutron fluxes between 10^7 and 10^{12} $\text{n cm}^{-2} \text{s}^{-1}$ for periods of a few minutes to several hours. Neutron irradiation stations are readily accessible. Thermal neutron beams may be used for radiography or controlled low neutron dose irradiations with beam intensities on target between 10^3 and 10^8 $\text{n cm}^{-2} \text{s}^{-1}$.

It is permissible to irradiate most solid materials in either polyethylene or aluminium cans.

REACTOR-BASED SERVICES

Neutron Radiography
Uranium Analysis
Quantitative Phase Analysis

Soil Moisture Calibration
Neutron Irradiation Services
Neutron Diffraction Stress Analysis



THE ANSTO RESEARCH REACTOR MOATA

REACTOR
BASED
SERVICES

NEUTRON RADIOGRAPHY

Radiography is the art of revealing the contents of a sealed "black box" without using a key. If a beam of penetrating radiation is directed through a black box, the rays of energy are absorbed or scattered to a degree which depends upon the atomic and nuclear properties of the various elements forming the composition of the object.

If a film emulsion is exposed to the emergent beam of radiation, an image of the areas of high and low penetration is produced which gives a very detailed portrayal of the contents of the sealed object.

Although there is a long history of the successful use of X-ray radiation for non-destructive testing, the advent of the nuclear industry added high energy gamma radiation sources and, more recently, neutron sources to the list of options available (Fig. 1).

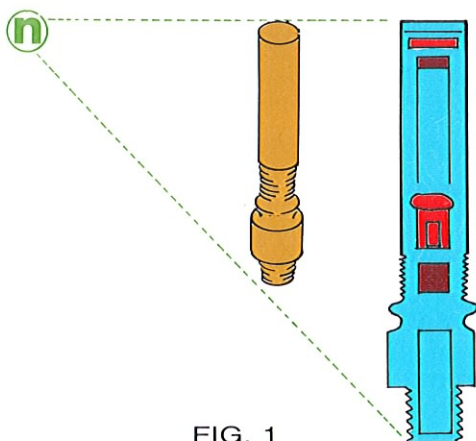


FIG. 1 THE NEUTRON RADIOGRAPHY PRINCIPLE

The steel casing of an automobile fuel injector (brown) is penetrated by neutrons to reveal images of non-metallic components (red) superimposed on the casing image (blue).

WHY NEUTRONS?

X-rays are strongly attenuated by dense materials and are therefore unsuitable for some radiographic applications. Consider a black box made up of a metallic element such as iron or aluminium containing light, non-metallic components such as polyethylene, carbon or ceramics. An X-radiograph of the object will reveal only the outline of the box. X-rays pass through the non-metallic components with little attenuation and the image of the walls of the box is much stronger than that of the contents making analysis difficult.

Neutrons have no electrical charge and hence are not influenced by the cloud of electrons through which penetrating radiation must pass in any solid or liquid object of normal density. Also, the nuclear properties of many non-metallic substances cause neutrons to be absorbed or scattered. Much less attenuation is caused by such elements as iron or aluminium. Consequently, a neutron radiograph of the black box would consist of a faint image of the metallic wall superimposed on a clearer image of the non-metallic contents.

APPLICATIONS

Applied Physics Division has provided a commercial neutron radiography service for more than ten years. Neutron radiographs have been made of aircraft components (Figs. 2, 3), explosives detonators (Fig. 4), cardiac pacemakers (Fig. 5) and electrical and electronic components. Even the growing root system of seeds has been radiographed in support of agricultural research. Radioactive sources in lead containers or unshielded sources may be examined without the film-fog problems normally associated with such materials.

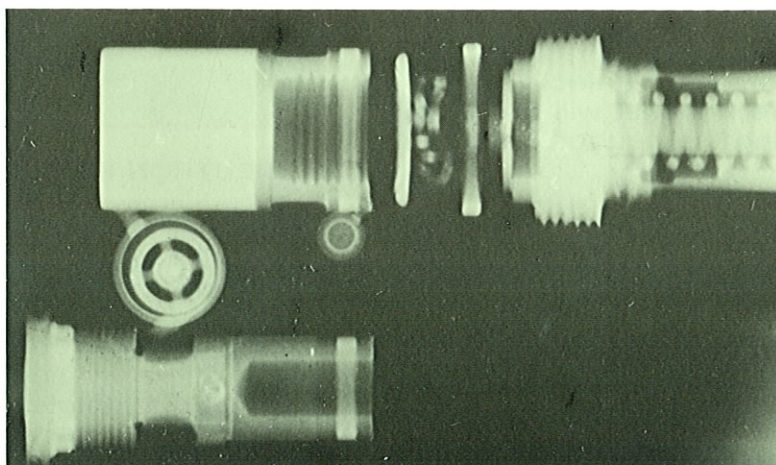


FIG. 2 NEUTRON RADIOGRAPH OF AN AIRCRAFT EMERGENCY DOOR LATCH

Images of an oil-filled cavity (top left), a small explosive charge (top middle) and several O-ring seals contrast well with the main aluminium structure.

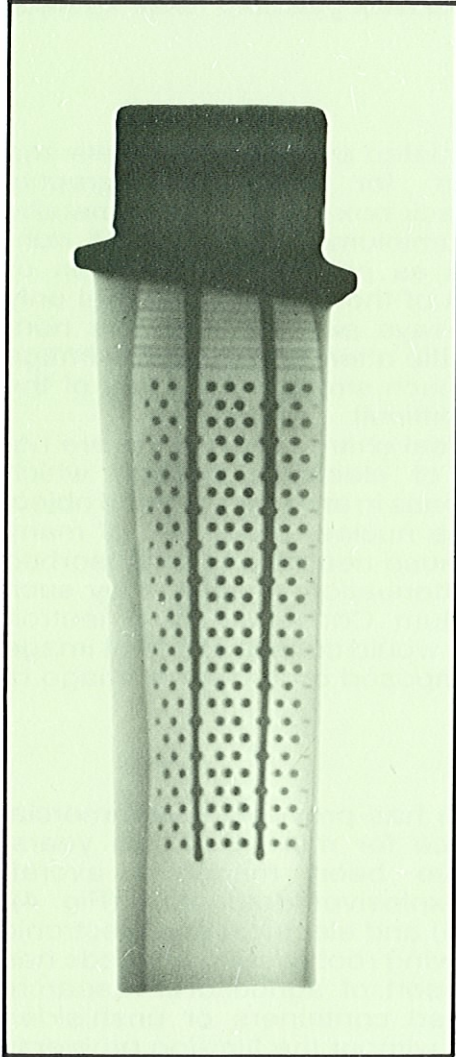


FIG. 3
NEUTRON RADIOGRAPH OF
AIRCRAFT ENGINE TURBINE
BLADE

If present, defective residual core material will be revealed using the neutron beam.

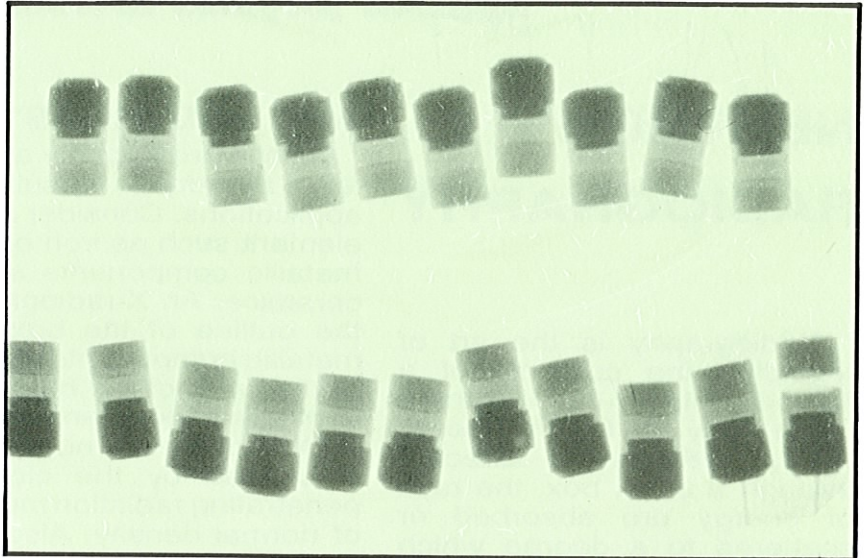


FIG. 4
NEUTRON RADIOGRAPH OF DETONATORS SHOWING
DEFECT GAPS BETWEEN LAYERS OF DIFFERING
CHEMICAL COMPOSITION

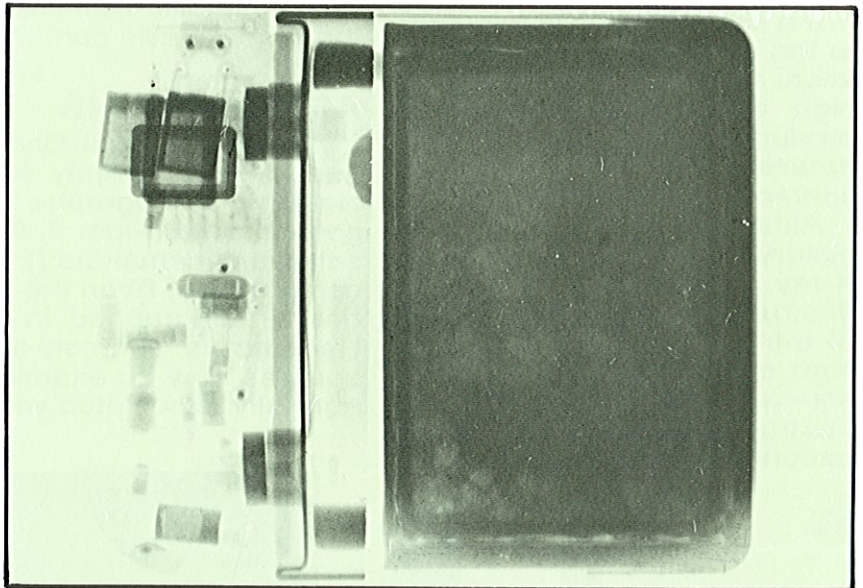


FIG. 5
NEUTRON RADIOGRAPH OF CARDIAC PACEMAKER

AVAILABILITY AND COSTS

Moata has one neutron radiography station in service with a maximum beam diameter of 100 mm on target and a neutron intensity of $1.4 \times 10^7 \text{ n cm}^{-2} \text{ s}^{-1}$ at maximum reactor power. A second station under construction will have a beam strength of $2 \times 10^7 \text{ n cm}^{-2} \text{ s}^{-1}$ on a target of diameter 170 mm.

The reactor service is provided at an hourly rate but the unit price for radiography is reduced if several items can be located on the target area of the neutron beam. Please refer to the APDAS price list for costs of the neutron radiography service.

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MOISTURE IN SOILS AND SIMILAR MATRICES

NEUTRON PROBES AND THEIR USE

The neutron method of determining the density of water in soil is based on the scattering and slowing down of the neutrons emitted by a source of fast neutrons incorporated in a probe (fig. 1). The probe is lowered into a borehole and the neutrons are scattered and slowed down by collisions with the atoms of the surrounding soil (fig. 2). Since hydrogen is by far the best scattering atom, the number of neutrons returning to the detector within the probe is a function of the density of the water in the soil. The soil water content is calculated from the slow neutron count rate and a calibration curve.

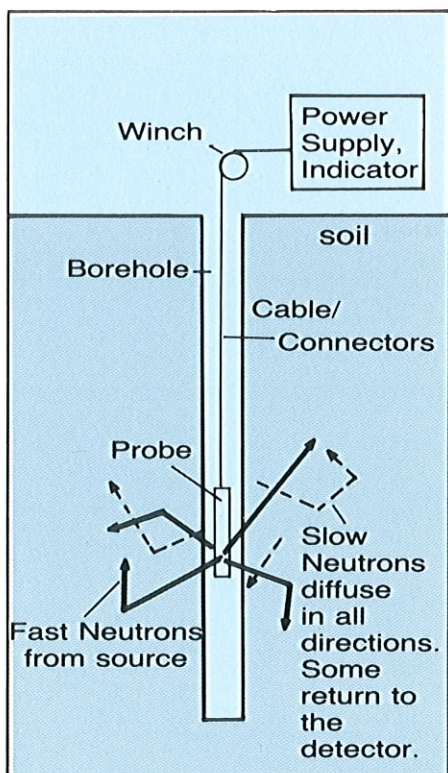


FIG. 2.

A Neutron probe in a borehole

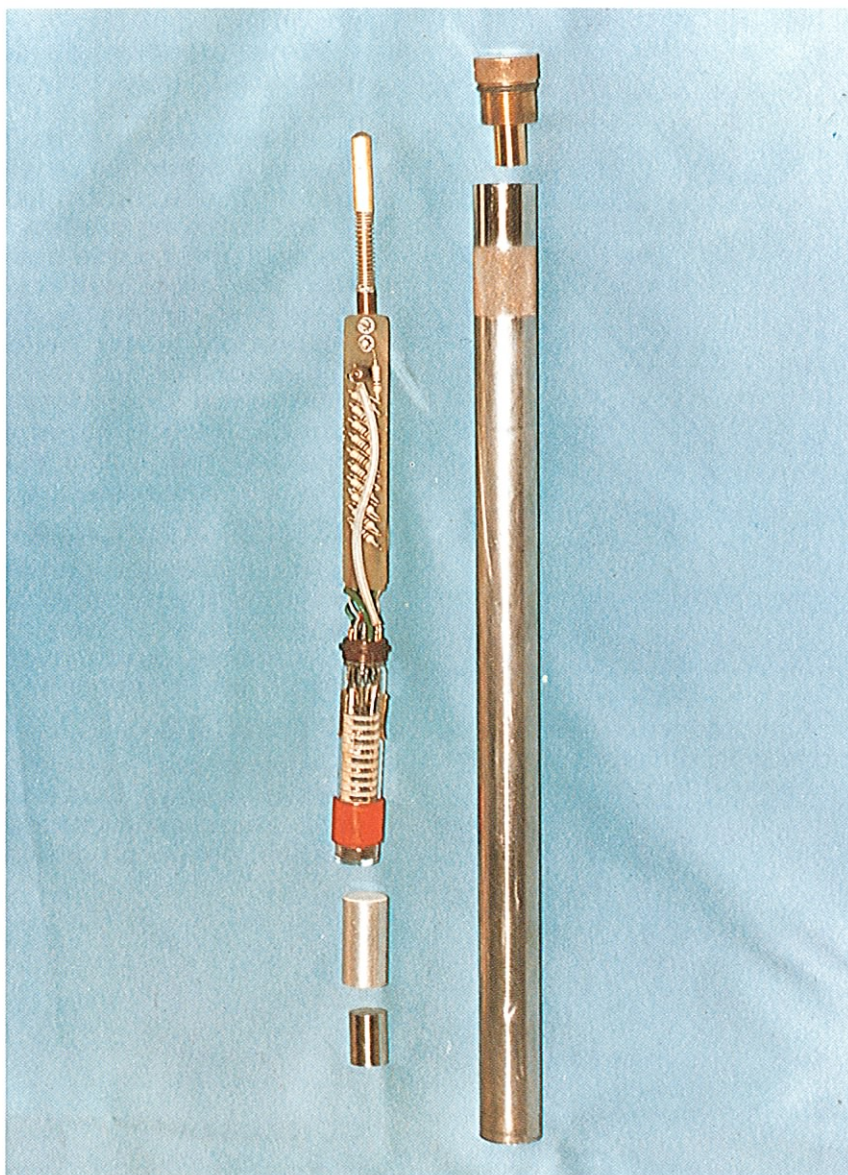


FIG. 1.

A Neutron Moisture Probe

The advantages of the method, compared to gravimetric sampling are speed, cost and precision. Repeated measurements are made in the same borehole to determine changes in water content.

PROBLEMS

The instrument responds to all hydrogen present and not only to that in the available water. Clays are particularly difficult in this respect so a correction factor is necessary.

Soil density affects the relation between water density and count rate (calibration) and must be determined either by gravimetric methods or from gamma-ray density probe measurements in the borehole.

Neutron absorption by elements in the soil affects the calibration by reducing the number of neutrons returning to the detector (fig. 3). The absorption can be derived from a complete chemical analysis of the soil which is

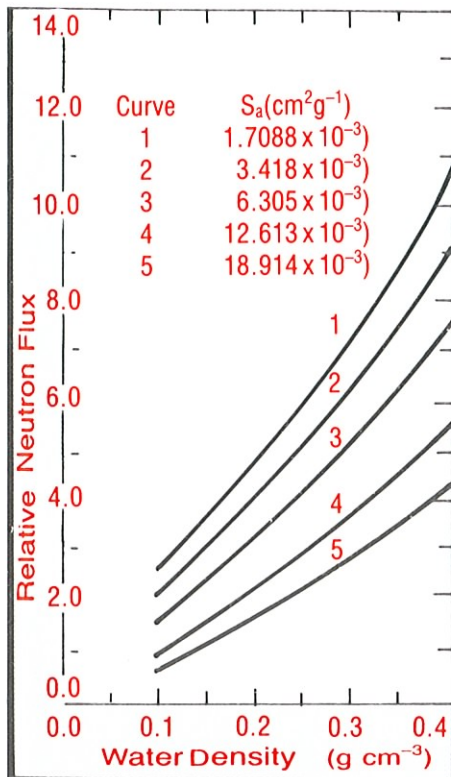


FIG. 3.

Calibration curves for soils with different neutron absorbing qualities.

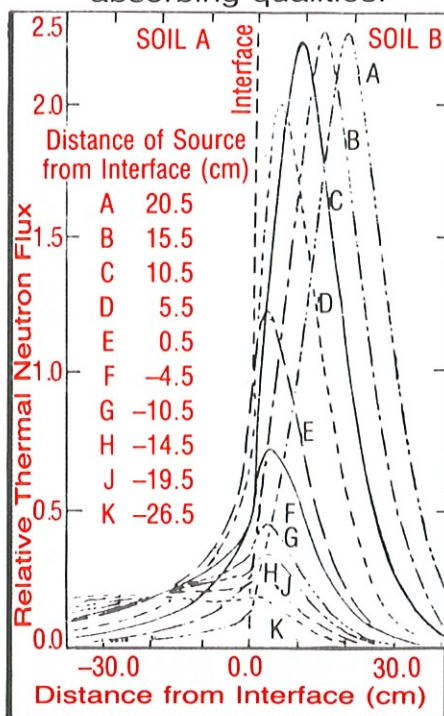


FIG. 4.

The thermal neutron flux resulting from a fast neutron source at different distances from a soil horizon.

expensive, or preferably by measurement in the research reactor Moata. The latter method uses a larger and therefore more representative sample and does not miss the effect of trace elements which may be highly absorbing.

Water density gradients in the soil may affect the measured water content. Correction factors for this perturbation can be determined from a series of measurements made on either side of the point of interest. This is a complex problem and the corrections vary with the other soil parameters.

Soil horizons present difficulties when the probe is near the horizon. In this case neutrons arrive at the detector from the other soil region which may be different and contain considerably more or less water.

Borehole liner materials must be considered and calibrations should be made using a sample of the liner used in the field. Metal pipes may be neutron absorbing whereas plastic pipes appear as water to neutrons and enhance the count rate. Corrections are possible for different materials.

OTHER APPLICATIONS

This technique can be applied to the measurement of moisture in seasoned timber, grain, concrete, coal heaps, mine spoil, etc. The probes will respond to the presence of carbon and hydrocarbons but techniques for interpreting the results will need developing.

SERVICES

Advice and consultation at ANSTO laboratories or customer sites. Soil cross-section measurements, probe calibration, calculations for correction factors, feasibility studies, research and development.

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