est), and a scaler to record the counts received in a preset time interval. Sometimes multichannel analyzers were used. All data reduction and sampling were manual tasks.

The neutron source was either a nuclear reactor, often requiring scheduling and long delay before completion of the analysis, or an operationally complex accelerator-type of fast neutron generator. The detector usually was of the scintillation type, often no more than 3 to 5 cm in length or diameter.

Today, the system is likely to be more elaborate, depending on the analytical needs. A reactor is an unexcelled source of slow or thermal neutrons. But the need for rapid analysis may suggest the use of a Californium-252 source if thermal neutron activation is desired and if nanogram sensitivity is not required.

The diversity of reactions produced by 14-MeV neutrons often dictates the use of accelerator-type neutron generators. Such devices are more acceptable to industrial users because of the availability of a hermetically sealed accelerator tube of high output and long life.

The sealed tube and its closed-cycle cooling system virtually eliminate the possibility of release of radioactive tritium or cooling water contaminants. This treatment simplifies the operational and safety constraints on the facility and on personnel.

Sodium iodide scintillation detectors still are used when the sample composition is known qualitatively and the readouts from the elements do not interfere with each other excessively. Sodium iodide detectors up to 15 cm or larger provide excellent efficiency and possess adequate energy resolution for many applications. Where interference is more of a problem, it often is helpful to use a sharper energy-resolution solid-state detector, such as lithium-drifted germanium.

To take full advantage of the energy resolution of modern detectors, it is necessary to use hundreds or even thousands of energy channels. Instead of using hundreds or thousands of single channel analyzers and scalers, modern systems achieve multichannel analysis by digitizing the detected pulse height. This is a measure of gamma ray energy; the analyzer stores the data in a digital memory module.

An analog-to-digital converter (ADC) produces the digital output, which is then interpreted as an address by the memory module. When a particular address is received, the contents of that memory location are increased by one count. Thus, a core memory array stores the multichannel data, providing the desired description of the gamma ray energy spectrum. In computerized systems, a portion of the computer core may be used for data storage.

Pneumatic transfer systems also have evolved, enabling rapid, safe transfers of samples from an input station to the neutron source for irradiation. The samples then proceed to a decay station, where unwanted, short-lived activities are allowed to die away, to a shielded count station containing the detector, and finally to a dump for storage or disposal.

Sometimes, a second set of decay and count stations are provided, in order to obtain more data before the sample is dumped. Sample activities die away rapidly; they normally permit disposal within a short time. But samples may be retained for other uses because of the nondestructive nature of activation analysis.

Modern systems feature computer control of sample transfer and irradiation, as well as computer data acquisition and reduction. A 16-bit, 32K-word minicomputer often is used, and a magnetic disc usually is added to the system to allow the use of highly sophisticated programs.

Operator interaction is via a CRT terminal or a teletype. And either a teletype or a line or matrix printer provides analysis hard copy output of composition and measurement precision. Special interfaces are required to couple the computer to the controlled hardware and to the detector.

When a sealed tube neutron generator is used, the facility can be located in any reasonably clean, well-ventilated ground floor laboratory. As little as 300 to 500 ft^2 of space will suffice when the accelerator is mounted 3m below grade and on a special mount with integral radiation shielding.

At about 3 or 4 m from the generator location or the closed cycle refrigeration unit, the dose rates during full-power operation are low enough to permit a 40-hr work week. The only routinely used radiation dosimeter usually is the film badge. More space may be required for sample preparation than for the analytical laboratory.

What is NAA?

Neutron activation analysis (NAA) is accomplished in three steps:

- ☐ **Neutron bombardment of the sample.**
- ☐ **Recording of the energy spectrum of the gamma rays produced by the mildly activated sample.**
- ☐ **Analysis of the significance of the features of the gamma spectrum.**

In a manner analogous to optical spectroscopy, the energies of the spectral peaks identify the elements present; the areas of the peaks define the quantities of each element. Most elements can be detected and measured by use of the NAA technique.