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COMPUTERIZED SYSTEM FOR THE APPLICATION OF FISSION NEUTRON CORRELATION TECHNIQUES IN NUCLEAR SAFEGUARDS

by

G. BIRKHOFF and L. BONDÂR

1972

Joint Nuclear Research Centre
Ispra Establishment - Italy
Physics Division

Paper presented at the
International Meeting on Non-Destructive Measurement
and Identification Techniques in Nuclear Safeguards
Ispra (Italy) September 20-22, 1971

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ABSTRACT

A computerized system is described (data processor) which seems capable of resolving the complex problems involved in the application of correlation techniques by non specialized personnel (inspectors). The basic components of the system are explained as there are calculation or measurement of neutron pulse distribution for given sample and detector arrangements and analysis by auto or cross correlation methods. A layout of the apparatus is given. The system has proved very powerful in the domains of planning execution and analysis of measurements with fissile materials of various shapes and isotopic compositions.

KEYWORDS

SAFEGUARDS
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NEUTRON DETECTION
SAMPLING
MONITORING
QUANTITATIVE ANALYSIS
PLUTONIUM
PLUTONIUM 240
CALIFORNIUM 252

Time correlation analysis among the neutron detection pulses is frequently applied in passive and active neutron assay techniques of fissile materials, for distinguishing fission neutrons from others. For example for Pu-240 spontaneous fission neutrons measurements in presence of (α,n) neutrons or discrimination of source neutrons by coincidence techniques. The application of this method is quite simple if restricted to small samples. The extension to larger samples becomes, however, very complex due to neutron multiplication. In the latter case it is rather difficult to elaborate a measuring routine for field applications which assures that measurements, taken during an inspection, will be useful and an optimum of accuracy. For this purpose we set up a computerized system. It is based on an inspection concept as outlined below.

A. Planning of an inspection (Chief Inspector)

- Find the optimum response of the detection system to be employed to a defined sample to be measured.
- Take calibration measurements and calculation with a standard with isotopic and geometrical data similar to that one of the sample.
- Evaluate corrections of calibration factor to be applied for measurements with the actual sample.
- Set up measurement strategy (number of samples to be measured, time per measurement, etc.)

B. Execution of inspection (Inspector)

- Repeat measurements on the spot with standard sample
- Take measurements with a sample
- Compare results with planning data,
  if good agreement : go on measuring
  if significant discrepancy : call Chief Inspector.

General Description of the System

The operation principle of the computerized system is explained in the schematic diagram Fig. 1 . Detector pulses are produced physically or simulated by a computer program. In the computer a data pair represents a signal; a label (λ) corresponding to a specific detector (-group) and the real appearing time (t) of the signal in the detection system. After collecting nearly thousand signals, time correlation analysis, that is, data reduction will be accomplished. In order to get sufficient high statistic this procedure must be repeated periodically and the reduced data accumulated. These reduced data, as a response of the detection system to the sample, serve for the verification of fissionable material content of the sample.

Detector Pulses from Counter Arrangement

In case of measurements a label (λ) and time (t)(as defined above) are to be attributed to each detector pulse and these data must be fed into the computer. An explanation of this procedure is given in the paper of M. Bernede, L. Stanchi :"Fast acquisition of neutron coincidences into a small computer", presented at the "International Meeting on Non Destructive Measurements and Identification Techniques in Nuclear Safeguards", held at Ispra on 20-22 September 1971.

Simulated Detector Signals

Simulation of detector pulses by computer program (Fig. 2) requires the preparation of some parameters and distribution functions. Spontaneous events follow Poisson distribution. $\bar{n}$ (number of fission per second) $\bar{\nu}$(average number of neutron per fission) and P_ν (distribution function of fission neutrons) being pure isotopic properties can be found in any nuclear book. The other parameters ε (detection probability), κ(probability to prove a fission) and l (mean lifetime) are depending on geometry and nuclear properties of sample and detector assembly. Such parameters require complex calculations checked and adjusted by specific measurements. For calculation we use the Monte Carlo transport code TIMØC (1), which is capable of resolving the neutron transport problem in a complicated geometry as in case of fuel samples embedded in a detector arrangement. Numerous techniques are known for measuring ε, κ and l. All these parameters are to be tabulated for typical sample geometries and isotopic compositions covering the range of most diffused fissile materials. Intermediate sample parameters are obtained by interpolation.

Time Correlation Analysis

There are different well known methods for separating correlated signals from Poisson-background. Usually special electronic instrumentation is employed for this purpose. If a small computer is available, it is more convenient to realize such electronics by software. Indeed, we programed several coincidence circuits based on autocorrelation methods.

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(1) KSCHWENDET, H. and RIEF, H.: "TIMOC - A general purpose Monte Carlo code for stationary and time dependent neutron transport" EUR 4519.e (1970)

Verification

Verification of the fissionable materials is obtained through the interpretation of the results from correlation analysis in terms of emission rates and multiplicities of fission neutrons, confronting measured and nominal data (declaration of properties). The sensitivity of these signatures have been investigated for samples containing Pu-240 and Cf-252 with different background of (α,n) neutrons. The results are satisfactory.

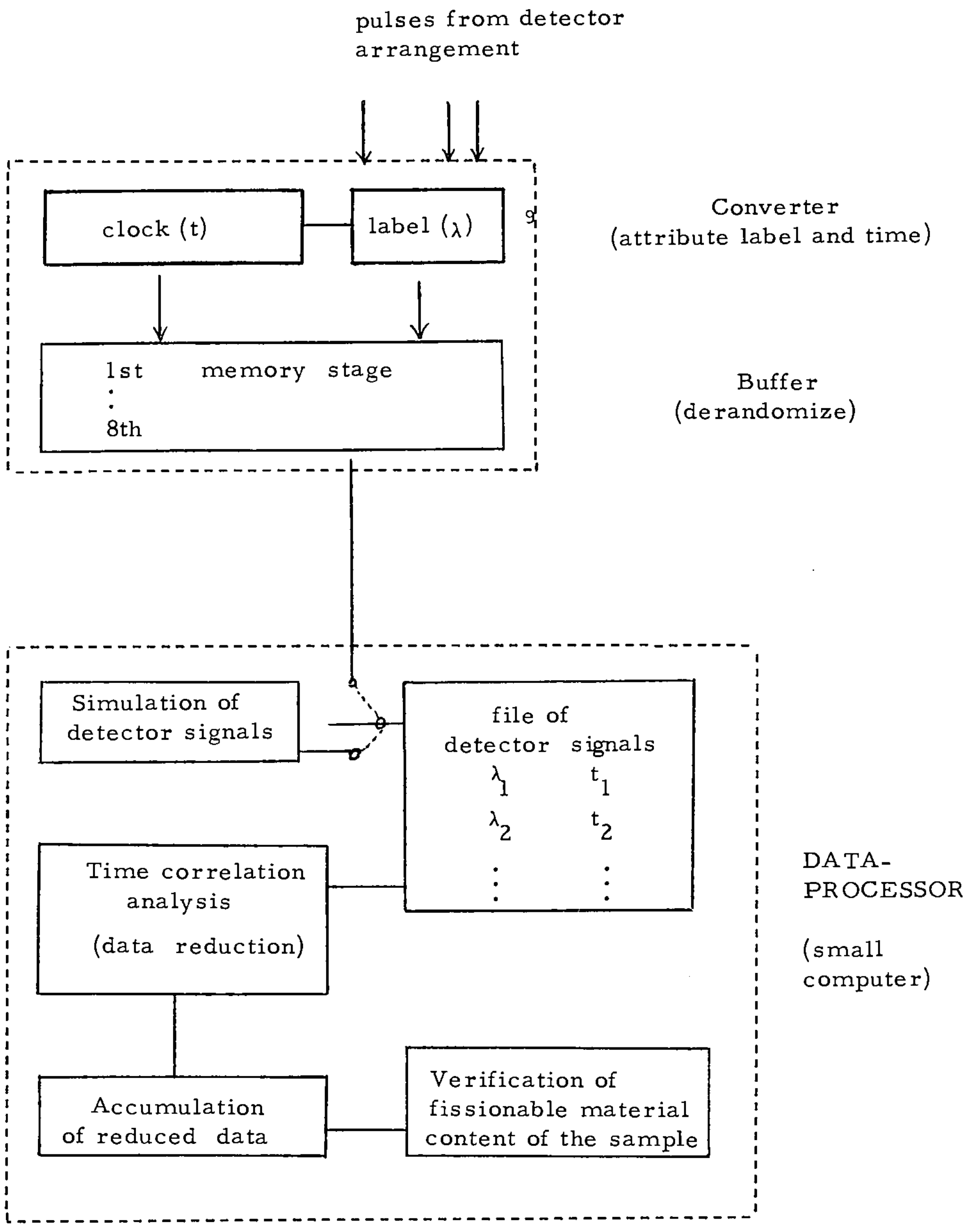

Fig. 1 : Computerized system for time correlation analysis of neutron detection pulses - (schematic)

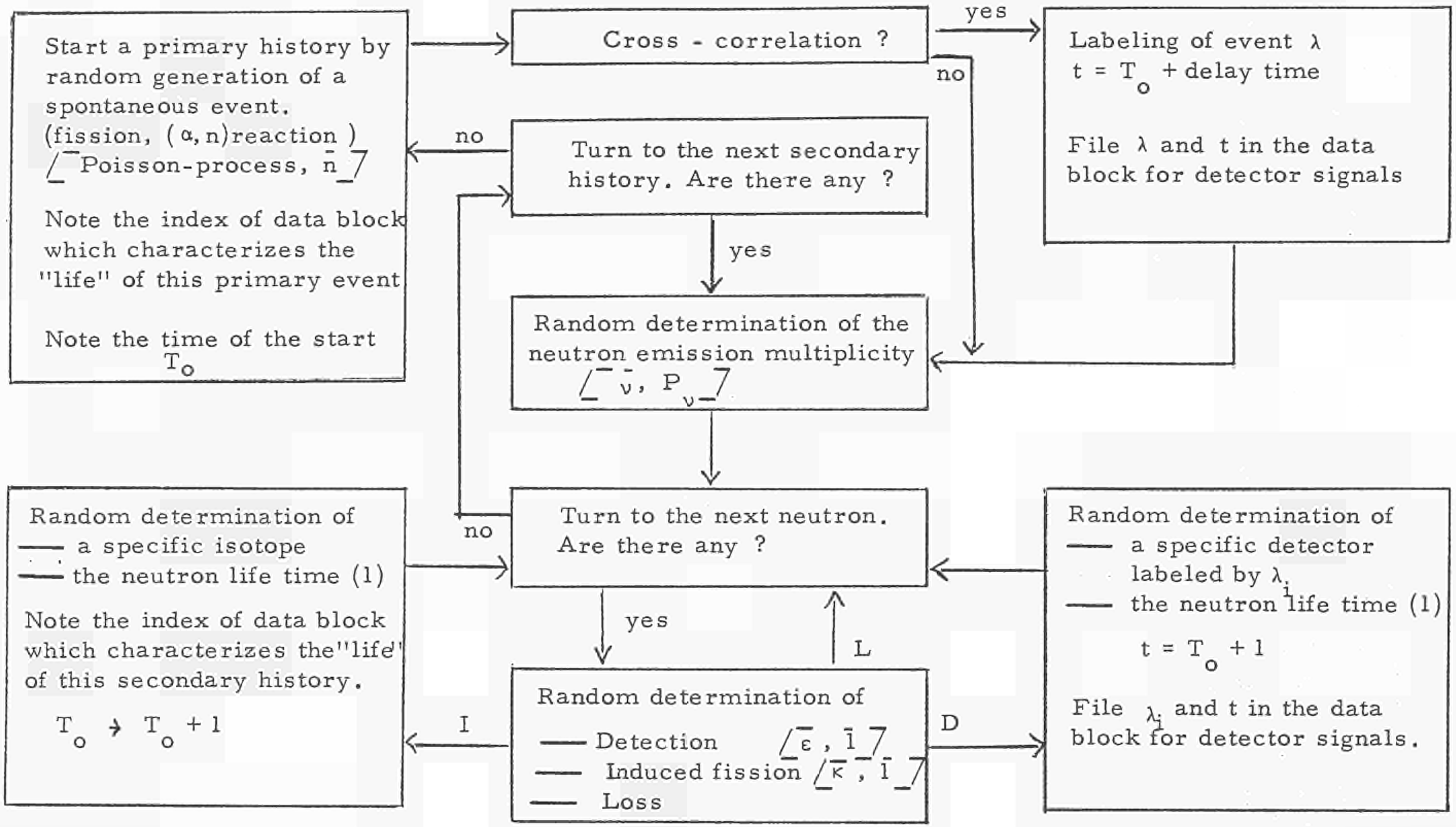

Fig. 2: Schematic flow diagram for the Monte-Carlo simulation of neutron history in a detector arrangement

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Alfred Nobel

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