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Accident Monitoring in Ventilation Stack

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Introduction

A ventilation stack of VVER 440 NPPs is serving to both of two reactor units constructed as twins. The air flow through the stack is approximately 162 m^3s^{-1} (5.10^9 m^3/yr) affected by the reactors operation mode (nominal power or refueling). The hermetic zone (enclosure of the primary system components) at an accident is not vented directly to the stack due to automatic changes in the ventilation system airflows. Hence no uncontrolled radioactive matter should appear in the stack. Nevertheless some scenarios have been considered when this may happen (e.g. fuel damage at transport operations, leakages to vented areas at accidents).

Standard gaseous effluent monitoring system RKS 2-03 provides the monitoring of the noble gases up to $2,2.10^9$ Bqm^{-3}. For the monitoring at accident conditions this may be inadequate. A typical value for a range of monitoring the radioactive matter in the air of common ventilation stack is 5.10^4 - 5.10^{13} Bqm^{3} [1]. The purpose of the monitoring is to detect and evaluate significant releases and to enable the long-term monitoring after an accident. Another typical values suggested for monitoring noble gases in a ventilation stack [2] are:

up to 10^{12} Bqm^{-3} at air flow of 200000 m^3h^{-1}

up to 10^{13} Bqm^{-3} at air flow of 20000 m^3h^{-1}

To fulfil the requirement for accident monitoring in the ventilation stack at Bohunice NPP a type of detector used in the environmental monitoring system has been considered for ease of installation and connection to accident monitoring network. The DC-4D-84 (Si) detector is available in two versions - low range and high range. Only the later one is considered in the paper.

Calculations

The basic parameters of the DC-4D-84/V detector provided by the manufacturer are:

Range of measurement for gamma rays: 0 to 1000 R/h

Probe basic sensitivity: 10 $imp.s^{-1}/R.h^{-1}$ for ^{137}Cs

Basic count-rate error of output pulses:

±10% for the range 0 to 500 R/h

-20% to +5% for the range 500 to 1000 R/h

Detector own background: max 0.5 $imp.s^{-1}$

Since the manufacturer provided the range and sensitivity in units of exposure, these have been converted to dose in air [3]. Then the response of the instrument can be expressed in terms of dose rate dividing an instrument response [$imp.s^{-1}$] by instrument sensitivity expressed in [$imp.s^{-1}/Gy.s^{-1}$]. Further if the response of the monitor is required in volume activity [$Bq.m^{-3}$] the conversion factor K [$Gy.s^{-1}/Bq.m^{-3}$] is needed.

In this work the conversion factor has been calculated using code AMOC-K a version for geometry of VVER ventilation stack. The computing method is based on solving Boltzmann photon transport equation by adjoint Monte Carlo calculation [4,5]. As a result of the calculation the photon fluences and the rate of kerma in air which approximates the dose rate in air, are obtained. As an example of the parametric calculation performed Fig.1 shows the dependence of dose rate on height of the measuring position along the stack axis. The dose rate versus radial position of measuring point at the height of 15 m is presented at Fig.2. In both cases the source assumed is ^{137}Cs homogeneously distributed in the air.

Experimental

The angular and energy characteristics of the detectors have been determined with detectors inserted into a Pb shielding as used in the environmental monitoring system. All measurements have been performed in the laboratory conditions. The built-in check source was dismantled except in kerma rate measurements.

The angular characteristics have been measured at the energy of 118 keV and 662 keV (^{137}Cs). A massive turn-table has been used enabling detector positioning parallel to the photon flux at 0 and 180° and with detector head in the turning center. An example of the angular detector response is presented in Fig.3.

The dependence of detector response on rate of photon kerma in air was measured from the level of laboratory background to 4,56 $Gy.h^{-1}$. An example of measurements for two detectors are plotted in Fig.4 as relative response error vs. dose rate.

The measurements of the detectors energy characteristics have been performed in the gamma irradiation laboratory and in the X-ray laboratory. Fig.5 presents an example of measured characteristics.

Discussion

From the calculations performed as illustrated by Fig.1 and Fig.2 it can be concluded that the response of the monitor is not very sensitive with respect to its position within the ventilation stack. Hence there is not any serious reason to prefer any particular position disregarding potential possibility of surface contamination of both the stack inner wall and the probe mounting construction. An estimated operational range of detector considered is $2,4.10^7$ to $4,8.10^{11}$ $Bq.m^{-3}$ ^{137}Cs or ^{137}Cs equivalent. Taking into account the air flow through the stack (approximately 570000 m^3h^{-1}) the upper value of the range is corresponding to the values suggested in [2].

The results of the measurements of the angular characteristics well corresponds to the expectations. For the energy of 662 keV the detector response is independent to the direction of photon flux up to the 70-80°. The effect of shielding can be observed at higher angles. The angular dependence is more pronounced at lower energies . At 118 keV the response does not changes only to 50°.

Systematic underestimation of the response with dose rate can be observed with average value about 10%. The influence of check-source is dominant at small dose rates (not plotted in Fig.4).

The energy characteristic is difficult to interpret. The data plotted at Fig.5 are normalized to the response of ^{137}Cs. After sharp rise at approximately 100 keV the response is overestimated. The influence of photons scattered from the wall, floor and ceiling is considered to be negligible due to precise flux collimation. The estimated contribution does not exceeds 10%.

Conclusions

The experimental measurements have been performed with greate care with several detectors, all with shielding designed for application in environmental monitoring system. The shielding affects mainly angular dependence of the response which in the calculation was considered isotropic. From the measurements can be derived that the data provided by the manufacturer should be accepted with a caution. The probe performance, although not ideal, enables its application in accident monitoring. However its recalibration would be strongly recommended. Based on experimental angular and energy characteristics the response of the detector can be calculated and conversion factor derived to express the response in volume activity of most probable nuclides composition in releases.

References

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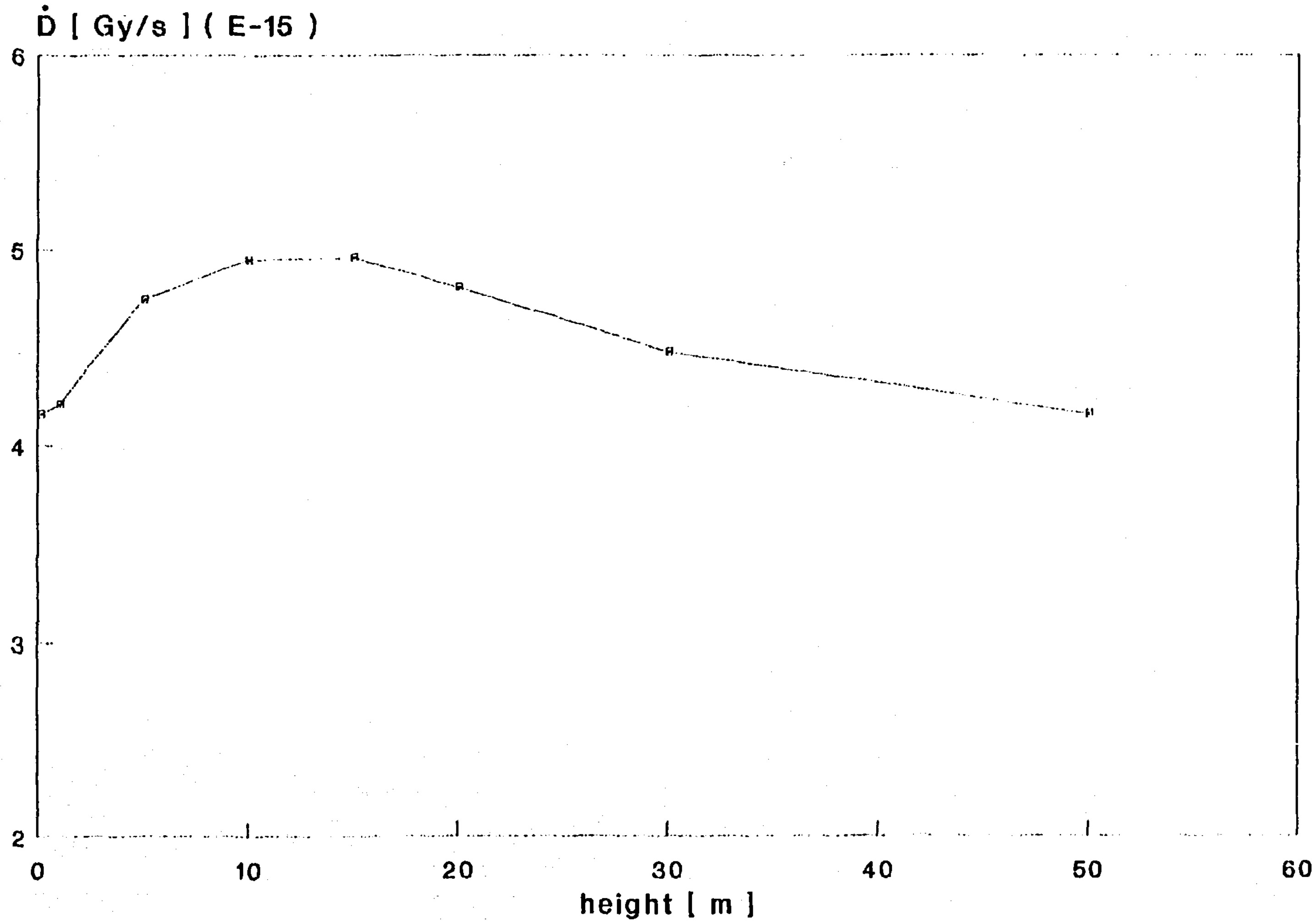

Fig. 1 DOSE RATE AT DIFFERENT HEIGHT OF MEASURING POSITION

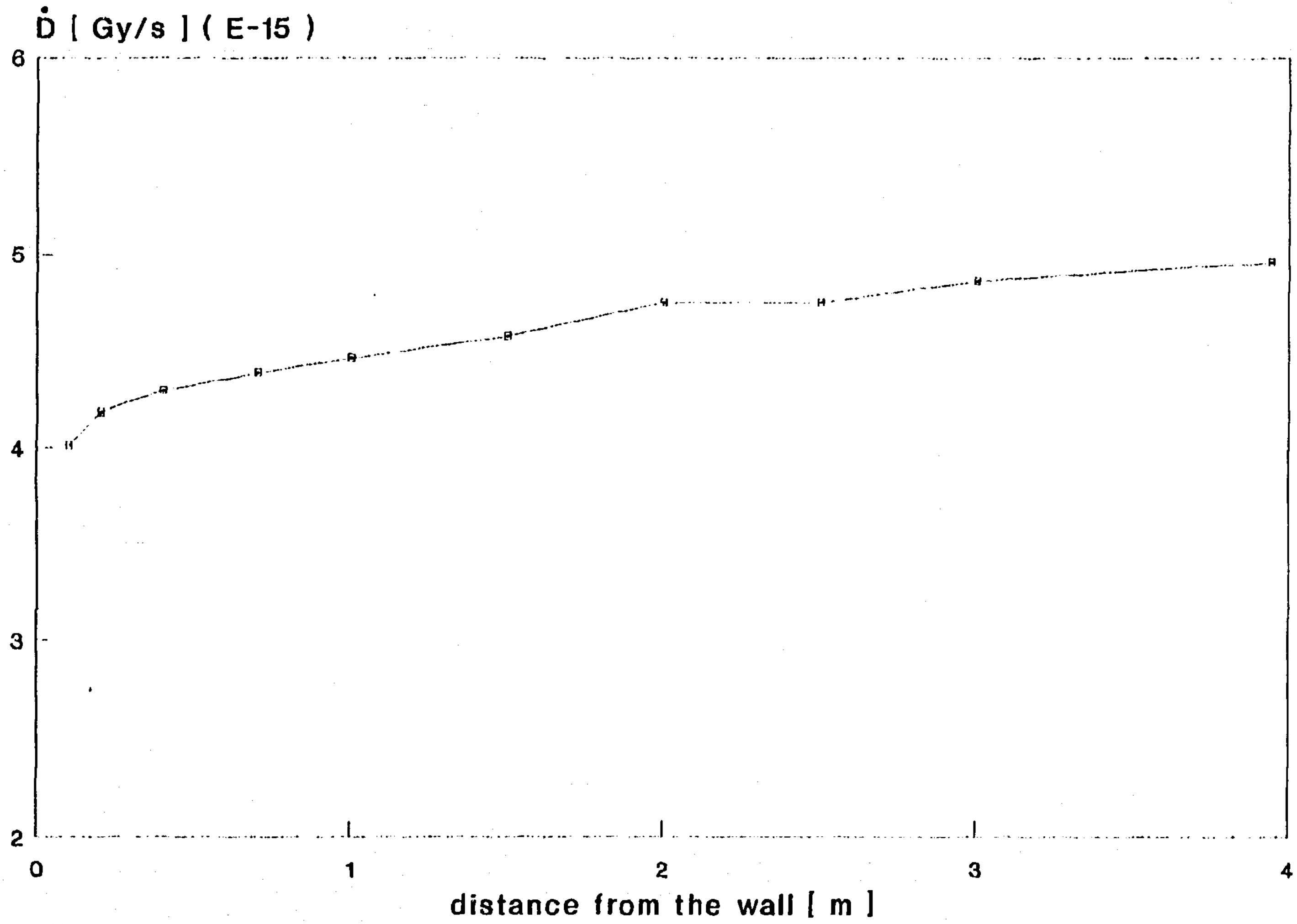

Fig. 2 DOSE RATE AT DIFFERENT RADIAL MEASURING POSITION

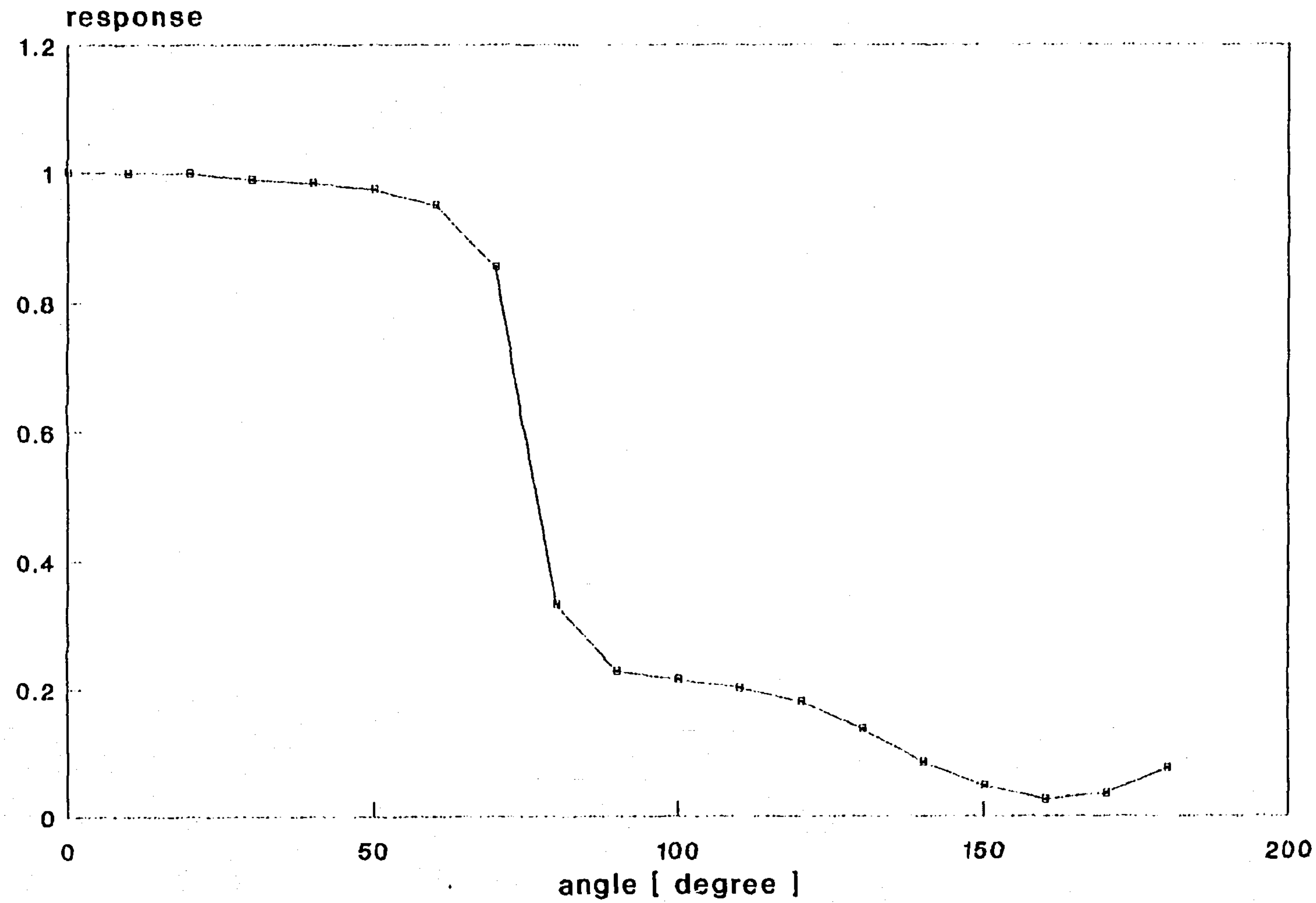

Fig. 3 ANGULAR DEPENDENCE OF THE DETECTOR DC-40-84/V

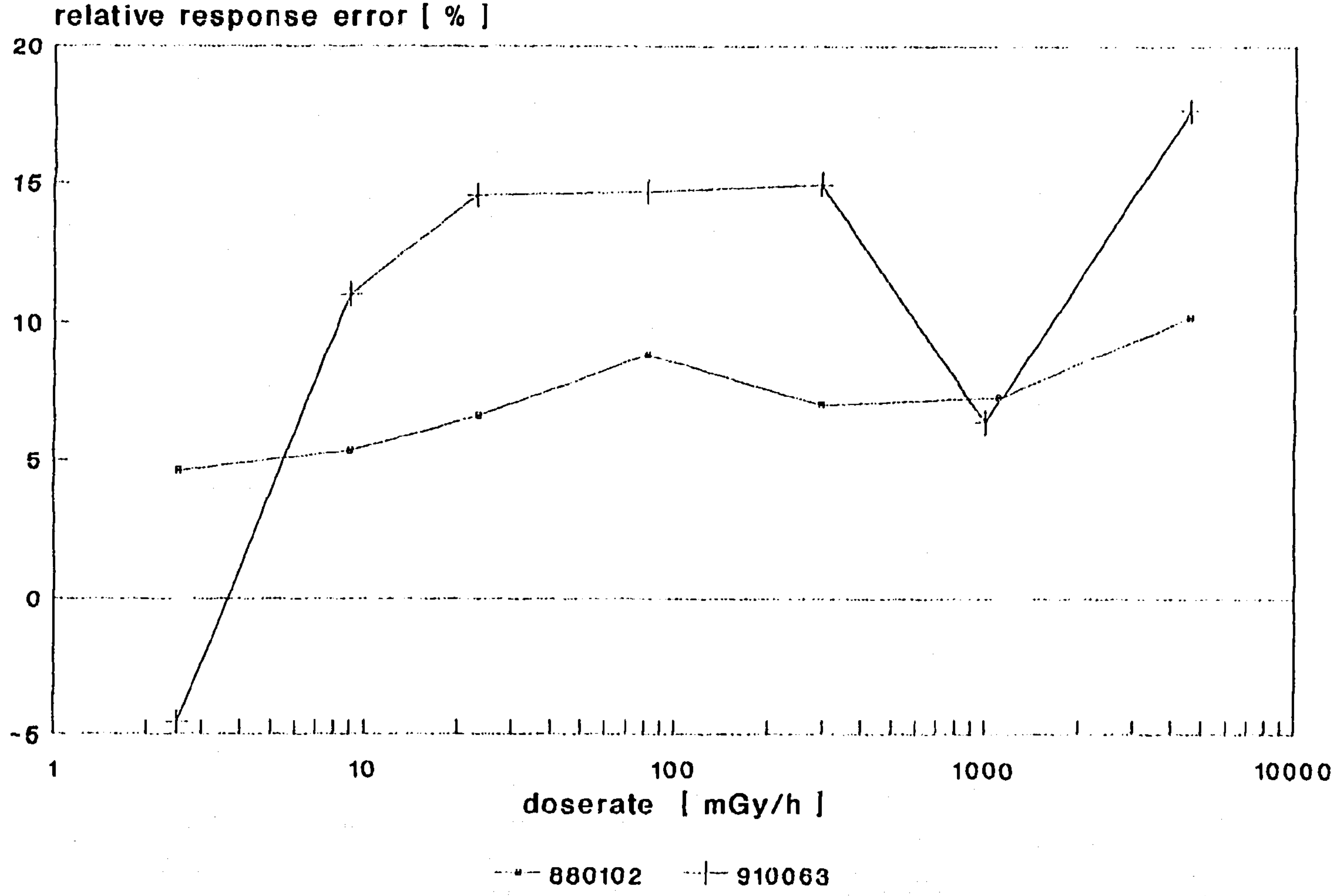

Fig. 4 RELATIVE RESPONSE ERROR OF THE DETECTORS AT DIFFERENT DOSERATES

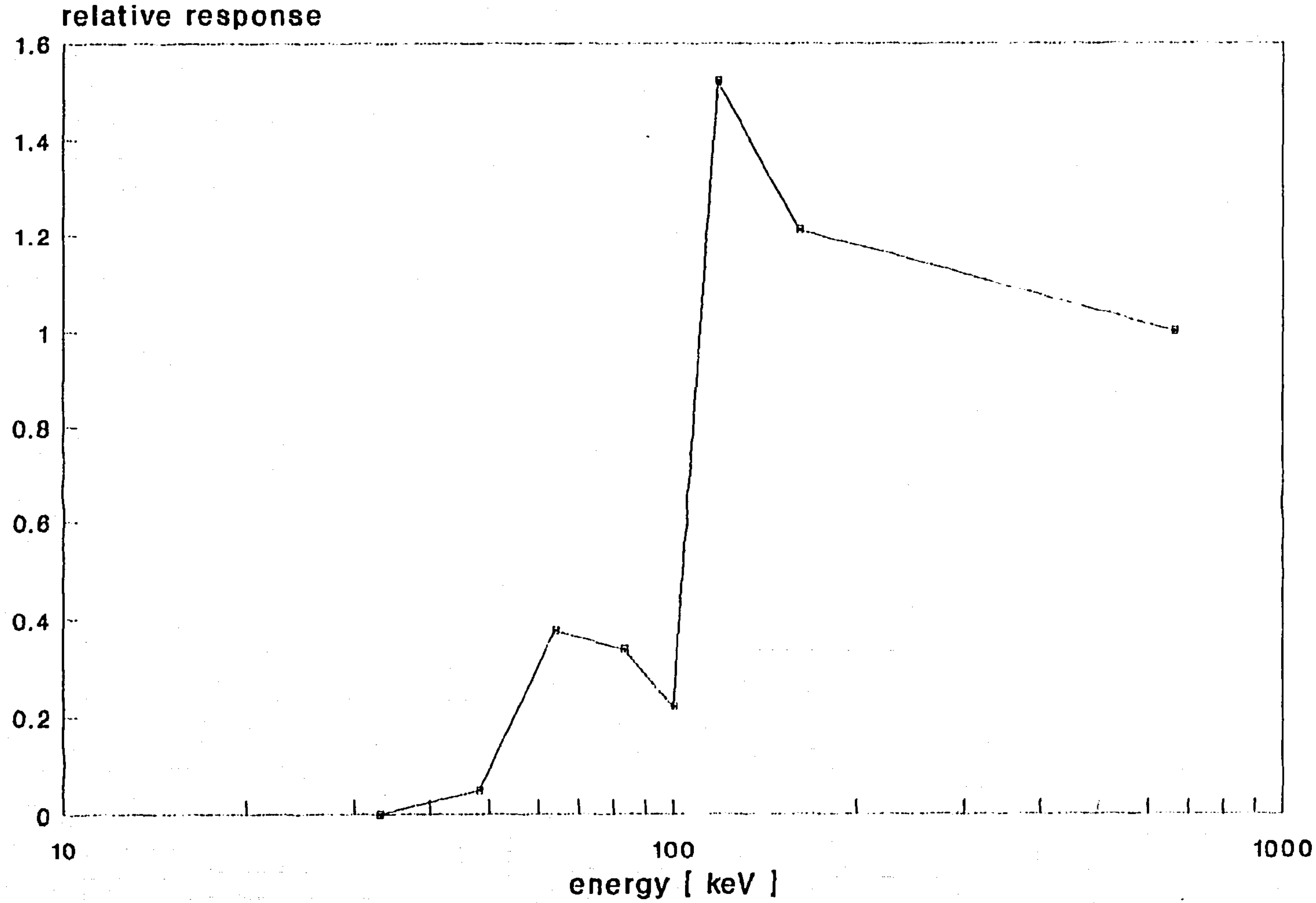

Fig. 5 ENERGY DEPENDENCE OF THE DETECTOR