RU0110741

SYSTEM TO DETECT NUCLEAR MATERIALS BY ACTIVE NEUTRON METHOD

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ABSTRACT

The report presents the results of the development of the system to detect nuclear materials by active neutron method measuring delayed neutrons. As the neutron source the neutron generator was used. The neutron generator was controlled by the system. The detectors were developed on the base of the helium-3 counters. Each detector consist of 6 counters. Using a number of such detectors it is possible to verify materials stored in different geometry. There is an spectrometric sñintillator detector in the system which gives an additional functional ability to the system. The system could be used to estimate the nuclear materials in waste, to detect the unauthorized transfer of the nuclear materials, to estimate the material in tubes (e.g. UF_6 at some facilities), etc.

The goal of the development and field of implementation

The goal was to develop highly intellectual industrial system to detect fissile materials by active neutron method measuring delayed neutrons. Possible application of the system could be as follows:

- Detection of illegal transfer of shielded fissile materials (e.g. Uranium in container in track)
- Measurements of fissile materials contents in different samples, including different kind of waste (enrichment must be measured by spectrometry).
- Different kind of usage in scientific laboratory for different kind of investigations.

Main Components of the SYSTEM

The system consist of:

- **Central station** including industrial PC card, display, counters cards, special cards to get information from the detectors and to sent signals to the neutron generator, power supply modules, software, etc
- **Neutron detectors**
- **Neutron generator**

PRINCIPLE OF ACTION

The principle is very simple. The target should be surrounded by the set of neutron detectors to achieve the necessary sensitivity. On command from central station the neutron generator produces the shot of neutrons. The neutrons penetrate the target and cause fission in fissile material in target. As a result of fission there are delayed neutrons which are registered by the neutron detectors. Signals go to the central station for processing and making decisions. The information are displayed on the screen. Example of the decay curve of delayed neutrons registered by the system is presented on Fig. 1.

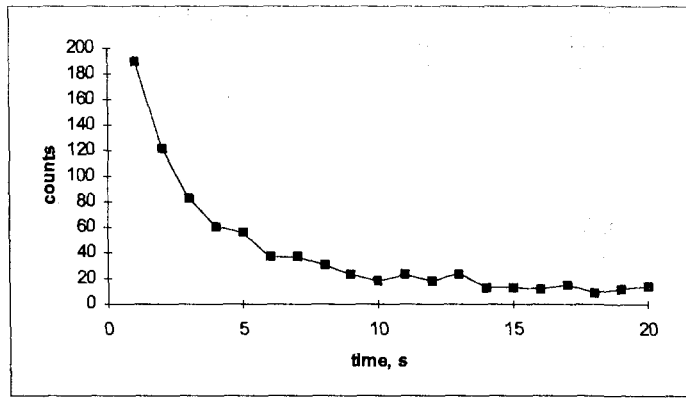

Fig.1

The simplified algorithms of functioning is as follows:

- The signal (command) from Central station to the neutron generator
- The shot of the neutron generator (one or a number depending on the command)
- The pause for time more than live time of the neutrons in the moderator
- Delayed neutrons measurements
- Information proceedings
- Go to stage # 1 if necessary to repeat this cycle as many times as necessary to achieve the required sensitivity of the system in the specific geometry of measurements.

Technical features of the SYSTEM

1. Central Station:

Type of registered activity	(any) detector dependence
Type of input signals:	pulsed signal 
Polarity	negative
duration, msec	from 5 to 15
frequency, Hz	from 0 before 100000
amplitude, V	from 1.5 before 15
Amount of input channels (detectors)	up to 12
Channels power:	
output voltage, V	from 11 before 15
current on each channel, mA	no more than 80
Amount of output analog signals	4
Ranges of output analog signals, V	(0...+10), (0...+5), (-5...+5)
Amount of output pulsed signals:	1
polarity	free
duration, msec	15±30%
amplitude, V	15±30%

Built-in minicomputer:	IBM-compatible, ISA
Volume of solid state disks SSD1, Kb	512
Volume of solid state disks SSD2, Kb	128
Communications	RS-232
Display	monochrome, 640x400
Control	keyboard AT
Voltage needed	network (170-230)V, (50-60) Hz
Power ,consumption, Wt	no more than 50
Level of the IP protection	IP32
Dimensions, mm	370x350x330
Mass, kg	no more than 6

2. Neutron detector:

Type of He-3 counters	SNM-18
Number of counters in the detector	6
Type of output information	pulsed sequence
Polarity of output pulses	negative
Voltage of output pulses, V	not less than 2
Duration of output pulses, msec	$5 \pm 10\%$
Sensitivity, neutron*cm^2/s	82
Voltage of power supply, V	12...16
Current of consumption, mA	no more than 50
Level of protection from surrounding ambiance	IP66 EN 60529
Dimensions, mm	405 x 410 x 120
Mass, kg	15
Length of communication link, m	100

3. Neutron generator:

The type of generator	Pulse Neutron Generator-01 standard
Neutrons per shot	10^7 neutrons
Maximum number of shots per s	30

Description of the SYSTEM

Central Station

Central Station is designed for receiving and processing of the information from sensors (detectors) and presenting information for the Operator on the screen of the display. Additionally it sends command signal to the neutron generator to make shots of neutrons.

Central Station is intended for non-stop operation and can be used within the range of temperatures from minus 10°C up to +40°C and at moisture up to 90%.

Central station is based on Micro PC technical means of the Octagon Systems company (USA). This system is based on the IBM PC architecture. It uses a number of controlling and peripheral elements (cards), united by 8-bit ISA-a bus.

Functional scheme of the central station is presented on the Fig. 2.

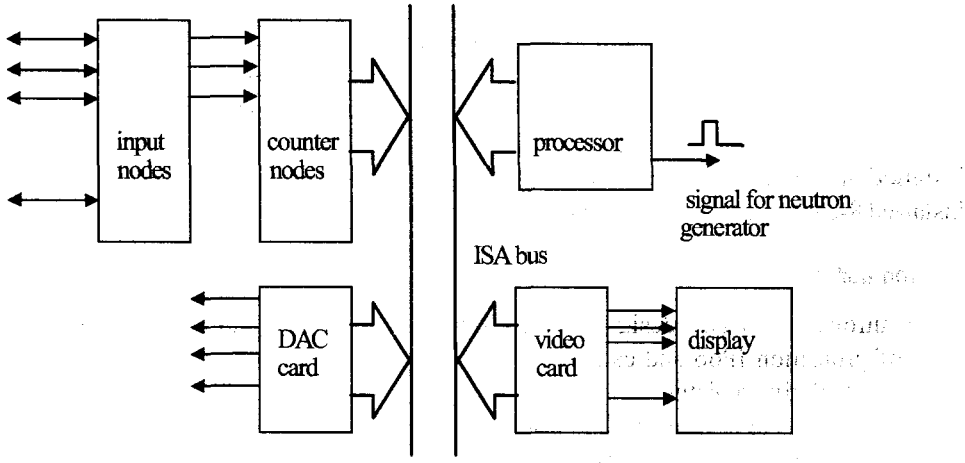

Fig 2.

Information from sensors (detectors) is going through "input card" to the timer-counter Card which is connected to ISA bus and throw it to the processor. "Input card" are additionally used to supply power to the sensors (detectors). Both signal (pulses) and power supply to the sensors are physically united in one coaxial cable. Processor performs control of the hardware (connected to the ISA bus), receives and processes information and puts it on the display.

Central station consist of:

- processor (5025A Control Card);
- video card (5420 Super VGA Card);
- display (Planar EL 640.400-CD3);
- 2 counter/timer cards (5300 Counter/Timer Card);
- digital-analog converter (5750 4-channel DAC Card);
- 2 input cards;
- modules of primary power supply.

Processor Card represents itself a PC on the base of processor 80386SX-25 MHz with 1 Mb operative memory (RAM).There are built-in disc subsystem on the base of solid state disks - microcircuits ROM (ROM) or RAM. Card can have up to 3 such disks:

- SSD0: ROM disk , containing in its composition BIOS and built-in DOS 6.0.
- SSD1: ROM disk up to 1 Mb on the base of the programmable by user memory.
- SSD2: ROM disk up to 1 Mb on the base of the programmable by user memory or RAM disk up to 512 Kb on the base of RAM with the battery support (or without it).

Video Card could support a number of the different type of displays. Some adaptation to the different types of displays could be performed using reprogrammable flash-memory. Different options of BIOS were delivered with this card as well. Card supports a majority of VGA modes.

Counter-timer Card (5300 Counter/Timer Card) is software-operated by the processor. There are 3 three-channel microcircuits of counters/timers 8254 and one microcircuit of parallel port 8255 on the card. The card in the system is used with six pulse channels on 8254 and one pilot channel on 8255.

Digital-analog converter (5750 4-channel DAC Card) is a 4 channel DAC. Each of channels of DAC realizes 12-bit transformation and works regardless of the others. By means of jumpers output voltage of each channel can be adjusted on ranges (0...5)V, (0...10)V or (-5...+5)V.

Input card is an original development for the device. Card consist of a converter of voltage 5 V/ 12 V for power supply of the sensors(detectors) and 6 channels for receiving of the information.

Central station is manufactured in plastic body with "door type" cover. On the cover ("door") are installed: display, speaker, regulator of brightness. Connectors of external cables and tumbler of switching "ON" a power supply are situated in "pocket" on back surfaces of body. Connection of keyboard is realized through the hole in the lateral wall. During operation the enclosure is installed on the stand, ensuring slopping 75 degrees for the horizontal plane. Inside of the body is installed 8-card framework and other auxiliary elements.

Neutron detector

Neutron detectors are designed for continuous (non-stop) operation. It is manufactured at the level of protection IP66 and can be operated under temperature range from minus 20°C up to +50°C and relative moisture up to 80%.

Neutron detector consist of six helium type counters (SNM-18) and electronics circuits. Electronics circuits performs amplification, discrimination and shaping of the signal. There is a stabilization of the input voltage. The power supply to the counters (SNM-18) is realized by a high-voltage converter.

Neutron detector is located in the plastic body with 405x 400x120mm dimension. There is a connector of type CP50-73 BO on one of the sides to connect a communication link.

Electronic cards, counters and paraffin moderator are made as united construction, which is fixed to the body of enclosure by 6 screws.

Results of tests

All technical features of the system were tested under laboratory conditions according to the program of testing. System successfully passed all the tests. Because of routine procedures and considerable volume of information the data are not presented on the report. It might be mention that the system has high stability and additional error due to the temperature is about (or less) 0.03%/°C.

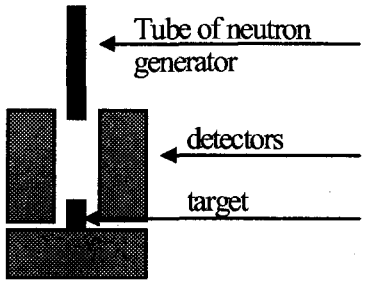

Fig. 3

As to the sensitivity of the system - it strongly depends on the geometry of the measurements, amount of the neutron detectors and number of neutron generator shots. Some experiments were performed in the geometry as it shown on the Fig. 3.

A number of small uranium samples were used in such geometry as a target. It was estimated that uranium emits approximately 0.95 delayed neutrons per g of U235 and 0.33 delayed neutrons per g of U238 per 30 shots of the neutron generator (neutron generator emits fast neutron).

In another experiment some plutonium samples were measured in passive mode (no shots from neutron generator) in the same geometry. Results are presented in the table and Fig. 3.

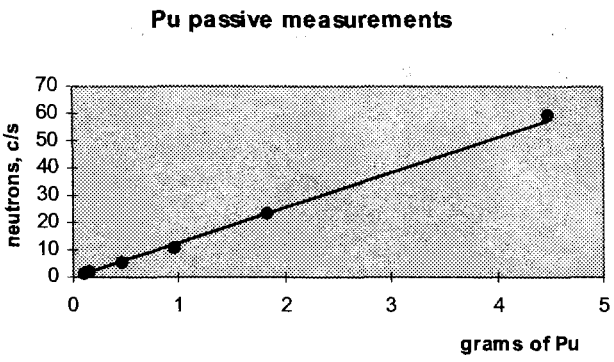

Fig. 3

Plutonium, g	Static measurements, c/s
0, background	0.2
4.48	59.7
1.83	23.5
0.96	11.2
0.47	5.8
0.16	2.5
0.11	1.6

Time of measurements - 5 min

Conclusion

The System to detect the fissile materials by active neutron method (by delayed neutrons) was successfully developed, manufactured and demonstrated. The advantages of the System:

1. Ability to detect the fissile materials when others passive methods can not do a job.
2. High level of the intellect, PC card.
3. Openness of the system.
4. Wide range of the possible application.