

LA-SUB-9646

Russian Federal Nuclear Center
All-Russian Research Institute of Technical Physics.
(RFNC - VNIITF)

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APR 24 1996

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Subcontract № 9281P0004-35

Task order № 004

Test and valuation of portal monitors of nuclear material with the use of plastic scintillators and
hand-held radiation detectors.

Final report

**TEST AND VALUATION OF PORTAL MONITORS OF NUCLEAR MATERIAL
WITH THE USE OF PLASTIC SCINTILLATORS AND HAND-HELD RADIATION
DETECTORS.**

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1995

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SUMMARY

The report is outturned on 24 sheets and contains 9 drawing and 7 tables.

The report is the finishing part of work fulfilled under the contract with Los-Alamos National Laboratory (USA) within the framework of the program of cooperation of American and Russian nuclear laboratories, aimed on strengthening of system of protection, control and accountability of nuclear materials.

The purpose of this work was to test portal and hand-held monitors manufactured by TSA company (USA) in order to upgrade a control of unauthorized pass out of nuclear and radioactive materials from controllable territory and valuation of availability of their application at Russian nuclear facilities.

In the report the results of tests of PM-700SP pedestrian portal monitors and PRM-470A hand-held monitors are given.

Key words are: control and accountability of nuclear materials, portal and hand-held SNM-monitors.

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INTRODUCTION

At present in Russian Federal Nuclear Centre - All-Russian Research Institute of Technical Physics (RFNC-VNIITF) works on application of modern means in system of protection, control and accountability of nuclear and radioactive materials (NRM) at site 20 begun, that in complex with the other elements of protection should ensure safety of NRM.

As a result of works carried out it is supposed:

- to adjust a computer accountability of NRM movement;
- to equip storages and premises for works with NRM by systems of physical control of NRM;
- to automate NRM-access system control;
- to install portal monitors at sites, where works with NRM are carried out.

For solution of these problems promotes a cooperation of Russian and American nuclear laboratories in the field of strengthening of system of protection, control and accountability of nuclear materials in both countries.

In particular, within the framework of a program of cooperation between Los-Alamos National Laboratory (LANL) and RFNC-VNIITF by way of technical mutuality the transferring to VNIITF of two pedestrian portal and five hand-held monitors of nuclear materials (NM) for installation and use them at NM work site arrangement was achieved.

According to the arrangement VNIITF was to carry out test of monitors and give valuation of suitability and expediency of application of american equipment for portal monitoring of NM at russian nuclear facilities.

Two PM-700SP pedestrian portal monitors and five PRM-470A hand-held monitors PRM-470A, the characteristics of which are given below, were transferred for the tests to VNIITF.

1. MAIN TECHNICAL CHARACTERISTICS AND PRINCIPLES OF WORK OF PM-700SP AND PRM-470A MONITORS¹.

1.1. Pedestrian portal monitor PM-700SP.

The TSA PM-700SP pedestrian portal monitor for radiometric detection of special nuclear materials consists of two pillars $20 \times 56 \times 239 \text{ cm}^3$ size each. Typical distance between pillars is 66 cm. The pillars are installed on a horizontal place. The pillars are connected among themselves by two two-inch conduits. Weight of each pillar is about 180 kg. Monitors power supply is 90 \div 250 V ac at 50 Hz frequency. The monitors electronic blocks are supplied by built-in battery and due to that monitors functioning does not depend on fluctuations of supplying net voltage, including a break in power supply for a term not less than 12 hours. Normal time, designed for a pass through monitor is 0.5 sec.

Main functional units of a monitor are:

- Scintillating detecting blocks (assemblies) of gamma-radiation with plastic scintillators of large $\sim 8850 \text{ cm}^3$ volume each. Each pillar has two detecting blocks. The energy level at which system take counts can be set in the range of 40 keV to 2 MeV. To reduce the background radiation and increase the monitor's sensitivity the detecting blocks are equipped by lead shadow shielding on the rear and side surfaces;
- Each pillar contains portal monitor controller (SC-750). One of the controllers is master and the other is Slave. The controller serves for monitor's work control, its testing and alarm system control;
- Occupancy detector. In a given monitor model each pillar has infrared occupancy detector sensing the crossing by a person of monitor's working zone;
- Alarm lights and buzzer for indication of alarm signal and output of appropriate Sonalert.

The principle of work of a monitor lies in following:

After monitor is turned on, the controller enters the power-up diagnostics routine. The program runs a number of tests. If any these tests fails, an error code is displayed. In case of successful completion of diagnostics, in order to check the alarm system the Sonalert is activated. It will then go into background count mode.

A red LEDs at occupancy detectors illuminate on power up, and turn off after three minutes warm up, that indicate about the readiness of a monitor for work.

In unoccupied state the monitor regularly updates value of background level, following its changes. The sequential account of background in 5 second interval takes place. The current background level is calculated as a result of the most recent four average.

At a passage through the monitor of a person the occupancy detector is activated and transfers the monitor into the fast count mode. The continuous account with 0.2 sec interval begins. The collected account is calculated after each count of the most recent several intervals (from 1 up to 16; recommended is 5) and compared with alarm signal level. If the collected account exceeds a predetermined level (alarm condition is found) calculated under the formula:

$$AL = N \cdot \sqrt{bkg} + bkg \quad (1)$$

¹ The information contained in this section is of interest for the Russian enterprises, which are supposed to receive a part of the information about the results of monitors tests.

where: bkg - background counts,

\sqrt{bkg} - statistical error of background measurement (σ),

N - number of σ , determining the level of alarm signal activating,

then the alarm signal is activated (a red pulsing lamp and Sonalert) for 5 seconds.

1.2. Hand-held PRM-470A monitor.

PRM-470A monitor is a sensitive search device for hand-held check of pedestrians and vehicles for detection and localization of special nuclear materials (SNM). Its registering element is a scintillating detector with plastic scintillator sensitive not only gamma-radiation but to fast neutrons too. It is easy and simple in operation, has small electric power consumption (work period without batteries recharging is 60 hours).

When turned on, monitor's internal test for the check of the main electronic blocks of a device is started: RAM, real clock timer (RTC) and ROM. In case of any of these tests failes then error code is displayed. After successful completion of the internal tests the current sensitivity level (number of Sigmas) and 5 minutes warm-up period for high voltage stabilization begins. Then the device for 10 seconds begins background counting. At the end of measurement the background value measured (number of counts per) is displayed. After background measurement the device goes into SEARCH mode.

In a search mode the current background level is saved and the device each 50 milliseconds measures and compares speed of pulses account with background level. For background comparison the most recent eighth 50 milliseconds intervals average account speed level is used. If an average level measured exceeds the alarm level then a short sound signal is given. Sound signals frequency depends on radiation intensity.

Besides the main mode (SEARCH MODE) in the device the mode background measurement (BACKGROUND MODE) is present. In this mode background changes are displayed constantly changing background accounts. The background is accumulated for 32 seconds. Average speed level of background pulses account is displayed. At entering the search mode the last measured background level is stored.

2. PROCUREMENT AND INSTALLATION OF PEDES RIAN PORTAL MONITORS.

After delivering of the equipment to VNIITF the incoming control with the purpose of to check the serviceability of the equipment after transportation was carried out. Acquainting with the equipment, training of the employees to work with it, the preliminary calibration were carried out in laboratory conditions.

At monitors survey the damages which could arise at transportation were not found.

Before the power turn on the DIP-switches sets were checked according to section 2.1.10 of the description. They corresponded the recommended.

During incoming control the following malfunctions were noticed:

- At one of the detectors there was no signal. After opening of a casing of discriminator it was found out that one of wires was not soldered to the leave of a signal plug;
- Because of socket contact damage an amber alarm lamp was not lighted.

The monitors calibration was performed according to section 4.5 of the description.

For monitors installation the Entrance Control Point (ECP) of RFNC-VNIITF experimental department working site was chosen, where works with nuclear and radioactive materials (high-enriched Uranium, Plutonium, low-enriched Uranium, ^{137}Cs , ^{60}Co , products of activation and decay) are carried out, as well as their storage is performed.

The specified site is not equipped by any other ECPs. Therefore after monitors installation the control all working personnel will be performed.

The scheme of portal monitors allocation is shown in Figure 1.

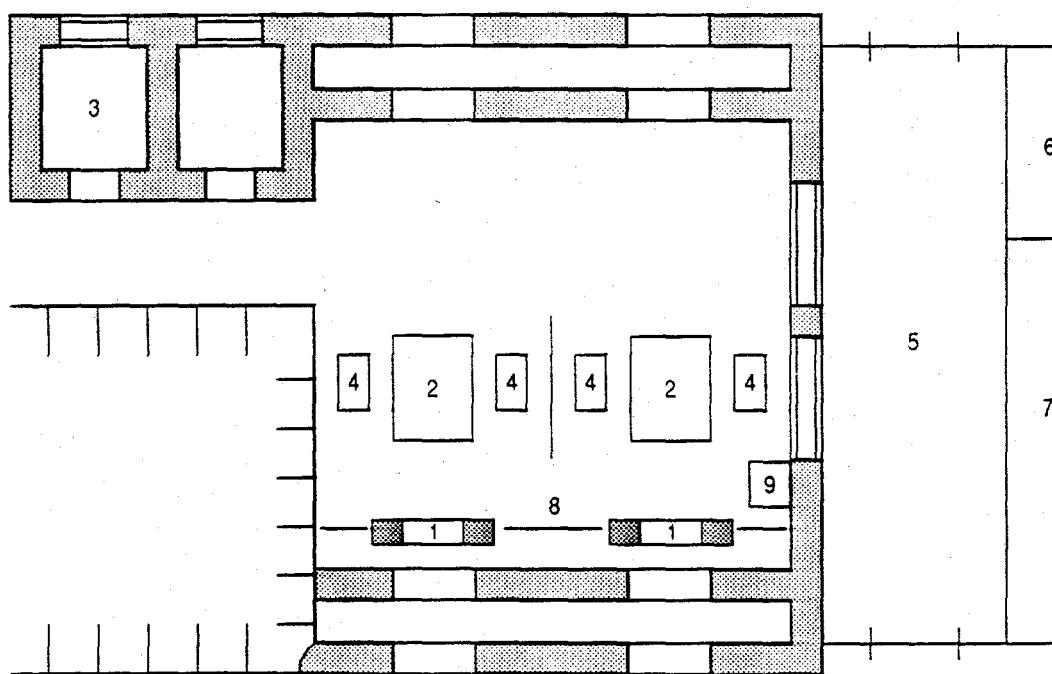


Fig. 1. The scheme of portal monitors allocation at ECP:

1. portal monitors;	6. safeguard zone boundary;
2. personnel identification equipment;	7. work site territory;
3. individual inspection room;	8. disciplinary fence parts;
4. safeguard subdivision personnel;	9. switching equipment.
5. vehicle inspection zone;	

Photos of portal monitors installed at ECP are shown in Figures 2 - 7.



Fig. 2. The Entrance Control Point (ECP) before portal monitor installation (view 1).



Fig. 3. ECP after portal monitor installation (view 1).

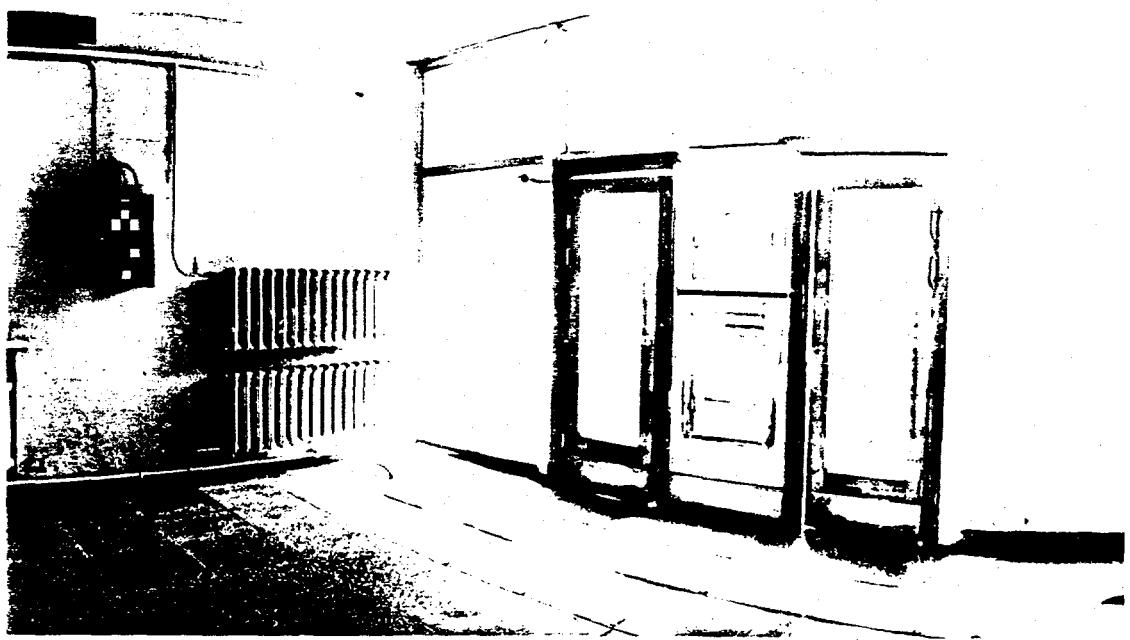


Fig. 4. ECP before portal monitor installation (view 2).



Fig. 5. ECP after portal monitor installation (view 2).

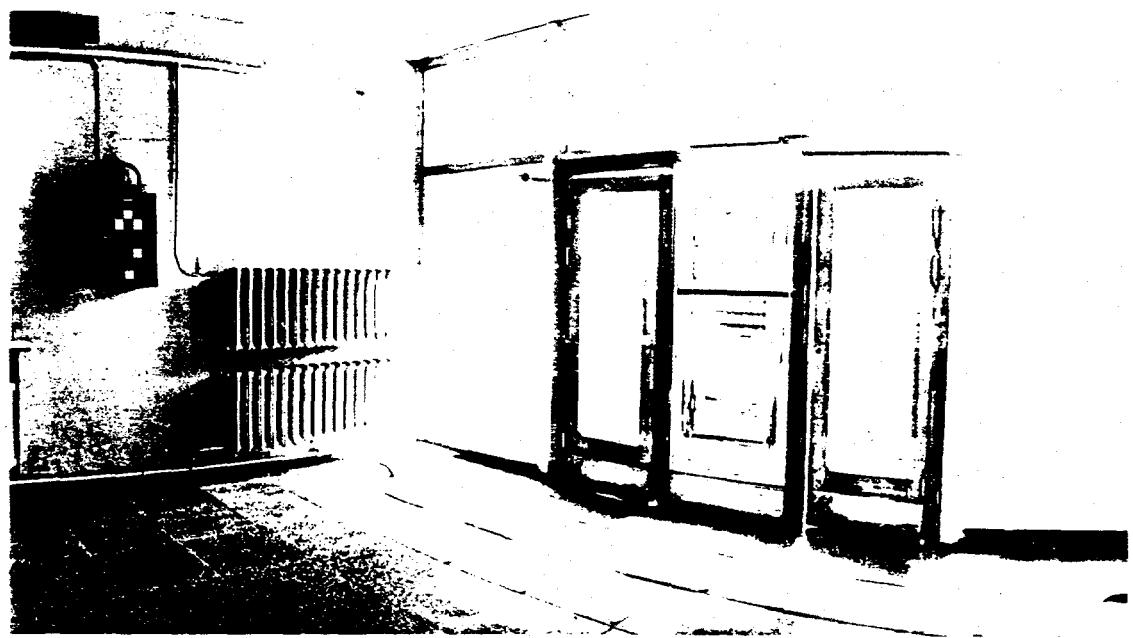


Fig. 4. ECP before portal monitor installation (view 2).



Fig. 5. ECP after portal monitor installation (view 2).

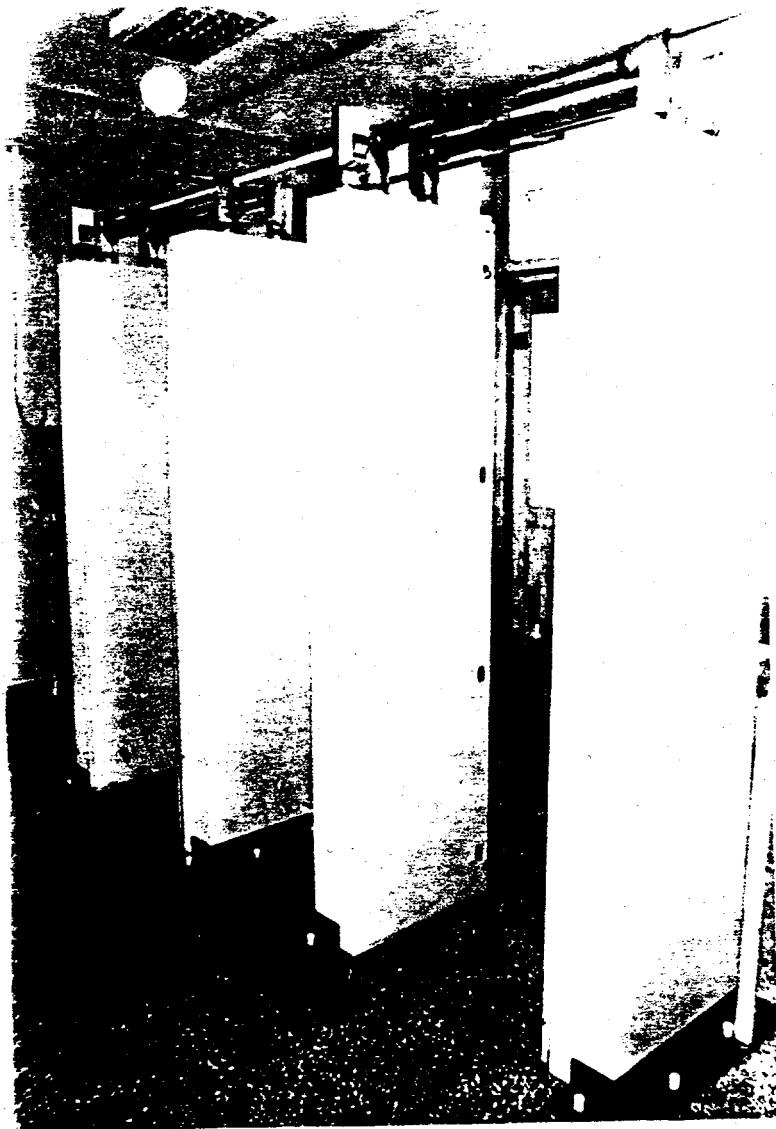


Fig. 6. Portal monitors PM-700SP (right-side view).

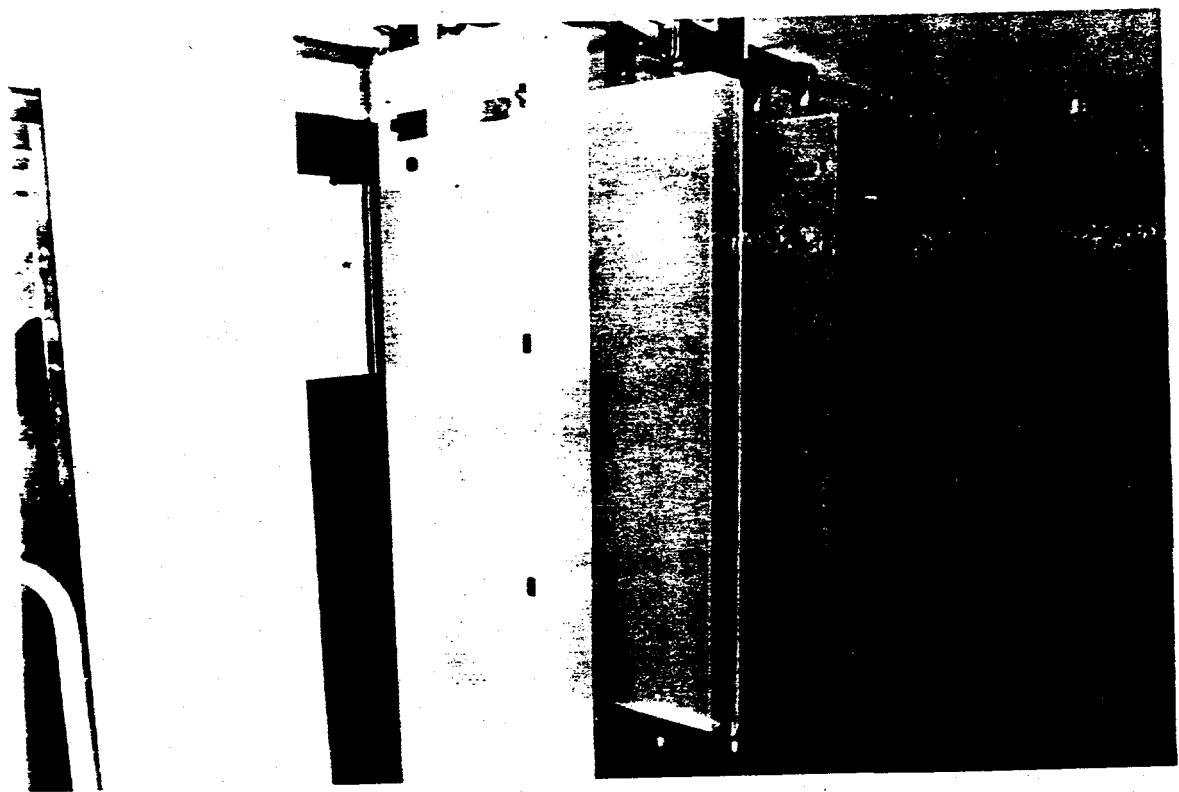


Fig. 7. Portal monitors PM-700SP (left-side view).

3. TEST OF MONITORS.

The purpose of pedestrian portal monitors tests is:

- In valuation of minimum detectable amounts of nuclear and the most frequently in VNIITF practice radioactive materials met at carrying them through ECP as without protection, as in protecting containers and packages;
- In check of monitors operation stability;
- In research of background fluctuation and this factor influence on the operational characteristics of the equipment;
- In comparison of sensitivity of American portal monitors and being at presence Russian-made radioactive materials monitors.

The tests were performed in 20...30 °C temperature mode conditions with lowered humidity.

3.1. Valuation of minimum-detectable amounts of nuclear materials.

The monitors sensitivity to nuclear and radioactive materials was checked up directly at ECP in those conditions, in which monitors will operate.

For the tests were chosen 90%-enrichment Plutonium samples in a kind of:

- small disks and cylinders 1 to 300 g weight;
- cylindrical bi-oxide Plutonium samples (PuO₂) 0.6 to 10 g weight;
- low-enriched Uranium disks ~ 20 mm diameter;
- a set of reference gamma sources ²⁴¹Am, ¹³⁷Cs, ⁶⁰Co, ¹³³Ba.

Am contents in Plutonium samples at a moment of tests performed was about 0.2 % (2000 ppm).

During the tests realization process the degree of decrease of monitors sensitivity at allocation of materials in protecting containers and packages was evaluated. Small-sized lead containers with 0.5 and 1.0 wall thickness were for this purpose were used. At measurements with enriched Uranium an additional sheet lead 0.1 and 0.2 thickness was used.

Monitors sensitivity was evaluated proceeding from criteria recommended by being present in our disposal American manuals [1 ÷ 3]. In them the sensitivity is determined as a quantity of special nuclear materials registered with probability of 50% at 95% degree of reliability. The number of operations corresponding the specified probability at a number of passes from 5 to 30 is also presented in these manuals. While realizing the tests we have decided that each test will include ten passes with samples through a monitor. In this case, if the number of operations of a monitor is not less then 9, than the registration probability will exceed 50% level at 95% reliability degree. The results of monitors sensitivity measurements are shown in tables 1-4. According to recommendations of the American manual during the measurements with the samples (sources) without protection they were put in a footwear at the internal part of the ankle. The measurements in protecting containers were performed at location of containers on a body at belt level.

Table 1. Results of sensitivity measurements of monitors PM-700SP for gamma-sources.

Source	Activity, Bk	Number of operations					
		Monitor 1			Monitor 2		
		Protection thickness, cm			Protection thickness, cm		
		-	0.5	1.0	-	0.5	1.0
¹³⁷ Cs	$1.1 \cdot 10^5$	10	10	10	10	10	10
²⁴¹ Am	$1.0 \cdot 10^5$	0			0		
²⁴¹ Am	$2.1 \cdot 10^5$	2			7		
⁶⁰ Co	$8.0 \cdot 10^4$	10			10		
¹³³ Ba	$\sim 10^3$	0			0		

Table 2. Results of sensitivity measurements of monitors PM-700SP for Plutonium dioxide samples.

Sample number	Weight, grams	Number of operations					
		Monitor 1			Monitor 2		
		Protection thickness, cm			Protection thickness, cm		
		-	0.5	1.0	-	0.5	1.0
1	0.6	10	4	0	10	1	0
2	0.7		6			3	
3	1.23		10	1		9	0
4	1.93			1			1
4 [*]	1.93			4			5
5	2.44			3			1
5 [*]	2.44			7			2
6	3.14			1			5
6 [*]	3.14			10			8
7	4.14			10			5
8	5.37			10			10

Notes:

1. PuO₂ sample of 0.6 g weight was packed into the cadmium cover 0.5 mm thick.

2. With the samples which numbers are labeled ^{*)}, the additional measurements were carried out at location of protecting containers in the pocket.

Table 3. Results of sensitivity measurements of monitors PM-700SP for high-enriched Uranium samples.

Sample number	Weight, grams	Number of operations									
		Monitor 1					Monitor 2				
		Protection thickness, cm					Protection thickness, cm				
		-	0.1	0.2	0.5	1.0	-	0.1	0.2	0.5	1.0
1	1.2	9					6				
2	5.0	10					10				
3	61		10	6				10	4		
4	106			4					5		
5	142		10	10	0			10	10	2	
6 ^{*)}	142				3					1	
7	203				3					1	
8	248				4					5	
9	290.2				6					4	
10	312				9					10	
11	409					4					7
12	454					9					8

Note:

The sample № 6 labeled ^{*)} during the measurements was located in the pocket.

Table 4. Results of sensitivity measurements of monitors PM-700SP for low-enriched Uranium samples.

Sample number	Weight grams	Number of operations					
		Monitor 1			Monitor 2		
		Protection thickness, cm		Protection thickness, cm			
		-	0.5	1.0	-	0.5	1.0
1	5.2	0			0		
2	13.7	0			5		
3	21.5	8	0		10	0	
4	245		10			10	
5	490			8			10

The measurements with sources which results are listed in table 1, were not intended for sensitivity determination and were of valuating purpose.

By the results of measurements indicated in the tables (2 ÷ 4) it is possible to make the following conclusions about the monitors sensitivity:

1. In case of unprotected samples the sensitivity is:

- For Plutonium - not less than 0.5 g;
- For high-enriched Uranium - about 2 g;
- For low-enriched Uranium - about 20 g.

2. When Plutonium samples are surrounded by the lead protection 0.5 cm thickness then the sensitivity drops to ~1.5 g, and when the protection is 1.0 cm then to 5.0 g;

3. When high-enriched Uranium samples are surrounded by the lead protection 0.1 cm then the sensitivity is evaluated by ~ 60 g; At 0.2 cm lead thickness it will be ~ 140 g; At 0.5 cm lead thickness ~ 300 g; At 1.0 cm lead thickness ~ 500 g.

4. When low-enriched Uranium are surrounded by the lead protection 0.5 cm thickness then the sensitivity is evaluated by ~ 250 g; At 1.0 cm lead thickness ~ 500 g.

The data received as a result of sensitivity measurements of tested monitors (according to american standards) permit to relate them to the third category of sensitivity (improved sensitivity) that corresponds to the PM-700SP monitor description.

During the fulfillment of monitors sensitivity valuation work the distributions of monitors sensitivity on their working volume were measured with the help of ^{137}Cs and ^{241}Am sources. The scheme of points location in which the sensitivity measurements were performed is shown in Figure 8. The measurements were performed in cross planes at 0.1 m, 1.2 m and 1.75 m distances from the floor (1.2 m distance corresponds to a belt level and 1.75 m corresponds to a head of the average person level).

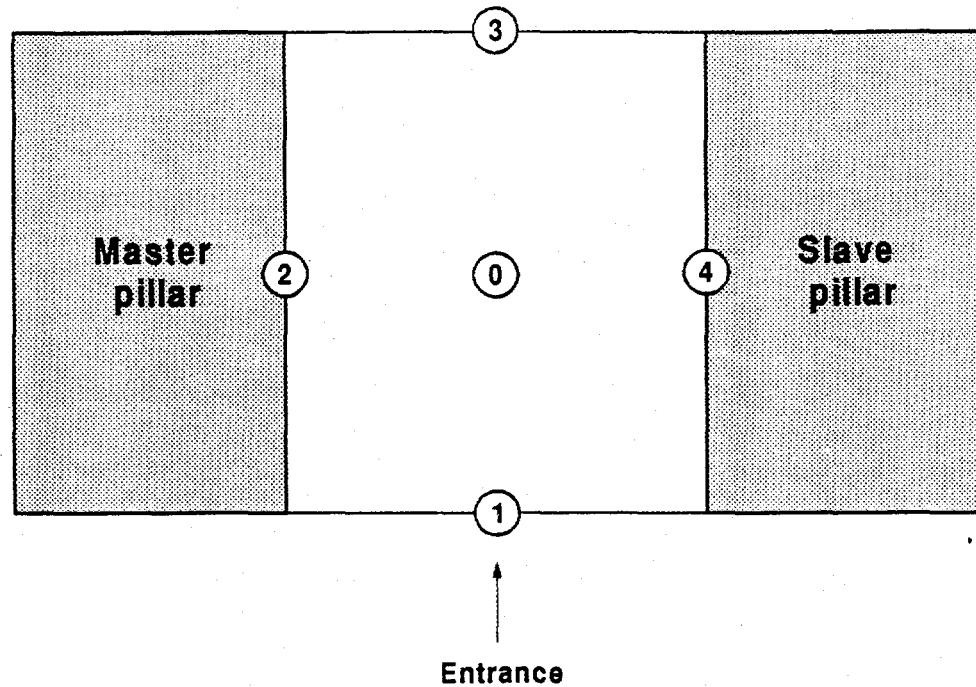


Fig. 8. The scheme of location of points of measurements in monitor cross plane.

The result of sensitivity distribution measurements on monitors working volume is listed in table 5.

Table 5. Sensitivity distribution on monitors working volume (relative units).

Source	Moni- tor №	Number of points														
		Plane 1 (0.1 m)					Plane 2 (1.2 m)					Plane 3 (1.75 m)				
		0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
²⁴¹ Am	1	0.68	0.32	1.51	0.62	1.40	1	0.77	0.93	0.73	1.12	0.91	0.84	2.52	0.56	2.32
	2	0.56	0.34	1.01	0.55	1.36	1	0.75	1.20	0.83	1.20	0.69	0.66	1.55	0.42	1.31
¹³⁷ Cs	1	1.08	0.68	1.97	1.00	1.89	1	0.72	1.31	0.85	1.33	0.74	0.68	1.63	0.47	1.33
	2	1.08	0.65		1.02		1	0.79	1.29	0.87	1.36	0.78	0.82	1.73	0.51	1.44

Notes:

1. Results of efficiency measurements of registrations for ^{241}Am and ^{137}Cs , are listed in table 5 in relative units. For the unit are taken efficiencies in "0" points (plane 2) located on a vertical axis at 1.2 m distance from a floor.
2. Registration efficiencies attitude of ^{241}Am and ^{137}Cs sources per unit of activity in the monitors central area is ~ 2.5 .

As it is visible from table 5, the most adverse variant the control is the location of a source in the ankle and head areas. The reduction of the efficiency in these cases in comparison with maximum significance is $(20 \div 30)\%$.

3.2. Check of monitors operation stability.

The check monitors operation stability was performed during experimental operation for a month. In this period (three times a day) monitors background indications were recorded daily, as well as monitors operation at etalone gamma-source ^{137}Cs of $\sim 10^5$ Bk presence (that is equivalent to ~ 4 g enriched Uranium passage through) was checked up.

The check of operation at a source passage through was performed for each monitor 41 times. In all cases at a source passage through the Sonalert and alarm light system were activated.

From the analysis of the monitors background indications follows that maximum non-correlated with one another changes of the monitors indications during experimental operation were $\sim 10\%$ part of the background level average. The algorithm realized in monitor at such operation instability excludes appreciable change of its sensitivity. The specified instability can become only a reason of the false operations.

3.3. Research of influence of background fluctuations on monitors operation.

Background fluctuations can make an essential influence on the operational characteristics of radiation monitors. They can result in an essential increase of the number of false operations and make difficult monitors operation. Increase of background level leads to the reduction of the monitors sensitivity.

The purpose of researches, which were performed during experimental operation was in reception of background fluctuations level data, as well as in studying of nuclear-physical facilities (being present at VNIITF experimental department territory) influence on monitors operation.

Monitors background indications changes curves in a period since June 21 to July 20, 1995 are shown in Figure 9 in relative units.

As it is visible from Fig. 9, a background level at monitors installation place can be considered practically constant.

* For study of nuclear-physical influence on monitors operation the static start-ups of IGRIK solution reactor [4] at rated power ~ 20 KWt were made, as well as a pulse generation of ~ 4 milliseconds duration and ~ 30 megajoules power flux was made.

At a static mode reactor functioning, at a place of monitors installation there were no background changes noticed.

~ The reactor functioning in a pulsing mode has resulted in operation of a monitor at a person pass through at a moment of pulse. Here the restoration of a background level has taken place for less than one minute.

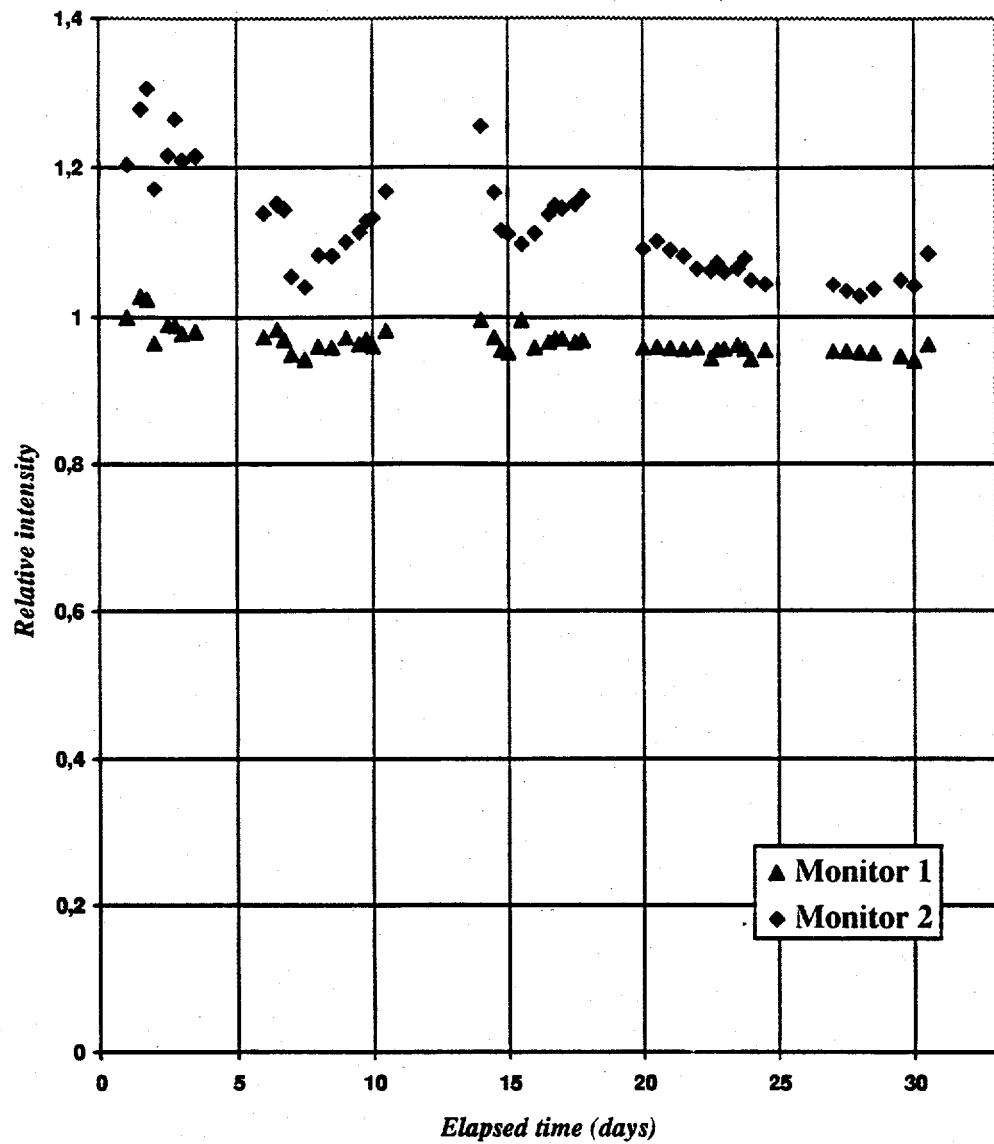


Fig. 9. Diagram of the change in monitor sensitivities during test operation.

During monitors tests realization process an attention was paid to increasing frequency of false operations at mass people pass through ECP and at monitors survey by site visitors. It is supposed that the reason of false operations is in background level changing at monitor's pillar surrounding by the people. This assumption was experimentally confirmed. At one of monitor's pillars surroundings by several persons the appreciable reduction of the monitor background indications was observed, and at their going from a pillar at a person pass through monitor moment a monitor operation has taken place. For the exception of false operations stipulated by this reason the disciplinary protections excluding people congestion monitors pillars were installed.

As it was marked above, the increasing of background level can result in reduction of monitors sensitivity.

To check the background level influence on monitors sensitivity a gamma-radiation detector was placed near one of them in such a way that background level for this detector has grown three times in comparison with being present. Tests with sample of low-enriched Uranium 490 g

weight in a protective lead container 1 cm thickness have shown, that appreciable change of monitor's sensitivity has not taken place.

Thus the main negative factor causing the false monitors operations is the reactor's work in a pulsing mode. However, as has shown experience the nuclear-physical facilities functioning does not create appreciable difficulties in monitors operations.

3.4. Comparison of sensitivity of PM-700SP monitor and radiometric device SRPS-2.

The most suitable of being present in our disposal Russian-made radiometric equipment on the basis of which pedestrian and vehicle portals can be assembled is radiometric device SRPS-2 [5]. It is intended for mixed neutron and gamma-radiation registration and signaling about excess of predetermined level of radiation. There are different modifications of a specified device distinguished by a complete set of detectors. We had in our disposal a device which was equipped by gamma-radiation detecting block with NaI (Tl) crystal 63 mm diameter and 63 mm height, as well as by a sensitive block of neutrons detecting on the basis of proportional counters filled by ^3He . Sensitivity of a device to spectrum decay neutrons is ~ 100 pulses per second at neutrons flow density in detecting block location - $1 \text{ n/cm}^2 \text{ sec}$.

Comparisons of sensitivities of radiometric device SRPS-2 and pedestrian portal monitor PM-700SP which were made with the use of high-enriched metal samples show, that at samples pass through in a pocket the sensitivity of specified devices is about identical and it is $\sim 2 \text{ g}$. If the sample is located in an ankle region, the SRPS-2 sensitivity drops proportionally to square of a distance between detector and the sample, i.e. about 40 times.

Inclusion of a neutron detector in a structure of pedestrian portal monitor on our sight is inexpedient, since the advantages of a given detector begin to be appeared at detection of Plutonium samples ($50 \div 100$) g weight well shielded by a lead. At $\sim (4 \div 5) \text{ cm}$ lead thickness the container will have large weight and it is impossible to carry it through unmentioned.

High-sensitivity neutron detector is expediently to include in a structure of a vehicle portal monitor for revealing of cases of transportation of well shielded Plutonium samples.

One of the constructive defects of SRPS-2 device is the absence of automatic tracking of background level.

3.5. Test of PRM-470A hand-held monitors.

For tests and valuation realization LANL has transmitted to VNIITF five PRM-470A hand-held monitors.

After monitors procurement they were checked according to the descriptions enclosed. All monitors have appeared in a serviceable condition.

In a fixed geometry with the sample gamma-sources ^{241}Am , ^{137}Cs , ^{60}Co a relative comparison of monitors efficiencies for various energy gamma-radiation was performed. The distance from a source up to a surface of a detector was equal to 20 cm. The results of measurements are listed in table 6.

Table 6. The results of comparison of monitors efficiencies depending on gamma-quantum energy.

Source	Efficiency of a monitor (number of counts per 10^4 γ -quantum's of source)				
	M1	M2	M3	M4	M5
^{241}Am	21.7	21.1	25.5	11.1	29.4
^{137}Cs	32.0	28.7	29.9	28.2	32.2
^{60}Co	24.7	24.7	25.5	22.6	26.8

Note:

An error of sensitivity measurements at measurements with ^{241}Am was $\sim 10\%$, and $\sim 5\%$ for the other sources of gamma-radiation.

As it is visible from table 6, all monitors has close sensitivity characteristics. It pays on self attention the lower sensitivity of the fourth monitor to ^{241}Am gamma-radiation. It can depend on a higher discrimination level of a peak discriminator.

One of hand-held monitors was tested for search and localization of special nuclear materials samples on a body of a person. The work was conducted with bi-oxide Plutonium samples 0.6 g weight, metal high-enriched Uranium 1.2 g weight, low-enriched Uranium 21 g weight. The samples one by one were put into a pocket and then pursuant to described in manual recommendations their detection with the help of a hand-held monitor was performed.

The detection of mentioned above samples on a body did not cause difficulties. For enriched Uranium and low-enriched Uranium samples localization the use of sound signal became convenient. Being guided by signals frequency we localized the specified samples within 10 cm limits. For Plutonium sample localization it was necessary to use display indications as for as at significant distance from the sample a sound signals frequency reached a maximum and did not vary at approach to a source.

The monitors indications are shown in the table 7 at its location at various parts of a body. The samples in all cases were placed in a left-hand lateral pocket.

Table 7. Account speed measurement of PRM-470A hand-held monitor at nuclear materials samples detection.

Sample	Account speed of a monitor			
	Monitor location			
	Breast	Back	Left pocket	Right pocket
PuO ₂ (0.6 g)	130	130	3900	150
²³⁵ U (1.2 g)	130	130	420	130
²³⁸ U (26 g)	130	130	450	
PuO ₂ (0.6 g) + Pb (2 mm) protection	130	130	1300	
²³⁵ U (1.2 g) + Pb (2 mm) protection	130		130	
²³⁸ U (26 g) + Pb (2 mm) protection	130		300	

Note:

In table 7 rough values close to average values of account speed of hand-held monitor are indicated.

As follows from table 7, samples of ~ 0.01 g weight Plutonium, ~ 0.2 g weight high-enriched Uranium, ~ 4 g weight low-enriched Uranium can be detected by hand-held monitor.

At the availability of lead protection ~ 2 mm thickness detectable Plutonium weight is ~ 0.03 g, low-enriched Uranium weight is ~ 8 g. 1.2 g weight high-enriched Uranium in such can not be detected.

4. EXPERIMENTAL OPERATION OF PORTAL MONITORS.

The experimental operation of portal monitors was performing for a month in a period since June 21 to July 20, 1995. During this period monitors worked round the clock. At working hours at ECP the experts were on duty. All cases of monitors operation were recorded and the reasons of these operations were found out. Monitors background indications were recorded regularly (three times a day). Once a day the check of monitors operation at ^{137}Cs gamma-radiation source was performed.

For a specified period 20 operations were registered. In one of them it was found out that as the reason of operation the old on-hand watches with lighting dial became, in an other case it was compass, which had one guard from safeguard service. There were no any other failures or any other equipment deviations from normal operation.

During experimental operation the PM-700SP monitors constructive defects were revealed, on which we wanted to pay attention:

- At switching-off or breakage of an occupancy detector alarm wire a monitor is operable externally but it discontinue completely the registration of nuclear materials and radioactive. At the existing design the switching-off of the alarm wire can be made from outsides and unnoticed. To avoid it, it is necessary to place the wires connected to the occupancy detector into a metal conduit or to place the detector into detector cabinet as it is made in a vehicle portal monitor VM-250. The best way is to perform the continuous control of an occupancy detector alarm wire integrity with external alarm system initiation at its breakage.
- In delivered to VNIITF monitors the switching-off of the third or fourth detectors does not result in external alarm system initiation, though the monitor sensitivity is appreciably reduced so. It is possible to save monitors working ability control if to increase essentially the account bottom level of amber lamp initiation. With the purpose of exception of appreciable change of monitor sensitivity while in service it is desirable to reduce also the top detectors account at amber lamp lights up. We recommend the following: a low account speed level ~ 512 counts per second; a top account speed level ~ 2048 counts per second. At new monitors development period in order to increase the monitors reliability it would be useful to install in them a system of internal testing of a detecting system, for example, with the help pulsing LED indicators. Amber lamp initiation indicating that pulses account speed has exceed the predetermined limits it is desirable to accompany it by a sound signal, because of amber lamp initiation can be unnoticed for safeguards.
- As for our opinion, the PM-700SP monitors are needed to be equipped by the additional external alarm system indicating that the monitor is in operating state. In monitors, that were installed in VNIITF it is possible to make conclusions about this fact only on occupancy detector operation at a moment person passage. At spontaneous monitor switching-off the safeguard personnel may not pay attention in a due time.

5. PROBLEMS ENCOUNTERED DURING WORK REALIZATION.

The were no any considerable difficulties at this work realization. There were some deficiencies:

- Red tape in Moscow airport "Sheremetyevo" with registration of the documents and delivering of pedestrian portal monitors to VNIITF;
- Delay of payment for performed work on 2 and 3 stages.

These deficiencies are eliminated. The hand-held monitors were sent to us through Ekaterinburg. Registration of their documents and their delivering to VNIITF have occurred without difficulties. The bills for the performed work were paid up.

THE CONCLUSION

PM-700SP pedestrian portal monitors tests results, as well as PRM-470A hand-held monitors tests results A have shown, that the specified American-made equipment for portal monitoring of special nuclear materials meets all requirements, which are required to such type equipment. This is high sensitivity, reliability, stability, simplicity in operation. PM-700SP pedestrian portal monitors insensitive to voltage changes in a supplying net. Their installation at ECP has not practically lowered its throughput. PM-700SP portal monitors installation and operation at RFNC-VNIITF experience has shown, that they can be successfully applied at Russian nuclear facilities.

The limitation of monitors of PM-700SP type application can be because of insufficient under the existing control and accounting of nuclear materials sensitivity requirements of specified monitors for high-enriched Uranium in protecting packages. For close to spherical metal high-enriched Uranium samples, placed in a lead cover ~ 1 cm thickness the PM-700SP monitors sensitivity is ~ 500 g.

VNIITF is interested in the further cooperation as with American nuclear laboratories, as with the private companies for the further development and introduction of portal technology with the purpose of improvement of a system of protection of nuclear materials as in VNIITF, as at branch enterprises located in our region. Our institute is ready to participate in portal monitors enriched Uranium pass-through in protecting packages detection development, taking into account, that the being present monitors for this purpose are not enough effective.

We consider that it is necessary to perform vehicle portal monitors tests during autumn-winter period in our region. VNIITF will perform this work successfully.

We offer also:

- To perform the adaptation of pedestrian and vehicle design documentation developed by american laboratories;
- To assembly the experimental samples in VNIITF using American technology, American furnishes partially and Russian-made (VNIITF-made also) furnishes partially and to calibrate them jointly;
- To install this portal equipment at VNIITF facilities.

We believe, that the cost of portal monitors made in such a way may be considerably lower because of transport charges reduction, smaller customs taxes, cheaper labor and a number of other factors probably.

Video tape with the record of working episodes of the jobs being performed by the contract and floppy disk with the text of report in Russian and English languages (in accordance with the contract) are enclosed to the report.

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