RESULTS OF THE INTEGRATED RADIATION DOSE MEASUREMENTS ON THE "SOYUZ" SPACESHIPS

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I. Introduction

In the manned spaceships "Soyuz" integrated radiation doses at different points of cosmonaut's body were determined in addition to dose rate measuring in the modules of the vehicle. This control is due to the following factors during a space flight:

- there is a dose field gradient inside the spaceship due to non-uniform protection of the modules. The crew moves along the modules and passes from one compartment into another;
- mutial cosmonauts' shielding as well as self-shielding of separate parts of the body due to their staying in the limited size of the module takes place;
- in accordance with the programme of the flight cosmonauts can leave the vehicle and go out into space.

So during the flight of the orbital station "Soyuz-4" and "Soyuz-5" the cosmonauts Khrunov E.V. and Elisyeev A.S. left their spaceship "Soyuz-5" and passed through the open space to "Soyuz-4".

This factors bring about a difference in the cosmonauts' individual radiation dose during flight. This difference occurs in both different cosmonauts and in separate parts of the body of the same cosmonaut.

II. Personal radiation monitoring

Personal radiation monitoring in the spaceships "Soyuz" was performed by passive dosimetry package (Fig.1). Every package contained thermoluminescent glass dosimeters'

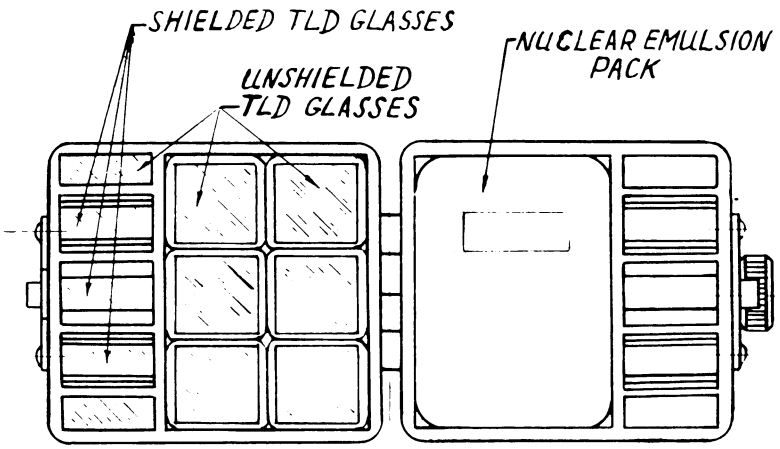

Fig. 1.
The passive dosimetry package

of two types and nuclear emulsions of four types[2,3] .
Thermoluminescent dosimeters used in this experiment had the following composition (according to the weight)[4] :

P_2O_5 - 80.0%
Al_2O_3 - 9.5%
MgO - 10.5%
Mn_3O_4 - 0.1 (over 100%)

Similar dosimeters were used earlier for measuring individual radiation doses of the cosmonauts on the spaceships "Vostok" and "Voskhod".[5-8]
The packages were located in the pockets of the cosmonauts' constant-wear garment at the following three points: on the chest, on the right side and on the right thigh.
The thermoluminescent glass dosimeters in the form of plates (by the size of 13 x 13 x 4 mm^3; 6 dosimeters in every package) and cylinders (diameter - 5 mm; height - 15 mm; 5 dosimeters in every package) were used on the spaceships "Soyuz".
Cylindrical dosimeters were shielded with the following filters: 2 mm Al ; 0,6 mm Sn + 0,5mm Al ;0,6mm Cd +0,5mm Al.
These dosimeters and the readout system technique provided dose measurements in the range of 5.0 millirads-5000 rads

with the accuracy ± 15%. The accuracy of low dose measurements (20 to 50 millirads) was ± 30%. The previous experiments show that tissue dose values determined by thermoluminescent glass dosimeters for proton radiation in the energy range of 20-660 Mev are well correlated to the tissue dose values for gamma radiation in the energy range of 0.05 - - 1.25 Mev.

In order to evaluate spectral distribution of the different components in the corpuscular cosmic radiation the methods utilizing nuclear emulsions with different sensitivities have been applied[3] . Each package contained emulsions of four types with different threshold sensitivities towards LET. Each emulsion registered all the particles whose linear energy transfer exceeded certain sensitivity threshold. Sensitivity threshold of the emulsions was determined using LET of the known charged particles which make tracks with grain densities distingwished at the background of fog[9] .

As it was shown[10] the assembly of these emulsions with various sensitivity allows to estimate linear energy transfer radiation spectrum in the range determined by minimum and maximum sensitivity thresholds of the emulsions.

III. Results

Data from the thermoluminescent.glass dosimeters were obtained immediately after the mission. The dispersion of the dosimeter data in one package was not more than ± 10%. Insignificant differences among the data of shielded and unshielded dosimeters were found in any measurements.

Individual dose values obtained by the thermoluminescent glass dosimeters are presented in Table 1.
The density flux of the corpuscular radiation in various LET ranges are given in Table 2.

The individual doses to the cosmonauts obtained as a result of these measurements corresponded to the data from the board dosimeters[11] enable us to estimate the radiation situation in the spaceships "Soyuz".

TABLE 1

"Soyuz" millirad doses from the individual cosmonaut dosimeters

Spaceship	Launch data day/mo/yr	Cosmonaut	Flight duration (days)	Location			Average dose rate mr/day	Note
				chest	right side	right thigt		
SOYUZ-3	26.10.1968	Beregovoy G.T.	4	85	85	-	21.2	
SOYUZ-4	14.01.1969	Shatalov V.A.	3	60	54	63	20	
		Volynov B.V.	3	75	67	-	23.6	
SOYUZ-5	15.01.1969	Yeliseyev A.S.	2	61	56	71	31.5	1 hour
		Khrunov Ye.V.	2	65	48	70	30.5	EVA
SOYUZ-6	11.10.1969	Shonin G.S.	5	64	66	87	14.4	
		Kubasov V.M.	5	61	58	87	14.0	
		Filipchenko A.V.	5	65	72	67	13.6	
SOYUZ-7	12.10.1969	Volkov V.N.	5	61	56	57	11.8	
		Gorbatko V.V.	5	62	63	66	12.8	
SOYUZ-8	13.10.1969	Shatalov V.A.	5	80	61	77	14.2	
		Yeliseyev A.S.	5	not used			-	
SOYUZ-9	1.06.1970	Nikolayev A.G.	18	222	240	250	13	
		Sevastyanov V.N.	18	385	390	448	22.6	

Table 2

Particle fluxes (particles/$cm^2 \times 10^{-5}$) in different LET ranges measured by nuclear emulsions on the "Soyuz" spaceships

Spaceship	LET range (Mev/cm)			
	$\geqslant 5$	$\geqslant 18$	$\geqslant 80$	$\geqslant 400$
Soyuz-4	2.1	1.4	0.25	0.03
Soyuz-5	2.0	1.5	0.3	0.03
Soyuz-6	2.6	1.9	0.13	0.01
Soyuz-7	2.4	1.7	0.12	0.01
Soyuz-8	2.5	1.8	0.12	0.01
Soyuz-9	x)	2.2	0.4	0.1

x) Highly sensitive emulsions exposed in the flight of "Soyuz-9" had significant background hindering flux count in this range.

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DISCUSSION

Paper : Results of measuring integral radiation doses aboard Soyuz space craft

JENKINS : Doses to the cosmonauts on the same flights are fairly uniform except for Soyuz 9, where one cosmonaut received almost twice the dose of the other. Can you explain this difference?

MARKELOV : The difference in doses received by cosmonauts of Soyuz 9 orbiting the Earth for 18 days could be attributed to the cosmonauts' staying in different space-ship modules for considerable periods of time during the mission.

HUMPHREYS : Could you give more information on the two types of thermoluminescent dosimeters used and comment on the difference, if any, in the results obtained.

MARKELOV : For Soyuz space ships thermoluminescent glass dosimeters of two different shapes were used, namely plates and cylinders. The cylinder dosimeters were shielded by filters and plate dosimeters were not. No significant difference in measurements between the two types of dosimeters were observed.

PORTAL : Je désirerais vous poser une question au sujet de l'utilisation des émulsions nucléaires à seuil de sensibilité différentiel.

Nous avons nous-même utilisé ce principe et en avions présenté les résultats au Congrès international sur la protection auprès des accélérateurs, qui s'est tenu à Paris (en 1962 si mes souvenirs sont exacts).

Nous avions alors observé que le seuil de sensibilité de certaines émulsions nucléaires variait avec la durée de conservation avant leur utilisation.

Avez-vous observé cette difficulté dans vos expériences?

MARKELOV : The nuclear emulsions used in our experiments have a storage period of up to 3 months. It has been found by calibration that during this period no significant changes in sensitivity threshold take place.

BRAUN : My question concerns the various kinds of radiation, so the per cent of electron-, proton- and γ radiation.

MARKELOV : The proton flux was the main contributor to the dose delivering about 95%. The contribution of electrons was up to 5% and of heavy particles (with LET greater than 440 MeV per cm of emulsion) was less than 1%.

ALLKOFER :

1) Is the variation of the measured dose between 10 and 30 mrad due to the solar modulation of primary cosmic radiation or are there other reasons?

2) Your measured dose is relatively low in comparison to the doses at SST level. Have you an explanation for this? I would expect a higher dose-rate in free space although we have at the SST level electrons, muons, and neutrons in addition to the protons.

MARKELOV :

1) The solar modulations constitute one of the reasons for variations in the measured doses. The other could be the difference in shielding between individual dosimeters.

2) On the basis of dose measurements conducted aboard space ships "Vostok", "Voskhod" and "Soyuz" we can consider the dose

FULLER: I can make a comment which reduces the apparent discrepancy between SST and spacecraft dose-rates which Prof. Allkoffer has pointed out -- if he is referring to our SST dose-rates. First our dose-rate is about 2 mrem per hour -- not mrad and for this figure a QF of 1.5 was used. Then there has been a considerable build-up of neutrons at SST altitudes which would not be present in space. Lastly, our measurements refer to the situation of a solar minimum whereas the space rates were obtained during a quiet period at solar maximum.