AIRCREW RADIATION EXPOSURE ASSESSMENT FOR YUGOSLAV AIRLINES

Dragoljub Antić[1], Žika Petrović[2]

[1]Institute of Nucl. Sciences "Vinča", P.O.Box 522, 11001 Belgrade, Yugoslavia

[2]Yugoslav Airlines (JAT), Bulevar umetnosti 16, 11001 Belgrade, Yugoslavia

INTRODUCTION

Cosmic-ray neutrons are produced by the interaction of galactic cosmic radiation with magnetic-field-bearing plasma cloud emitted from the sun (solar wind) and with the atmosphere. This neutron radiation varies with altitude, geomagnetic latitude and in different solar events. Commercial aircraft's have optimum cruising speed of 800 -900 km/h and the cruising altitude near 13 km. The flight paths are assigned according to airway corridors and safety requirements. The relatively high dose-equivalent rates at cruising altitudes near 13 km (about 1-2 μSv/h) cause exposures greater than 5 mSv/y (the maximum permissible dose for the general population) for a crew with full-time flight (500 - 600 h/y). The radiation exposure of the crew in commercial air traffic has been studied for the associations of the air crews and airline management and published, [1-5], and regulatory authorities are slowly accepting the fact that there indeed is a problem which needs investigations and protective regulation, [6-8].

The radiation exposure assessments of the crews in Yugoslav Airlines (JAT), are presented in this paper. Yugoslav Airlines (JAT) has the fleet of 30 aircraft's and 65 years of experience in commercial traffic (3.500.000 passengers per year and 35th on the IATA list before the war in Yugoslavia).

ANNUAL DOSE ASSESSMENT FOR YUGOSLAV AIRLINES CREWS

The flights of selected groups of crews (from each work category group of pilots and cabin crew members) have been studied during one year. All flights (about 17000) of selected 34 pilots and co-pilots and 41 cabin crew members have been analyzed. Each work category group of pilots and cabin crew members has mostly full-time block hours during 1989 (the last year of normal traffic for JAT). Selected pilots make four groups, for four aircraft types in use by JAT (DC-9, DC-10, B-727, B-737), and two groups of the co-pilots ("flight engineers" for B-727 and DC-10). Cabin crew members make three groups of pursers and two groups of STW/STD (they include both male and female workers).

Pilot (aircraft)	Total time of flights [h:min]	Annual effective dose [mSv]
1,2,3,4,	423:01 297:48 428:23 484:40	0,295 0,210 0,316 0,343
5 (DC-9)	324:29	0,316
6,7,8,9(B-727)	548:33 512:54 497:15 473:19	0,799 0,628 0,674 0,675
10,11,12,13(DC-10)	508:57 499:37 505:49 489:26	1,748 1,712 1,724 1,722
14,15,16,17(B-737)	467:49 507:51 440:20 419:28	0,523 0,448 0,464 0,392
Co-Pilot (aircraft)	**Total time of flights [h:min]**	**Annual effective dose [mSv]**
18, 19, 20, 21,	492:40 529:43 512:29 497:15	0,728 0,820 0,743 0,674
22, 23, 24(B-727)	508:32 489:02 467:15	0,716 0,667 0,688
25, 26, 27, 28,	25:08 366:04 428:57 447:24	0,260 1,221 1,467 1,540
29, 30, 31, 32,	360:39 452:28 387:10 416:51	1,247 1,562 1,326 1,421
33, 34 (DC-10)	461:14 430:20	1,528 1,491

Table 1. Aircraft types, total times of flight during one year and assessed annual effective dose for four selected groups of pilots and two groups of co-pilots ("flight engineers")

Model for calculations of the annual absorbed doses and effective doses uses data for annual cosmic-ray dosimetric profile in the lower atmosphere for solar minimum, taken from literature, [2]. The flight paths of aircraft's during various phases of the flight are approximated by different vertical profiles according to the

operational flight plans, with constant climbing and descending speed and the flights at constant altitude. The average times spent during climbs and descents were assumed using a set of the data for the flights.

Cabin crew (Pursers 35-57) (STW-STD 58-75)	Total time of flights [h:min]	Aircraft (in % of the total time of flight)					Annual effective dose [mSv]
		DC-9	DC-10	B-727	B-737	ATR-42	
35	420:37	5	95				1,38
36	563:33	2	82	6	10		1,77
37	487:23		66	34			1,38
38,39	458:58 452:33		100				1,66 1,57
40,41	449:19 163:57						1,60 0,57
42	397:57	10	87	3			1,25
43	505:11	11	56	27	6		1,25
44	429:44	10	74	5	11		1,25
45	511:21	3	67	26	4		1,37
46	603:11	3	57	39	1		1,51
47	286:15	22	47	28	3		0,58
48	166:54		84	16			0,54
49	284:58		76	24			0,88
50	545:16	1	56	43			1,40
51	379:10	25	69	5	1		1,03
52	474:25	1	55	43	1		1,18
53	485:01	34	62	3	1		1,22
54	633:34	42	48	5	4	1	1,28
55	492:09	5	60	35			1,27
56	525:12	4	59	4	17	16	1,25
57	385,16	1	62	37			0,99
58	510:30	2	63	1	34		1,27
59	350:10	26	5	69			0,47
60	348:02	1	11	3	67	18	0,41
61	501:19	1	77	2	20		1,48
62	507:55	1	58	4	19	18	1,19
63	430:09	27	70	1	2		1,14
64	449:23	20	78	2			1,33
65	470:39	1	52	38	2	7	1,16
66	424:09		71	24		5	1,14
67	521:45	2	4	92	2		0,77
68	131:12	3		9	88		0,13
69	243,19	2	56	41		1	0,60
70	526:05	9	78	12	1		1,55
71	473:17	1	53	5	21	20	1,07
72	461:57		69	1	15	15	1,20
73	449:20		73	8	8	11	1,23
74	348:43		56	2	23	19	0,79
75	295:53		74	1	18	7	0,85

Table 2. Aircraft types, total times of flight during one year and assessed annual effective doses for three selected groups of pursers ("cabin chiefs" 35-41, "check pursers" 42-49, "pursers" 50-57) and two selected groups of STW/STD ("seniors" 58-66, "STW/STD" 67-75)

About 17000 flights have been simulated and annual effective doses for each of analyzed pilots and cabin crew members have been assessed. The calculated annual effective doses for each selected pilot and co-pilot are presented in Table 1. and for each selected cabin crew member in Table 2.

The results show that the doses for the long-distance flights (DC-10 aircraft) are higher than the doses for domestic and continental flights. This demonstrate an assessment of the effective dose during the flight Belgrade - Beijing - Belgrade (1,22 mSv, [10]). Exposure of air crews can be up to 5 times higher than the average exposure of the ground based occupational workers. The assessed annual effective doses (1-2 mSv) are smaller than the maximum permissible dose for the general population (5 mSv), but they are comparable with the values for some radiation workers. The model for the calculations includes minimized influence of the cosmic neutrons. The newly reevaluation of health effects of the radiation (ICRP 1990.) changes proposed limits for the general public and professional radiation workers. Inflight radiation exposures of air crews can be higher then the newly proposed limits for the general public, [7]. The exposure rates during solar flares can rise up 3-4 times (many times in extremely rare cases), lasting for several hours up to several days, [7].

The calculated values for Yugoslav Airlines (JAT) are generally less than doses from similar studies, [7-9], because of the structure of the intercontinental flight (only two aircrafts DC-10 in use in 1989.), but the problem is interest for future studies according to the newly proposed limits of ICRP.

Assessed doses for cabin crew members have the variations for similar block hours. The reason for this is that cabin crew members function in various aircraft types.

Some discussions and comparisons with experimental results and the results from literature are also realized. The validity of the flight path approximation in calculations is analyzed, [10]. The comparison shows the small difference (1%-5%). An example for the flights Belgrade - Athens and Athens - Belgrade-Belgrade (two types of the aircraft) shows the difference less than 1% (the calculated effective dose according to the operational flight plan is 2, 157 μSv, and these value by using the approximation of the flight path is 2.039 μSv), [10]. Similar results gives the calculation for the flight Frankfurt - Belgrade (2, 645 and 2.624 μSv, [10]).

A dosimetric experiment has been realized during a routine flight (the flight Belgrade - Podgorica - Belgrade, February 24, 1994). Dosimeter 6150 AD 2 - Automess GmbH (D-6802 Ladenburg), S/N 57787 has been used. Dosimeter has measuring range 0,1 μSv/h -10 mSv/h, energy range of gamma radiation 60 keV - 3 MeV. The measured dosimetric profile (altitude vs. effective dose rate) is compared with the theoretical values, [2]. The results confirm the validity of the used model for calculations, [11].

The calculated values can have an uncertainty of about 20%: the cosmic rays vary with solar cycle (more than 10%) and geomagnetic latitude (about 2%) and the approximation of the real flight paths includes an additional uncertainty (1-5%).

CONCLUSIONS

The presented study shows that the crews of the intercontinental flights can receive significant annual effective doses (1,5 -2,0 mSv). The exposure of the crews is comparable with natural radiation level on the ground level (it can be up to 5 times higher for some air crew members in the intercontinental flights), but smaller than maximum permissible dose for general population. The annual exposures of the passengers are generally smaller than the exposures of the air crews, because the passengers have a limited number of flights per year compared with the members of the air crews.

REFERENCES

1. T.Foelshe: *J.Aircraft*, v.14, pp. 1226-1233, 1977.
2. K.O'Brien, J.E.McLaughlin: *Health Physics*, v.22, pp. 225-232, 1972.
3. J.E.Hewitt et al.: *Health Physics*, v.34, pp. 375-384., 1978.
4. T.Nakamura et al.: *Health Physics*, v.53, pp. 509-517, 1987.
5. J.W.Wilson, L.W.Townsend: *Health Physics*, v.55, pp. 1001-1003, 1988.
6. K.E.Duflschmid: "Aircrew Radiation Exposure" *Rad. Symp.of IFALPA*, Frankfurt, 1994.
7. H.-J.Lebuser: "Radiation Exposure of Air Crews and the associated health risk" *IFAA 10th World Congress*, Nicosia, 1993.
8. S.Watanabe et al.: "Radiation Exposure of Civil Aviation Crew Members" IFAA 10th World Congress, Nicosia, 1993.
9. P.J Oksanen: "Calculated annual Cosmic Radiation Doses for FINNAIR Flight Crews", FINNAIR, Vantaa, 11.8. 1993.
10. D.Antić, P.Marković, Ž.Petrović: *Proc.of Asia Congress on Rad.Protection, Paper 170*, Beijing, 1993.
11. D.Antić, Ž.Petrović: *Book of Abstracts of 1st Mediterr. Congress on Rad. Protection*, p. 94, Athens, 1994.