RADIATION SAFETY IN AVIATION

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Authorization

The Radiation Act stipulates that the party running a radiation practice is responsible for the safety of the operations. The responsible party is obliged to ensure that the level of safety specified in the ST Guides is attained and maintained.

Under section 70, paragraph 2, of the Radiation Act (592/1991), STUK – Radiation and Nuclear Safety Authority (Finland) issues general instructions, known as Radiation Safety Guides (ST Guides), concerning the use of radiation and operations involving radiation.

Translation. In the event of any differences in interpretation of this guide, the Finnish and Swedish versions shall take precedence over this translation.

1 General

Ionising radiation known as cosmic radiation reaches the Earth from outer space. While the dose rate of this radiation is minimal at ground level, it increases with altitude to create a radiation safety impact that must be considered in flight work.

This Guide presents the requirements governing radiation safety of aircrews exposed to cosmic radiation and the monitoring of their exposure. This Guide applies to undertakings engaged in aviation operations at altitudes exceeding 8000 metres under a Finnish operating licence and to Finnish military aviation. The radiation exposure of aircrews at altitudes of less than 8000 metres is so minimal that no special measures are required to investigate or limit exposure to radiation.

The definitions of the terms used in this Guide are presented in Appendix A.

The investigation and limiting of exposure to natural radiation are governed by Chapter 12 of the Radiation Act (592/1991), and Chapter 7 of the Radiation Decree (1512/1991). The common European aviation regulations EU-OPS (points 1.390, Cosmic radiation and 1.680, Cosmic radiation detection equipment) also impose requirements on parties engaged in aviation operations with respect to exposure to cosmic radiation and the protection of aircrews. More detailed provisions concerning air transport of radioactive materials are laid down in the Decree on the Transport of Dangerous Goods by Air (210/1997) and the statute OPS M1-18 by the Finnish Transport Safety Agency.

2 The party engaged in aviation operations must investigate the extent of radiation exposure

Parties engaged in aviation operations must investigate the exposure caused to aircrews by cosmic radiation if it is found, or if there is any cause to suspect, that the annual effective dose of an individual worker may exceed 1 mSv. In practice, this applies to all parties engaged in aviation operations at altitudes of more than 8000 metres.

The reports of such investigations must be submitted to Radiation and Nuclear Safety Authority (STUK). The reports must specify the most common flight routes and altitudes used by the respective airlines, together with the aircraft types and airline contact details. In addition, the reports must also include estimated annual radiation doses received by aircrews and the calculation principles of these estimations (e.g. ordinary route doses and annual maximum flying times). These estimates may be made in the manner shown in Appendix B or by using a calculation method suitable for cosmic radiation dose determination (see Chapter 5).

If the report provided by the party engaged in aviation operations indicates that the workers are exposed to cosmic radiation to the extent that the annual effective dose may exceed 1 mSv, the party engaged in aviation operations is required to take care of the workers' radiation protection and the informing of the workers (see Chapters 3 and 4).

Section 45 of the Radiation Act lays down provisions concerning the obligation of the responsible party to investigate radiation exposures. These obligations also apply to parties engaged in aviation operations. The limiting of exposure to natural radiation is governed by Section 27 of the Radiation Act, and the statutes concerning the protection of aircrews are set forth in Section 28 a of the Radiation Decree.

3 The radiation exposures of aircrews are limited and monitored

The responsible party must implement the radiation protection of aircrews in accordance with the requirements presented in this chapter. If a responsible party makes use of services of workers employed by outside undertakings, this Guide shall apply to the protection of these outside workers as well. As employers, it is the duty of the outside undertakings to ensure that these matters are properly managed.

The responsibilities concerning workers of outside undertakings are set forth in Section 37 a of the Radiation Act.

3.1 The planning of operations must take into account maximum exposures

The responsible party must maintain records of employees' work shifts. A party engaged in aviation operations must plan operations so that the individual worker´s annual effective dose from cosmic radiation does not exceed 6 mSv. In addition, according to the optimization principle, the radiation exposure of workers must be kept as low as reasonably achievable.

Radiation protection during pregnancy is based on the principle that the foetus must be protected in the same manner as any other member of the population. The flight work of a pregnant woman must be organized so that the equivalent dose received by the foetus is as small as reasonably achievable. When a woman has announced her pregnancy, the equivalent dose during the remainder of the pregnancy must not exceed 1 mSv. If the effective dose due to cosmic radiation received by the woman is less than 1 mSv, then the equivalent dose received by the foetus will also be less than 1 mSv. In order to arrange work as required to protect the foetus, the responsible party must encourage workers to inform the responsible party of their pregnancies as early as possible.

If a person is exposed at work to some other ionising radiation in addition to cosmic radiation, the exposure due to that radiation must also be determined. In addition, care must be taken to ensure that the total radiation exposure does not exceed the maximum values specified for radiation exposure.

The dose constraint specified for aviation operations is a operation-specific limiting value prescribed under Section 7 of the Radiation Decree; the purpose of this is to ensure that workers' exposure levels during their flight work do not exceed the typical levels. Radiation protection during pregnancy is prescribed in Section 5 of the Radiation Decree, and the maximum values of radiation exposure are set forth in Sections 3–5 of the Radiation Decree.

3.2 Radiation doses are determined and recorded

Monitoring of radiation exposure involves determining and recording of individual radiation doses. Individual doses may be determined using the methods explained in Chapter 5. For the purpose of dose recording, the responsible party must record the following details for each worker

- name
- personal identity number
- task
- result of dose determination
- factors affecting radiation exposure, including flight times and routes.

Human beings are also exposed to minor levels of cosmic radiation at ground level. This radiation exposure is not work-related, and therefore it is not taken into account when the radiation exposure caused by aviation operations is determined.

3.3 When flying at high altitudes, abnormal radiation exposures must be prepared for

A powerful, sudden solar flare can increase cosmic radiation in the upper atmosphere. Steps must be taken to prepare for sudden solar flares when flying at altitudes of more than 15 000 metres.

Aviation regulation EU-OPS 1.680 sets forth the requirements for measuring instruments and alternative dose determination methods for aviation operations at altitudes of more than 15 000 metres.

3.4 Medical surveillance takes place on the basis of workplace reports and aviation regulations

The need for health examinations as a part of medical surveillance must be considered on the basis of workplace reports referred to in the Decree of the Council of State as well as on the basis of the requirements set forth in aviation regulations. There is no need to conduct regular health examinations for aircrews for reasons of radiation protection.

Provisions concerning the medical surveillance of workers are laid down in the Occupational Health Care Act (1383/2001) and in the Decree of the Council of State (1485/2001) issued pursuant to the said Act, concerning health examinations of persons engaged in work involving special health risks. Aviation regulations also include requirements on occupational health care of aircrews.

4 Aircrews must be informed of radiation and their exposure

The responsible party must inform workers of cosmic radiation and its health drawbacks, and advise them of typical exposure levels at work. When beginning work and during the course of work, workers must be provided with adequate information concerning the regulations and guidelines for monitoring exposure to cosmic radiation; they must also receive adequate information concerning the degree of their exposure due to their tasks, and its health impacts. Women must also be advised of radiation protection during pregnancy, and they must be encouraged to notify their employers of their pregnancy as early as possible after the pregnancy has been verified.

The responsible party must take care to ensure that each individual worker is notified annually of the results of the monitoring of radiation exposure.

5 Radiation exposure is determined with an appropriate calculation programme

An appropriate calculation programme of proven reliability must be used for determining exposure to cosmic radiation. Reliability may be demonstrated, for example, by means of international comparisons.

The calculation programme must:

- be suitable for determining cosmic radiation doses
- be documented and tested
- yield results in the form of effective dose or ambient dose equivalent (see Appendix C and Guides ST 1.9 and ST 7.2)
- be sufficiently accurate: at a confidence level of 95%, the result must not deviate by more than 33% below or 50% above the proper value.

Examples of calculation programmes of proven reliability are CARI, EPCARD and FREE.

6 STUK must receive information for the purpose of regulatory control

The responsible party must submit the information and documents referred to in this chapter to STUK for regulatory control of radiation exposure arising from aviation operations.

Provisions concerning STUK's right to conduct inspections and obtain information are laid down in Section 53 of the Radiation Act.

6.1 When starting radiation exposure monitoring, the methods are described first

The responsible party must inform STUK of the method that it uses to determine radiation exposure and demonstrate that the calculation programme meets the requirements imposed in Chapter 5. In addition, an account must be provided concerning the information that is entered into the calculation programme as well as concerning the accuracy of the results.

If the radiation exposure of workers is determined by an outside undertaking, the responsible party must notify STUK of the address of this undertaking. The responsible party must also provide an account of how radiation exposure is determined and how the proper information exchange is arranged.

6.2 Aircrews' dose data are regularly reported for the Dose Register

The responsible party must annually report the radiation exposure monitoring results for entry into the Dose Register by STUK. The information to be reported comprises the identifying details, the task and the result of dose determination for each worker.

The information for the immediately preceding calendar year must be reported for the Dose Register by no later than the end of January. The data transfer must comply with separate instructions issued by STUK.

It is the duty of every Finnish employer to ensure that the radiation exposures of its Finnish employees are reported for the Dose Register when these employees are working for foreign airlines.

Provisions concerning STUK's Dose Register and the responsible party's duty to report radiation exposure monitoring results to STUK as instructed by STUK are laid down in Section 34 of the Radiation Act.

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Appendix A

Definitions

Cosmic radiation
Ionising radiation originating in outer space.

Flying time
Actual flying time, i.e. the time the aircraft is airborne.

NOTE! Flying time is not the same as the total flight time known as block hours.

Aircrew
Workers in the service of the responsible party, or subcontracted workers, carrying out duties in the flight deck or passenger cabin of an aircraft during flight.

Responsible party
Party engaged in aviation operations in which the annual effective dose due to cosmic radiation received by the worker can exceed 1 mSv.

Appendix B

Assessment of radiation exposure due to cosmic radiation

The magnitude of exposure to cosmic radiation depends on the flying time, altitude and route, and on periodic fluctuations in solar activity. The following table shows estimates of the flying times at various altitudes giving rise to an effective dose of 1 mSv at a latitude of 60° North and at the equator.

Example 1. A worker flying on a route with a typical altitude of 33 000 feet, i.e. about 10 000 metres, may fly for approximately 320 hours at a latitude of 60° North before receiving an effective radiation dose exceeding 1 mSv. The corresponding flying time at the equator is 750 hours. It should be noted that this calculation uses the actual flying time, which is always less than the total flight time (known as block hours).

Example 2. A worker flying for 500 hours a year on a route that is near to a latitude of 60° North and for which the typical flight altitude is 33 000 feet, and for a further 300 hours a year on a route that is near to the equator and for which the typical flight altitude is 39 000 feet, will receive an annual effective radiation dose of (500 h / 320 h) · 1 mSv + (300 h / 490 h) · 1 mSv = 2.2 mSv.

Table. Estimated flying times at various altitudes giving rise to an effective dose of 1 mSv at a latitude of 60° North and at the equator. The flying times shown in the table are actual flying times and not total flight times.

Flight altitude (feet)	Flight altitude (metres)	Flying time (hours) at altitude of 60 °N	Flying time (hours) at the equator
27 000	8230	630	1330
30 000	9140	440	980
33 000	10 060	320	750
36 000	10 970	250	600
39 000	11 890	200	490
42 000	12 800	160	420
45 000	13 720	140	380
48 000	14 630	120	350

Appendix C

Radiation exposure quantities

The maximum values for radiation exposure are given as equivalent doses and effective doses. These are calculated quantities that cannot be measured directly. Measurements and calculated values of cosmic radiation may be given as ambient dose equivalents, enabling calculation of equivalent dose and effective dose approximations. All of these quantities are based on the absorbed dose, which is a physically measurable quantity describing the dose due to ionising radiation.

The weighting factors for different types of radiation, tissues and organs are presented in Guide ST 7.2.

Absorbed dose

The absorbed dose D is the mean energy imparted by ionising radiation to a mass element in the matter, divided by this mass element dm:

$$D = \frac{d\bar{\varepsilon}}{dm} \qquad (1)$$

The unit of the absorbed dose is the gray (Gy). 1 Gy = 1 J· kg^{-1}.

Equivalent dose

The equivalent dose $H_{T,R}$ in tissue or organ T is obtained by multiplying the average absorbed dose $D_{T,R}$ in the tissue or organ by a radiation weighting factor w_R:

$$H_{T,R} = w_R D_{T,R} \qquad (2)$$

where

w_R is the radiation weighting factor for radiation quality R, and

$D_{T,R}$ is the average absorbed dose in tissue or organ T caused by radiation quality R.

If the radiation is composed of several radiation qualities with different w_R values, the equivalent dose H_T is:

$$H_T = \sum_R w_R D_{T,R} \qquad (3)$$

The unit of equivalent dose is the sievert (Sv).

Effective dose

The effective dose E is the sum of the equivalent doses H_T, multiplied by the tissue weighting factors w_T:

$$E = \sum_T w_T H_T = \sum_T w_T \sum_R w_R D_{T,R} \qquad (4)$$

The unit of the effective dose is the sievert (Sv).

The effective dose is used primarily to estimate the risk of stochastic harmful effects of radiation on an individual.

Ambient dose equivalent

The ambient dose equivalent H*(d) is the dose equivalent at a point in a radiation field which would be caused by the corresponding expanded and aligned field in an ICRU sphere at a depth d on the radius opposing the direction of the aligned field.

The unit of the ambient dose equivalent is the sievert (Sv).

ICRU sphere

The ICRU sphere is an object specified by the International Commission on Radiation Units and Measurements, ICRU, roughly equivalent to the human body as regards the absorption of energy from ionising radiation. The ICRU sphere is 30 cm in diameter, made of tissue-equivalent material with a density of 1 g · cm^{-3} and a mass composition of 76.2% oxygen, 11.1% carbon, 10.1% hydrogen and 2.6% nitrogen.