RADIATION SAFETY IN AVIATION

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Authorization

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.

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.

Translation. Original text in Finnish.

1 General

Natural 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 cannot be disregarded.

The investigation and restriction of exposure to natural radiation are governed by chapter 12 of the Radiation Act (592 of 1991) and by chapter 7 of the Radiation Decree (no. 1512 of 1991) issued pursuant to the said Act. The common European aviation regulations JAR-OPS 1 (points 1.390, Cosmic radiation and 1.680, Cosmic radiation detection equipment) also impose requirements on parties engaged in aviation with respect to exposure to cosmic radiation and protection of aircrews. Under section 3 of the Radiation Act, further provisions on industrial safety and employee protection shall also apply.

This Guide presents the requirements governing radiation safety of aircrews exposed to cosmic radiation and monitoring of such exposure. It applies to enterprises engaged in aviation under a Finnish operating licence and to Finnish military aviation at altitudes exceeding 8,000 metres. The radiation exposure of aircrews at altitudes of less than 8,000 metres is so minimal that no special measures are generally required to investigate or limit exposure to radiation.

2 Definitions

Cosmic radiation shall denote natural ionising radiation originating in outer space.

Responsible party shall denote a party engaged in aviation operations in which the annual effective dose due to cosmic radiation received by the worker may exceed 1 mSv.

Aircrew shall denote workers in the service of the responsible party working in the flight deck or passenger cabin of an aircraft during flight.

Flying time shall denote actual flying time, meaning the period during which the aircraft is airborne. Flying time is therefore not the same as the total flight time known as block hours.

3 Dose constraints and maximum values

The effective dose due to cosmic radiation received by an aircrew worker may not exceed 6 mSv per annum. This dose constraint is an operations-specific maximum value imposed pursuant to section 7 of the Radiation Decree (1512 of 1991) in order to ensure realisation of the principle of optimisation prescribed in section 2 of the Radiation Act.

Under section 5 of the Radiation Decree, a foetus must be protected in the same way as a member of the population. When a woman has announced her pregnancy, her work must be organised so that the equivalent dose received by the foetus will be as small as reasonably achievable. The equivalent dose during the remainder of the pregnancy is under no circumstances allowed to exceed 1 mSv.

If a person is exposed at work to other ionising radiation in addition to cosmic radiation, then the exposure to the said other radiation must also be determined. Care must also be taken to ensure that the total radiation exposure does not exceed the maximum values prescribed in sections 3–5 of the Radiation Decree.

4 Investigation of radiation exposure due to cosmic radiation

A party engaged in aviation operations must determine the exposure caused to aircrews by cosmic radiation if it is found, or if there is cause to suspect, that the annual effective dose may exceed 1 mSv. The Radiation and Nuclear Safety Authority (STUK) is empowered to order a party engaged in aviation operations to perform such an investigation if the said party otherwise fails to do so (section 45 of the Radiation Act).

The report of the investigation is to be submitted to STUK. The report must specify the most common flight routes and altitudes used by an airline, together with aircraft types and contact details. It must also include an estimate of the annual radiation dose received by aircrews, of ordinary route doses and of annual maximum flying times. The estimate may be made in the manner shown in appendix A or using a calculation method suitable for cosmic radiation dose estimation (see chapter 6).

If the report provided by the party engaged in aviation indicates that the workers are exposed to so much cosmic radiation that the annual effective dose may exceed 1 mSv (section 27 of the Radiation Decree), then the operation constitutes a radiation practice under section 11 of the Radiation Act. The party engaged in aviation is then deemed to be a responsible party, as defined in this ST-Guide.

5 Protection of aircrews

The responsible party must arrange the radiation protection of aircrews in accordance with the requirements of section 28 a of the Radiation Decree (no. 1512 of 1991) and of this chapter. This ST-guide also applies to any workers belonging to outside enterprises who are working for the responsible party. As an employer, it is the duty of the said outside enterprise to ensure that these matters are properly managed (section 37 a of the Radiation Act).

5.1 Limitation of radiation exposure

The responsible party must maintain records of employee work shifts. Work shifts and flight routes must be planned to ensure that the worker's annual effective dose does not exceed 6 mSv.

The flight work of a pregnant woman must be organised so that the equivalent dose received by the foetus will be as small as reasonably achievable. The equivalent dose during the remainder of the pregnancy is under no circumstances allowed to 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 shall also be considered to be less than 1 mSv.

To ensure that the radiation dose reveived by the foetus is minimised, the worker must notify the responsible party of her pregnancy immediately after the pregnancy has been verified.

5.2 Monitoring of radiation exposure

Monitoring of radiation exposure involves determining individual radiation doses and dose recording. Individual doses may be determined using the methods explained in chapter 6. For the purpose of dose recording, the responsible party must record the following details for each worker:

- name
- identity number
- duties
- 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 due to work, and so it is not taken into account when determining the radiation exposure caused by aviation operations.

5.3 Monitoring of abnormal radiation exposure

A powerful and 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 JAR-OPS 1.680, Cosmic radiation detection equipment, sets out the requirements for measuring instruments and alternative dose determination methods for companies engaged in aviation operations at altitudes of more than 15,000 metres.

5.4 Health surveillance

The health of workers must be surveyed in the manner stipulated for health examinations of persons engaged in work involving special health risks in the Occupational Health Care Act (no. 1383 of 2001) or in the Decree of the Council of State (no. 1485 of 2001) issued pursuant to the said Act. Aviation regulations also include requirements on occupational health care of aircrews.

The need for medical examinations as part of health surveillance must be considered on the basis of the workplace report referred to in section 3 of the Decree of the Council of State and of the requirements of aviation regulations. There is no need to conduct regular medical examinations of aircrews for reasons of radiation protection.

5.5 Informing aircrews

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 the work, the worker must be provided with adequate information concerning the regulations and guidelines for monitoring exposure to cosmic radiation, and concerning the degree of exposure caused by the worker's duties and the health impact of the said degree of exposure. Women shall also be advised of radiation protection during pregnancy, and must be encouraged to notify the employer of any pregnancy immediately 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 monitoring of radiation exposure.

6 Methods of determining radiation exposure

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 dosages
- be documented and tested
- yield results in the form of effective dose or ambient dose equivalent (see Appendix B and Guide ST 7.2)
- be precise: the uncertainty of results at a confidence level of 95 per cent may not exceed -33 per cent or +50 per cent.

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

7 Notifications to the Radiation and Nuclear Safety Authority

The responsible party must submit the information and documents referred to in this chapter to STUK for supervision of radiation exposure arising from aviation operations. The right of STUK to conduct inspections and receive information is prescribed in section 53 of the Radiation Act.

7.1 Notifiable details on initiating radiation exposure monitoring

The responsible party must advise STUK of the method that it uses to determine radiation exposure and demonstrate that the calculation programme meets the requirements imposed in chapter 6. An account must also be provided of the information that is entered into the calculation programme and of the accuracy of the results.

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

7.2 Details to be notified to the dose register

The responsible party must annually notify the results of radiation exposure monitoring for entry in the dose register of STUK. The notifiable information comprises the identifying details, the duties and the result of dose determination for the worker. The responsible party must also notify the route doses and flight profiles used in calculating individual doses. Route doses must be calculated at least once a year.

The information for the immediately preceding calendar year must be notified to the dose register by no later than the end of January. Data transfer must comply with separate instructions issued by STUK.

It is the duty of every Finnish employer to ensure that the radiation exposure of its Finnish employees is also notified to the dose register when the employee is working for a foreign airline (section 35 of the Radiation Act).

Bibliography

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Appendix A

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 x 1 mSv + 300 h / 490 h x 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	8,230	630	1330
30,000	9,140	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 B

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.

Absorbed dose

The absorbed dose describes the quantity of energy transferred from radiation into a unit mass of target substance.

The absorbed dose may be expressed for any medium that is the target of radiation. When the target of radiation is a human being, the absorbed dose is generally given as the average dose absorbed by some individual tissue or organ.

Absorbed dose is measured in joules per kilogram (J/kg). This unit is known as the gray (Gy). As one gray is a very large radiation dose, it is usual in practice to use milligrays (mGy) or micrograys (µGy).

Equivalent dose

The harmful health impacts of ionising radiation depend not only on the size of the absorbed dose, but also on the nature of the radiation. For this reason, the equivalent dose quantity has been defined to describe the undesirable health impact on tissues or organs. The equivalent dose is obtained by multiplying the average absorbed dose received by the tissues or organ by a characteristic weighting factor for each type of radiation. The weighting factor is determined according to the potency of the radiation quality in question for causing damage to living tissue.

The equivalent dose is not generally reckoned separately for various organs and tissues when assessing the radiation exposure of a foetus, but instead is determined for the foetus as a whole.

The unit of equivalent dose is J/kg, i.e. the same as for the absorbed dose, but for the sake of clarity this unit is then called the sievert (Sv). The millisievert (mSv) and microsievert (µSv) are also used.

Effective dose

Various organs and tissues are sensitive to the late effects of radiation in various ways. The overall harm to health from radiation exposure of organs or tissues is described by the quantity effective dose. The effective dose is obtained by multiplying the equivalent dose by a weighting factor describing the radiosensitivity of organs and tissues and summing these weighted doses. The effective dose may be used to assess the risk of stochastic harmful effects of radiation. The unit of effective dose is the sievert (Sv).

Ambient dose equivalent

When seeking to take measurements or calculate estimates in a radiation field caused by radiation penetrating deeply into an object, the applicable quantity is the ambient dose equivalent. The unit of ambient dose equivalent is also the sievert (Sv).

The definitions of absorbed dose, equivalent dose, effective dose and ambient dose equivalent, and the weighting factors for radiation and various tissue and organ types are set out in greater detail in Guide ST 7.2.