
**COMMERCIAL AND BUSINESS
AVIATION ADVISORY CIRCULAR**

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**MEASURES FOR MANAGING EXPOSURE TO COSMIC RADIATION OF
EMPLOYEES WORKING ON BOARD AIRCRAFT****INTRODUCTION**

This *Commercial and Business Aviation Advisory Circular (CBAAC)* recommends that air operators develop a program for managing the cosmic radiation exposure of their employees who work on board aircraft.

REFERENCES

1. *Canadian Aircrew Radiation Environment Study (CARES) Report, Volumes 1, 2 and 3, Royal Military College of Canada and Defence Research Establishment Ottawa, March 1998*
2. *Cosmic Radiation Exposure of Aircrew Project Report, Volumes 1 and 2, Royal Military College of Canada, March 2000*

DEFINITIONS

Ambient dose equivalent means the standardized operational quantity used specifically for the measurement of radiation exposure with radiation detection equipment.

Cosmic radiation means radiation consisting mainly of charged particles originating from galactic and solar events.

Effective dose means the unit equal to the equivalent dose in a tissue or organ of the human body, which is multiplied by a corresponding tissue weighting factor and summed over the tissues and organs. It is the radiological protection quantity that expresses the biological risk resulting from radiation exposure.

Equivalent dose is the amount of energy absorbed in a tissue or an organ multiplied by a factor that takes into account the specific type of radiation (radiation weighting factor). This unit allows all types of ionising radiation to be expressed on a common scale.

Millisievert (mSv) is the unit used by the International System of Units (SI) to express the equivalent dose or the effective dose.

Occupational exposure means exposure caused by cosmic radiation incurred by employees working on board aircraft. (In the context of this Circular, management of occupational exposure is only being recommended where annual doses are likely to exceed 1 mSv.)

BACKGROUND

From the earliest days following the discovery of ionising radiation, it was apparent that such radiation was hazardous to biological systems in large doses and at relatively high dose rates. It was further apparent that some way of controlling exposures was required to minimize the harmful effects. For chronic, low dose exposures, regulatory bodies have adopted a conservative linear no-threshold (LNT) assumption for radiation protection purposes. In Canada, the Canadian Nuclear Safety Commission (CNSC) sets radiation dose limits for exposures arising from nuclear facilities or nuclear substances; the provincial and federal governments set radiation dose limits for exposures arising from x rays. On an international level, the International Commission on Radiological Protection (ICRP), in its 1990 Publication No. 60 (ICRP 60), recommended that the occupational exposure limit for workers should not exceed an effective dose of 20 mSv per year averaged over 5 years, with not more than 50 mSv in any single year. The ICRP also recommended that the exposure limit for the general public should not exceed an effective dose of 1 mSv per year. These recommendations were adopted by the CNSC in the *Nuclear Safety and Control Act*, May 31, 2000.

Under the leadership of Transport Canada, the Air Transport Association of Canada (ATAC) sponsored, in part, phase I of a study (the *Canadian Aircrew Radiation Environment Study* (CARES)) conducted by the Royal Military College of Canada (RMC) and the Defence Research Establishment Ottawa (DREO) between August 1996 and January 1998 (Ref. 1). The study was conducted in co-operation with employees and management from selected major, regional and charter air operators. The goal of the study was to document route dose (as a quantity of ambient dose equivalent). In this report, the annual exposures of selected aircrew were also estimated by folding these data with data on the flight schedules for that reporting year (i.e., when the galactic radiation was at a maximum). The report was also written so that, in a similar manner, individuals could also estimate their exposure.

In the CARES study, it was determined that the higher the altitude, latitude and duration of the flight, the greater the aircrew exposure. For example, the highest measured total ambient dose equivalent was 0.052 mSv on the route from Beijing to Vancouver at an average altitude of 35,000 feet for a total air time of 10.5 hours (at solar minimum). The measured dose rates from the natural background cosmic radiation field at altitude are typically one hundred times greater than those experienced at ground level. The selected aircrew in this study were exposed to an annual ambient dose equivalent that ranged from 1 to 6 mSv per year (in the given measurement period of the solar cycle). In fact, this level of exposure is similar to that received by workers who are monitored for occupational radiation exposure in Canada, such as medical workers and nuclear energy workers. Health Canada's Radiation Protection Bureau (RPB) analysed the results of the study to assess the impact of cosmic radiation exposure and recommended measures that should be taken by air operators to manage such exposure (Ref. 2).

The Transport Canada Aviation Occupational Health and Safety Division participated in the CARES study in an advisory capacity. It further acted as the liaison office between the RMC/DREO, the RPB, the air operators and the unions throughout this study. Transport Canada also participated in funding a second phase known as the *Cosmic Radiation Exposure of Aircrew Project* (Ref. 2) and currently participates in funding a third phase.

Based on the RMC/DREO study and the RPB's assessment of the health impact of exposure to cosmic radiation, Transport Canada recommends that Canadian air operators develop a program containing the following measures to manage the cosmic radiation exposure of their employees based on the likelihood of exceeding an exposure of 1 mSv annually.

RECOMMENDED MEASURES

All Canadians are exposed in some way to cosmic radiation whether or not they work for an air operator. However, aircrew are exposed to higher levels of cosmic radiation than the general Canadian

population.

Under Part II of the *Canada Labour Code*, Canadian employers are responsible for the health and safety of their employees at work at all times. With the recommendation of the ICRP to recognize the occupational exposure of aircrew, international organizations such as the European Commission have adopted this recommendation to establish uniform criteria among their Member States to manage the cosmic radiation exposure of employees working on board aircraft. It is desirable that Canadian criteria correspond as closely as possible to those criteria accepted by the international community.

For these reasons, Transport Canada urges Canadian air operators to implement the following measures:

1. Occupational Exposure

Canadian air operators whose aircrew are likely to receive annual doses greater than 1 mSv should regard their employees as being *occupationally exposed* to cosmic radiation, and measures should be taken to manage this exposure. By being regarded as such, aircrew would benefit from measures developed by their employers for managing their exposure to cosmic radiation while working on board aircraft.

2. Control of Occupational Exposure to Cosmic Radiation

Doses should be kept “as low as reasonably achievable”, taking into account economic and social factors (known as the *ALARA principle*). Even though it is unlikely that aircrew will exceed the recommended annual dose limits of 20 mSv with current practices, procedures should be developed to control the exposure of individual aircrew members, thereby minimizing the associated risk. Transport Canada recommends that Canadian air operators set the annual dose limit at 20 mSv. This limit is in accordance with the ICRP 60 and has also been recommended by the RPB in its analysis of the CARES results.

3. Intervention Level

An intervention level is a level at which a specific protective or remedial action is taken. Although it is unlikely that aircrew would reach the annual dose level of 20 mSv in present conditions, as mentioned previously, it is recommended that an intervention level of 6 mSv be adopted. This level would correspond with the intervention level currently used in some countries of the European Community and may be used in others in the near future. The 6 mSv intervention level is estimated using 3/10 of the nuclear energy worker 20 mSv limit. This level is also prudent in keeping with the ALARA principle, where some intervention must be taken well below the nuclear energy worker limit. When employees approach 6 mSv, the air operator would put measures in place to adjust their working schedule so that their subsequent flights, for the remainder of the calendar year, would result in minor additional exposure. These measures should be developed in consultation with the Policy Health and Safety Committee or, if there is no Policy Committee, the Work Place Health and Safety Committee in accordance with Part II of the *Canada Labour Code*.

4. Application of Dose Levels

Management of occupational exposure to cosmic radiation is only being recommended where it is likely that aircrew will exceed an exposure of 1 mSv annually (which corresponds to the ICRP 60 and the CNSC exposure limit for the general public). This dose is within the range of variation of natural background radiation and controls for lower exposures are not justified.

5. Control of Exposure

As the source of exposure on board aircraft in flight cannot be controlled, the only viable control measure is managing the time of exposure, the altitude and the latitude, i.e., flight time, and low altitude and southerly latitude flights. Moreover, future long duration flights at very high altitudes (above 50 000 ft) will require some measure of additional control because of the possibility of sporadic exposure from solar flares during solar cycle maximum conditions.

6. Overexposures

The source of exposure is relatively constant, and accidental overexposure of individuals is not likely to occur. The exception to this is the rare solar flare that may subject aircrew to higher radiation doses. However, aircraft flying at very high altitudes should be equipped with dose rate meters or receive monitoring information from satellites or ground stations. While solar flares may occur suddenly, evasive action, such as reducing the altitude of the aircraft on an ad hoc basis, will reduce the dose. In particular, early warning notices are available on the U.S. Space Environment Center Web site:<http://www.sel.noaa.gov/>.

7. Monitoring

Although the cosmic radiation field at altitude is complex, once measured by a sophisticated suite of instrumentation, it is well known. Moreover, as the flux of radiation within an aircraft is fairly uniform, individual monitoring will not be necessary.

It is recommended that existing route dose data be used to predict employee doses. While it may be useful to monitor the doses received on each flight, there are logistical difficulties in matching the flight dose to an employee's record.

Periodically, area monitoring or personal dosimetry should be performed for validation purposes.

Aircraft that fly above 50,000 feet (15 km) should be equipped with area monitoring equipment or obtain monitoring information from satellite or ground stations to measure route doses. This will permit evasive action to be taken should the dose rate increase from solar flare activity.

8. Computer Code

During the course of the second phase called *Cosmic Radiation Exposure* of Aircrew Project (Ref. 2) for Transport Canada, the existing route dose data (Section 7) were developed into a prototype measurement based computer code to predict the correct route dose for any route desired. However, as an alternative, the theoretically based CARI or EPCARD codes, developed in the U.S. and Europe respectively, could also be used for such dose prediction.

Computer programs used for this purpose should take into account sunspot activity and seasonal variation (the heliocentric potential variation is provided by the U.S. Federal Aviation Administration (FAA) on their Web site:<http://www.cami.jccbi.gov/aam-600/610/600radio.html>).

While it is acknowledged that there will be uncertainties in the dose estimates, it is considered that these will be adequately accurate for managing exposure to cosmic radiation.

9. Dose Records

Using a computer code, air operators will be able to keep a permanent record of cumulative doses for each crew member who is likely to exceed 1 mSv annually. This record should be made available to the employee and his or her representative with the employee's permission.

Air operators should ensure that the dose record of their employees is sent to the National Dose Registry in a format and at a frequency that is determined by the Registry and Transport Canada. The National Dose Registry is a database containing dose records of all workers who are monitored for ionising radiation exposure in Canada. The data is used by regulators for monitoring compliance with existing regulations and by Health Canada for publishing reports on occupational radiation exposures and epidemiological research. It is also made available to employees upon request. The Registry is located at the following address:

Health Canada
Radiation Protection Bureau
775 Brookfield Road
Mail Stop: 6302 C2
Ottawa ON K1A 1C1

When the computer code from the Transport Canada study becomes available in 2001–2002, air operators could develop a dose management system for use in routine operations. The dose records could then be kept for their employees, and Transport Canada will make arrangements with the National Dose Registry to schedule an information session for them.

10. Non-Operating and Commuting Aircrew

Non-operating aircrew transported to another station on flights associated with an annual dose greater than 1 mSv should also have their doses recorded as occupational exposure, even though they are in transit and not actually servicing that flight. Similarly, those who commute by aircraft or who are returning to their home base but not on duty should have their doses recorded (ferry flights).

11. Pregnant Employees

Employees should inform management of their pregnancy as soon as they become aware of it. During pregnancy, lower dose limits apply to protect the fetus, which is more sensitive to radiation. Working conditions of pregnant employees, after informing management, should be such as to make it unlikely that the additional equivalent dose to the fetus will exceed 1 mSv during the remainder of the pregnancy. This would provide an acceptable level of protection to the fetus. Assigning pregnant crew members to flights where less than 1 mSv is incurred annually or to ground duties well before the end of pregnancy should provide sufficient control of cosmic radiation exposure. These measures would correspond to the provisions in Part II of the *Canada Labour Code* under which a pregnant employee who is concerned about the health of the foetus may cease to perform her job until such time as a medical practitioner has determined whether or not there is a risk. If there is a risk, the employee may then be reassigned to other duties.

12. Information for Employees

It is the responsibility of the employer, in this case the air operator, to ensure that employees are informed of the potential risks of cosmic radiation exposure and the measures taken to ensure that these risks are minimized. The manner in which this information will be presented should be agreed upon by the work place health and safety committee.

It is particularly important that female employees be advised of the need to control doses during pregnancy as well as the need to notify management as early as possible so that any dose control measures needed may be introduced.

FUTURE DISPOSITION

Although the precautionary measures recommended in this Circular may be implemented on a voluntary basis, Transport Canada intends to regulate the exposure of Canadian aircrew to cosmic radiation in the very near future.

CONCLUSION

The measures described above are provided to assist air operators in developing a voluntary program for protecting the health of their employees working on board aircraft. Air operators who develop a program for monitoring and controlling the exposure of their aircrew to cosmic radiation should advise Transport Canada of the existence of their program and send a copy to Transport Canada for information purposes. Air operators may also seek guidance or further information for the development of their program from Transport Canada. Questions may be forwarded by e mail to:

CosmicRadiation/RadiationCosmique@tc.gc.ca

or to the following address:

Transport Canada
AARXG
Place de Ville, Tower C
330 Sparks Street, 4th floor
Ottawa ON
K1A 0N8

ADDENDUM

Subsequent to the April 5, 2001, original issuance of CBAAC #0183, PCAIRE, a Canadian company located in Ottawa, Ontario, completed development of the measurement based computer code referenced on page nine of this CBAAC, in the first paragraph of number eight. At the writing of this addendum, in March 2006, the PCAIRE website was: <http://www.pcaire.com/>

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