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ACREM: A NEW AIR CREW RADIATION EXPOSURE MEASURING SYSTEM*

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INTRODUCTION

Cosmic radiation has already been discovered in 1912 by the Austrian Nobel Laureate Victor F. Hess [1]. After Hess up to now numerous measurements of the radiation exposure by cosmic rays in different altitudes have been performed, however, this has not been taken serious in view of radaition protection..Today, with the fast development of modern airplanes, an ever increasing number of civil aircraft is flying in increasing altitudes for considerable time. Members of cilvil aircrew spending up to 1000 hours per year in cruising altitudes and therefore are subject to significant levels of radiation exposure.

In 1990 ICRP published its report ICRP 60 with updated excess cancer risk estimates, which led to significantly higher risk coefficients for some radaition qualities. An increase of the radiation weighting factors for mean energy neutron radiation increases the contribution for the neutron component to the equivalent dose by about 60%, as compared to the earlier values of ICRP26. This higher risk coefficients lead to the recommendation of the ICRP, that cosmic radiation exposure in civil aviation should be taken into account as occupational exposure. Numerous recent exposure measurements at civil airliners in Germany, Sweden, USA, and Russia show exposure levels in the range of 3 - 10 mSv / year. This is significantly more than the average annual dose of radiation workers (in Austria about 1.5 mSv / year).

Up to now no practicable and economic radiation monitoring system for routine application on board exits. A fairly simple and economic approach to a practical, active in-flight dosimeter for the assessment of individual crew exposure is discussed in this paper.

COSMIC RADIATION

A continuous rain of energetic photons, protons and other atomic nuclei enters the Earth's atmosphere from outer space. Although its origin is not really known, it is clear, that the largest contribution stems from outside the solar system (galactic cosmic radiation), a smaller contribution is caused by the sun (solar cosmic radiation). The flux density of the cosmic particles is about 1000 per m^2 per second. The particles are ionised nuclei, about 90 % protons, 9% alphas and the rest heavier nuclei, distinguished by there high energies up to 10^{20} eV. The most part is within of 10^{8}eV to 10^{11}eV [2]. This so called primary cosmic rays collides with the nuclei of atoms in the upper atmosphere and produce showers of secondary particles. In addition to the influence of the 11 year cycle of solar activity in cosmic radiation solar particle events change the dose rate in aircraft altitudes. In the case of solar flares it can increase for some minutes to hours by a factor of 100.

ACREM APPROACH

The exposure of aircrew can be measured with different methods [3]. In principle by active or passive dosimeters. Because of the independence of the ambient dose as well as the individual absorbed dose for each crew member, of the location in the airplane, individual dosimetry is not necessary. The individual dose rate can assigned according to flight schedule or other methods.

An other way is to calculate the absorbed does for certain flights using appropriated computer codes. There are some publications based on a cosmic transport code called LUIN [4]. Even though the calculations are in

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good agreement with measurement results, they can not account for any statistical events like solar particle events.

An economical and simple method to assess the radiation exposure, presently being developed in our laboratory, is realised with ACREM (Air Crew Radiation Exposure Measuring) system [5]. ACREM is based on a combination of measurement of the ionising component (GM-counter) and calculation of the neutron component. For this the LUIN-code is applied for the momentary position of the aircraft, determined by an integrated GPS (global positioning system). A principle schematic of the Air Crew Radiation Monitor (ACREM) is shown in fig.1.

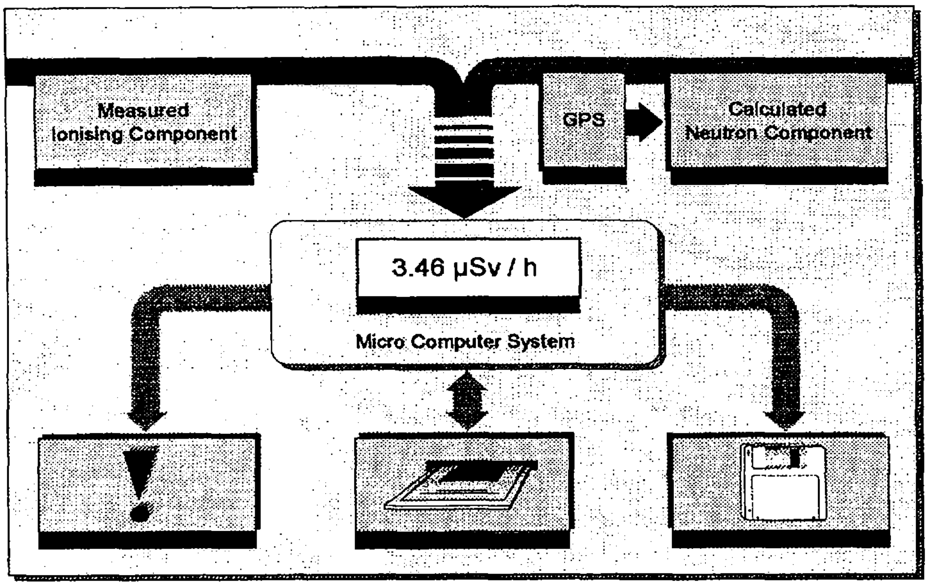

Fig.1: Principle schematic of the ACREM system

A wide-range gamma doserate meter, based on two GM-detectors and microprocessor controlled electronic, special designed for Austrian military and civil protection, is used to measure real-time, continuously the equivalent dose / rate of gamma radiation in the airplane.

The mentioned LUIN code for cosmic ray transport provides the neutron as well as the ionised component of absorbed dose at each position of the aircraft. The relation of the total calculated absorbed dose to the calculated ionising component gives a so called conversion factor for a certain aircraft position. This factor is tabulated for suitable values in altitude and grid distances and stored in a database of a micro computer system. This makes a fast data access possible.

The measured ionising component is weighted with the calculated conversion factor and provide an estimation of the ambient dose equivalent / rate in typical time intervals of some 10 Seconds, for a momentary flight position. The result is stored in real-time mode and direct readable on a display. A warning system tells about unusual high dose rates. Dose assessment to crew members is achieved by personal chipcard.

TEPC MEASUREMENTS

For verifying the ACREM system we will use as reference instrument a low pressure tissue-equivalent proportional counter (TEPC) on board an aircraft. This type of dosemeter enables the absorbed dose in tissue-equivalent (TE) material, nearly independent of the type of radiation. TEPC looks like the most suited instument for cosmic radiation measurements, but up to now they are very complex systems, need qualified personnel and periodical service. Fundamental principles of dosimetry with a TEPC and its use in radiation exposure measurements have already been described in more detail [6,7,8].

Our TEPC dosemeter consists of a spherical proportional counter with an inner diameter of 12.55 cm and a wall (TE-plastic) thickness of 2.13 mm. An outer housing cylindrical in shape is made from 1.27 mm thick aluminium and grounded to serve as electrostatic shield. The TE-gas chamber simulates a diameter of 2 µm of a tissue volume with a density of 1 g/cm³. For data acquisition we use usual micro channel analyser (MCA) and linear as well logarithmic amplifier.

In - flight measurements with a TEPC reference instrument are under preparation, ground studies were done at the SPC - facility of CERN. Fig.2 shows a TEPC spectrum measured in a mixed high energy radiation field at the cosmic radiation facility of CERN: A secondary beam extracted from the SPS accelerator (about 200 GeV, positively charged particle) entered into collision with a copper target located inside of a concrete shielding. The TEPC instrument was located behind the shielding. This simulates nearly the condition of cosmic radiation in aircraft altitudes [9]. The absorbed dose y·d(y) in fig.2 was calculated from the measured frequency distribution as a function of the lineal energy y. The dose equivalent y·h(y) is obtained by multiplication with a quality factor using the ICRP21 as well as the ICRP60 Q/L definition [10, 11]. The mean quality factor for this measurement was calculated to 3,60 for the ICRP21 and 4,25 for the ICRP60 definition.

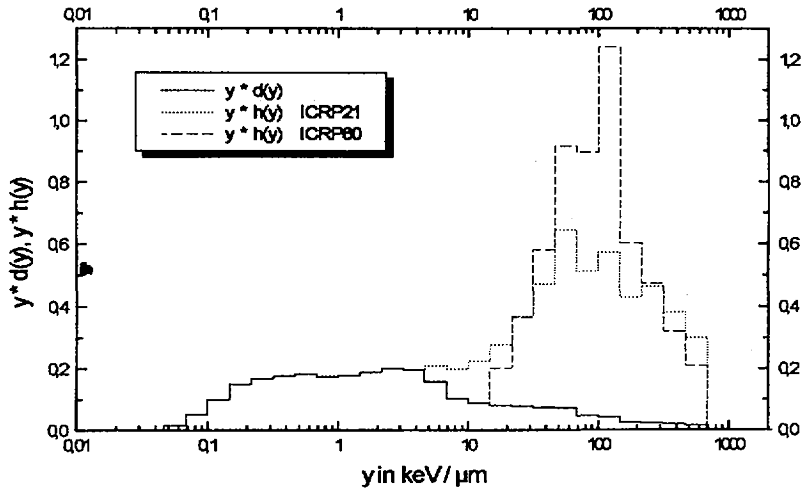

Fig. 2: Absorbed dose y·d(y) and dose equivalent y·h(y) for ICRP21 and ICRP60 - Q/L definition, as a function of lineal energy y measured in a mixed high energy radiation field in the SPS-facility of CERN.

CONCLUSION

ACREM is a simple and economical solution for active airborne dosimetry. This method takes also account of the contribution of solar particle events, changing flight pattern and altitude, as well as additional exposure by unforeseen incidents during transport of radioactive material.

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