# ACTIVE DOSIMETER FOR ON BOARD AIR - CREW - EXPOSURE

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International Commission on Radiation Protection ICRP60 recommend that the cosmic radiation exposure in civil aviation should be taken into account as occupational exposure. Recent measurements at civil airlines show a radiation exposure in the range of 3 - 10 mSv / year. An economic and simple active method to assess the radiation exposure in aviation altitudes is described in this paper. This method takes account of the contribution of solar particle events, changing flight pattern and altitude. First experimental data by in-flight measurement are presented.

## INTRODUCTION

In 1990 ICRP published its report ICRP 60 with updated excess cancer risk estimates, which led to significantly higher risk coefficients for some radiation 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. During the last year the Seibersdorf group for radiation protection studied an active dose assessment method for aircrew [1].

## ACREM CONCEPT

The exposure of air crew can be assessed by different methods [1], basically by using active or passive dosimeters. Detailed in-flight dose investigations on different positions at aircraft has shown that individual dosimetry for each crew member is unnecessary, since the personal and area dose equivalent are essentially independent of the location at aircraft.

Several cosmic ray transport codes exist which are able to calculate the radiation exposure at aviation altitudes. The well-known CARI code has been used for some years to calculate the equivalent dose between two flight destinations and was up-dated last year by CARI 3. Basis for the CARI 3 calculation is the more detailed transport code called LUIN94 [2]. Even though the calculations are in agreement with measurement results, for dose assessment they require knowledge of the actual flight pattern and can not account for unexpected solar particle events. To solve this problem active dosimetry is necessary.

An economical and simple active method to assess the radiation exposure, presently being studied in our laboratory, is realised with ACREM (Air Crew Radiation Exposure Measuring) system. ACREM is based on a combination of measurement of the ionising component and calculation of the neutron component. Up to know we use a GM-counter with an energy range of 50 keV to 1.3 MeV for dose measurements. The instrument is based on the Seibersdorf Radiation Protection Survey Meter SSM-1, designed for Austrian military and civil protection. Two GM-detectors and microprocessor controlled electronic, are used for real-time, continuous measurement of the equivalent dose (rate) at aircraft.

For calculations the transport code LUIN94 is used. LUIN94 provides the neutron component, as well as the ionising component of equivalent dose caused by cosmic ray for different flight patterns and altitudes. The sum of both components gives the total equivalent dose. The relation of the total calculated equivalent dose to the calculated ionising component gives a conversion factor for a certain aircraft position. This factor is tabulated for suitable values in altitudes and grid distances and is stored in a database of a micro computer system. This provides fast data acquisition. The ionising component measured by a GM-counter, is weighted with the

1 Developed under Research Contract by Allgemeine Unfallversicherungsanstalt, Vienna; Patents pending

calculated conversion factor. The result gives an estimation of the equivalent dose (rate) in typical time intervals of some 10 seconds, for a momentary flight position. The dose value 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 chip card. The concept of the Air Crew Radiation Monitor is shown in fig.1.

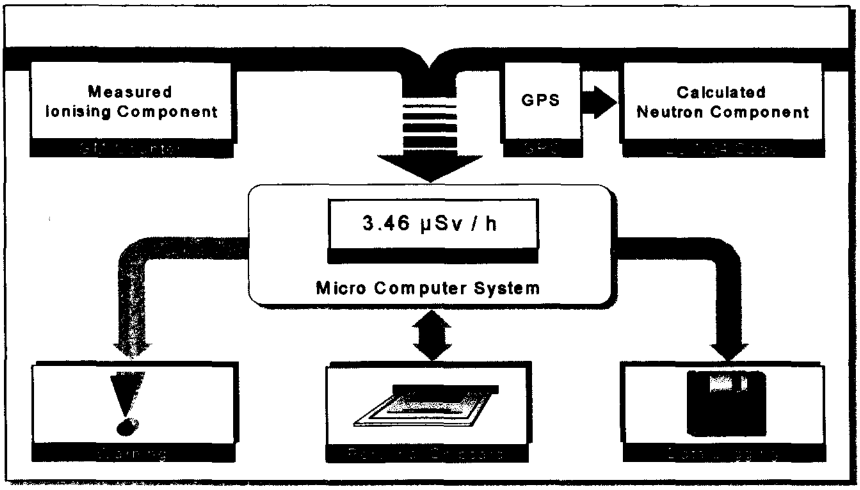


**Fig. 1:** The concept of the active aircrew dose assessment system - ACREM

PRELIMINARY RESULTS

Recently first in-flight measurements have been performed in co-operation with Universität der Bundeswehr, Munich, Germany. The experiments were performed on a Boeing 707 of the German Airforce during a flight from Cologne to El Paso with an intermediate landing in Washington. A low pressure tissue-equivalent proportional counter (TEPC) serves as reference instrument. The used TEPC system with an internal $^{244}Cm$ calibration source, has been described in greater detail in [3]. Additionally a Reuter-Stokes, high pressure ionisation chamber was on-board to compare results with the low-LET component of TEPC measurements. All detectors were calibrated for $^{137}Cs$ at the radiation calibration facility of Seibersdorf. The overall uncertainty for measurements by the GM-counter as well as by the ionisation chamber is about 20 %. The uncertainty for TEPC measurements is nearly the same.

For first data analysis the ionising component of cosmic rays and the low-LET measurements by TEPC will be discussed. Fig.2 shows the dose equivalent rate in µSv/h provided by measurements with the GM-counter (SSM-1), the ionisation chamber (Reuter Stokes RS 111) and the TEPC (low-LET) at the flight route Washington - El Paso. Additionally the dose equivalent rate for the ionising component, calculated by LUIN94, is included for several flight-positions. The integration time for GM-counter and ionisation chamber data points was about 30 seconds. The bar of TEPC data points indicates a measurement time of 1000 seconds. Fig.3 shows the same measurement situation like Fig.2 but for the flight route Washington - Cologne.

During the Washington- El Paso flight mostly the same altitude was used: 39.000 feet. The latitude decrease from 39° north to less than 32° north rather directly. All measurements and the calculations describe this well known fact by reduction of the dose equivalent value, caused by interference of cosmic rays and earth magnetic field. The largest dose value of 4.5 µSv/h was measured by the GM-counter at the most northern position of this flight, for measurements by the Reuter Stokes chamber 3.7 µSv/h at the same position. The TEPC low-LET data and the LUIN94 data fit the Reuter Stokes data very well.

At the flight from Washington to Cologne several different altitudes have been used. All instruments describe the change of altitudes very precisely. The latitude increase from 39° north to 55° north (about 3:00 UTC) and decrease at Cologne to 50° north. Since the changing of altitude and latitude goes in parallel a significantly observations of the "latitude-effect" like at the Washington - El Paso flight can not be expected. More detailed analysis would be necessary. Dose equivalent values range from 2.1 µSv/h at 29.000 feet, 3 µSv/h at 33.000 feet to about 3.5 µSv/h at 35.000 feet.

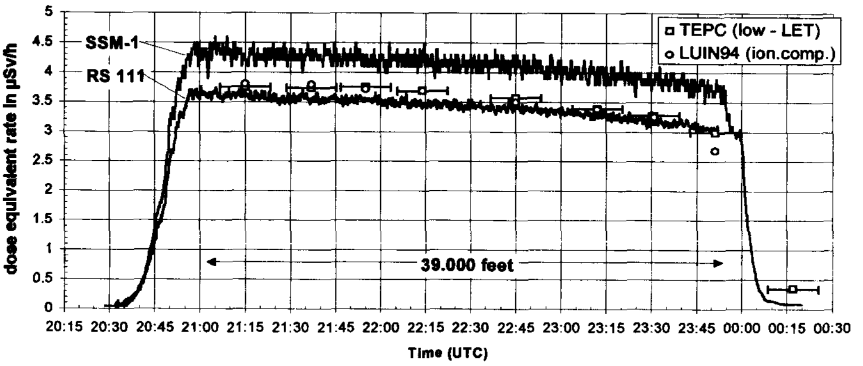


**Fig. 2 :** Dose equivalent rate determined by GM-counter (SSM-1), Ionisation Chamber (RS 111), TEPC (low LET component) and LUIN94 (ionising component) at the flight route: Washington - El Paso.

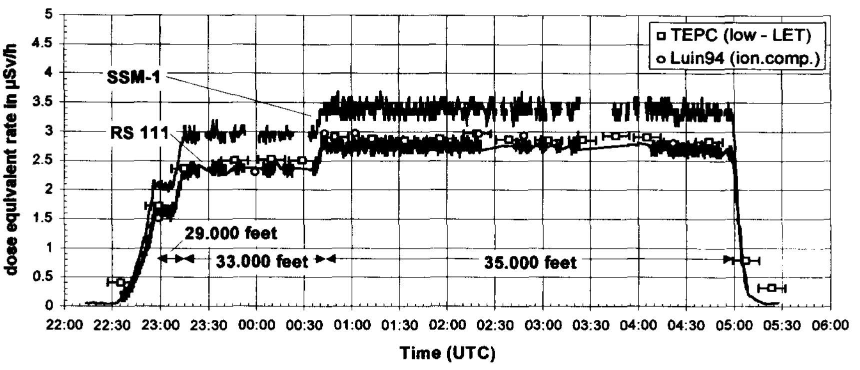


**Fig. 3:** Dose equivalent rate determined by GM-counter (SSM-1), Ionisation Chamber (RS 111), TEPC (low LET component) and LUIN94 (ionising component) at the flight route: Washington - Cologne.

## CONCLUSION

Taking measurement uncertainties into consideration no significant difference between used instruments and calculations could be observed.

ACREM, if eventually verified under routine flight conditions, can be a simple and economical solution for active airborne dosimetry. This method can also account for the contribution of solar particle events, changing flight pattern and altitude.

## ACKNOWLEDGEMENTS

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