FLIGHT SAFETY NOTES

KUWAIT AIRWAYS

No. 0206 **July 2006**

Radiation Hazards to Flight Crew

Prepared by: **Dr.M.S.Rajamurthy**
Senior Researcher Flight Safety
Capt.Shawki Al-Ablani
Deputy Operations Director

Approved by: **Capt.Shawki Al-Ablani**
Deputy Operations Director
Flight Safety and Quality Assurance

Flight Safety & Quality Assurance
OZ/OE

KUWAIT AIRWAYS CORPORATION
KUWAIT

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Introduction

Everyday, we are exposed to radiation. Heat and light are radiation that can be felt and seen. But we are exposed to other kinds of radiation that human senses cannot detect. Figure.1 shows the electromagnetic spectrum covering the entire range of radiation. We continuously receive this invisible radiation from the sky, ground and the air.

As shown in the figure invisible radiation is made up of non-ionizing and ionizing radiation. Radiation that has enough energy to move atoms in a molecule around or cause them to vibrate, but not enough to remove electrons, is referred to as "non-ionizing radiation." Examples of this kind of radiation are sound waves, radio waves, visible light, and microwaves.

Ionizing radiation has enough energy to remove tightly bound electrons from atoms, thus creating ions. When ionizing radiation passes through matter, it causes some of its atoms to become electrically charged or ionized. In living tissues, the ions caused by such radiation can affect normal biological processes.

Ionizing radiation comes in the form of alpha particles, beta particles, gamma rays and x-rays. Alpha particles which are positively charged can easily be stopped by paper or skin. Beta particles are electrons and have greater penetration than alpha particles but can be stopped by thin layers of glass or water or metal. Gamma and X-rays are electromagnetic radiation and are very penetrative. Heavy shielding like lead and concrete is required to stop them.

While ionizing radiation has many uses like X-ray screening, cancer treatment, sterilization of medical equipment, inspection of mechanical components for internal defects, new varieties of crops by radiation induced mutations etc, it is also harmful. This is the type of radiation that we refer to when we talk of radiation hazards.

The primary risks of radiation are carcinogenic and genetic effects. These are also called stochastic effects. Radiation can produce mutations through structural streaks in chromosomes or through changes in the order based on the DNA chain. If this occurs in germ cells it can be transmitted to future generations. A small amount of radiation absorbed by the body does not always damage the cells. If it does, the cells can sometimes repair themselves. Damaged cells can die right away, or if they survive, may be transformed into cells that could cause tumor.

Sources of Radiation

<u>Natural Radiation</u>

Nature is the largest source of radiation. Humans are primarily exposed to natural radiation from the sun, galactic cosmic radiation and naturally occurring radio active elements found in the earth's crest.

The galactic cosmic radiation is due to the high energy particles from outer space beyond our solar system. Galactic cosmic radiation includes alpha, beta particles, gamma rays and X-rays. The radiation levels at air carrier flight altitudes, varies inversely with an approximate 11 year cycle of rise and decline in solar activity. This is brought out by the magnetic fields associate with solar wind continuously emitted by the sun.

The earth’s magnetic field (geo-magnetic field) provides some shielding from incoming cosmic radiation. The density of the radiation is affected by earth’s magnetic field. As a result the shielding is greatest over the geomagnetic equator (near the geographic equator) and decreases to zero as one approaches the north or South Pole regions. Thus at a given altitude, the radiation dose increases with distance north or south of the equator until it reaches a plateau at high latitudes.

In addition due to the partial shielding of earth’s atmosphere, the dose increases with altitude. For a given latitude location, the radiation at sea level is around half to one percent of the value at 40,000 ft altitude. Buildings and the fuselages of aircraft provide little protection from radiation.

Solar flares substantially increase the cosmic radiation.

The Earth's Crust is made up of materials that are naturally radioactive. Uranium, for instance, is dispersed throughout rocks and soil, mostly at very low concentrations. So are thorium and potassium-40. They nearly all emit gamma rays which irradiate the whole body more or less uniformly. Since building materials are extracted from the earth, they can be slightly radioactive, and people are irradiated indoors as well as out of doors. The radiation doses vary according to the rocks and soils of the area and the building materials in use.

Radon is a naturally radioactive gas that comes from the uranium that is widespread in the earth's crust. It is emitted from rocks or soil at the earth's surface and disperses in the atmosphere unless it enters a building, in which the concentration can build up. Radon decays to form other radioactive atoms which, when inhaled, can lodge in the lung and irradiate tissue. The radiation dose can most easily be reduced by preventing the radon gas from entering it in the first place.

Since radioactive materials occur everywhere in nature they get into drinking water and food. Potassium-40 in particular is a major source of internal irradiation, but there are others. Potassium-40 in the body varies with the amount of muscle, for instance, being twice as high in younger men as in older women. Some foods, for example shellfish and Brazil nuts, concentrate radioactive materials so that, even when there is no artificial radioactivity, people who consume large quantities can receive a radiation dose significantly above average. Tobacco smoking produces residual radiation in lungs and poses a high degree of radiation risk.

<u>Artificial radiation</u>

Major source of artificial or man made radiation is the x-rays generated for various applications – medical and non-medical. Nuclear tests and nuclear facilities do contribute to artificial radiation.

Radiation measurement

Radiation is measured in terms of exposure and is called **Roentgen (R).** One Roentgen is equal to depositing in dry air enough energy to cause 2.58E-4 coulombs per kg. The unit used to measure the energy absorbed by a material is called **Rad** **(Radiation Absorbed Dose)**. **Rem (Roentgen equivalent Man)** is a unit used to derive equivalent dose which relates the absorbed dose to the effective biological damage of the radiation. To determine the equivalent dose, absorbed dose is multiplied by a Quality factor which is unique to a particular type of radiation.

In the SI System absorbed dose and equivalent dose are measured in Gray and Sievert (Sv). One Gray is equivalent to 100 rads. One **Sievert** is equivalent to 100 rem. Except for US, Sievert is the commonly used unit.

Table.1 gives the equivalent doses due to radiation from various sources.

A dosage of 50 mSv per year will increase the risk of Cancer by 0.3%. As per the IAEA International Basis Safety Standards, the public limit is 1mSv in a year or in a special circumstance 5 mSv in a year, provided that the average dose over five consecutive years does not exceed 1 mSv per year.

Radiation sources for the flight crew

The flight crew is exposed to cosmic radiation much more than others. With the security issues becoming paramount, they have the possibility of getting exposed to X-ray devices like scanners and fluoroscopy equipment.

Fortunately, the metal detectors used at the airports use magnetism for detection and hence are free from radiation.

The X-ray screening machines used to check the baggage; both unaccompanied and on-board are other sources of radiation. If they are sufficiently shielded, the stray radiation to the surrounding could be reduced. The screened baggage does not have any residual radiation.

The walk through scanners used in large international airports use x-rays. However, the radiation dose of these machines are claimed to be much lower than that for a medical x-ray as the scanner is mainly detecting items like metal rather than the details of soft tissues. The effective dose claimed is 0.1 microSv.

While the radiation exposure due to these is small, the accumulated exposure to the flight crew could be a appreciable and comparable to the cosmic radiation to which they are exposed.

FAA on In-Flight Radiation Exposure

FAA in its advisory circular AC no.120-61 on “Crewmember training on in-flight radiation exposure” recommends air carriers to inform crewmembers of radiation exposure and associated health risks. It details the topics that have to be covered in this exposure.

They are

1. Types and amount of radiation received during air travel
2. Variables that have an effect on the amount of radiation
3. Guidelines regarding exposure to ionizing radiation, including recommended limits for workers
4. The risk to crewmembers and fetuses associated with cosmic radiation
   - Health effects of ionizing radiation at air carrier flight altitudes
   - Uncertainties about the effects of low doses of radiation
   - Comparison of cosmic radiation risks with other health risks
5. Special consideration during pregnancy, including early recognition and prompt reporting of the same to the management; voluntary nature of this disclosure; employee and management responsibility to ensure the exposure of the unborn child not to exceed recommended limits.
6. Managing exposure to radiation risks, including:
   - How changes in amount & type of flight assignments alters estimated risk;
   - How changes in amount & type of flight assignments can affect proximity limits
   - How crew members may obtain estimates of cosmic radiation received during flight segments
   - Radioactive material shipments as source of radiation exposure

Documents of FAA office of Aerospace medicine [ref.4, 5 and 6] give details of the radiation exposure of air carrier crew members and the associated risks.

To take care of the increased radiation during solar flares, a Solar Radiation alert system has been developed that considerably reduces the risk to exposure to excessive radiation following severe solar disturbance. Accompanying the alert is a message with estimates of radiation levels at altitudes from 20,000 ft to 80,000 ft at a specified high latitude and recommended maximum flight altitude at these latitudes.

<u>The FAA recommended limit for an aircrew member is a 5 year average effective dose of 20 mSv per year with no more than 50 mSv in a single year. For a pregnant aircrew member starting when she reports pregnancy to management, the recommended limit for the conceptus is 1mSv, with no more than 0.5 mSv in any month.</u>

<u>Pregnant crew members can minimize occupational radiation exposure by working on short, low-altitude, nearer to equator flights</u>

Farrol Kahn, Director of Aviation Health (AH), a non-profit body dealing with aviation health issues in U.K. in her article "High altitude may be bad for your health" quotes a limit of <u>6mSv per year for aircrew</u>. This reflects more stringent requirement in Europe.

Radiation exposure to KAC crew

To get representative values of the galactic/cosmic radiation to which KAC crew are exposed, representative radiation exposures were computed using CARI-6 program of FAA Civil Aerospace medical institute, USA. This program takes the flight profile and duration as its inputs and gives as output the radiation exposure in mSv. Sample results obtained are shown in table.2. Table 3. summarizes the radiation received in flight for various destinations. As can be seen in the table, the highest dosage is experienced in flights to Europe and USA. The dosage per block hour for New York flight is four times that for flights to Asian sub-continent and the flights to Middle East. B777 crew makes twenty round trips per year on average, amounting to 500 block hours per year. The exposure for this is the exposure is 2.985 mSv which is well below the maximum threshold of 20 mSv stipulated by FAA and below 6 mSv quoted by Aviation Health of U.K.

Not withstanding this observation, the long term effects of low doses is not very clear. Farrol Kahn reports that over the past decade several air crew studies have been conducted. In a British Airways survey of 411 pilot deaths, incidences of malignant melanoma, colon and brain cancers were slightly higher than normal. A research on 2740 Air Canada pilots found an increased incidence of prostrate cancer and acute myeloid leukemia. A significant study on 1577 female flight attendants working for Finnair during 1940-1992 showed twice the risk of breast cancer compared with general population.

The point to be borne in mind is the cumulative long term effect of the lower dose. This is still being debated over by the medical and health communities. Like the old adage – no drug is safe; we can say radiation is not safe.

Conclusions and Recommendations

The scientific and regulatory literature available in the open domain gives a picture which appears to be safe but at the same time there is need to consider radiation hazard seriously. There is a need to educate the flight crew on the possible hazards due to cosmic radiation as well as means of minimizing the same. The hazard is of greater concern to female aircrew members.

The study shows that the airport screening machines for both the check-in baggage and on-board baggage do not carry any residual radiation. However, the x-ray screening and fluoroscopy equipment if used exposes the crew to radiation on ground as well. This should be minimized to ensure that over a period, the flight crew does not accumulate radiation exposure in excess of the limits stipulated. The current aircraft structures will not be able to absorb or divert the cosmic radiation. As a result, the flight crews are constantly exposed to radiation during their flight duties.

Only means of minimizing the radiation exposure to flight crew is to minimize their exposure to man-made radiation at the airports. Exposure to cosmic radiation can be minimized by suitably distributing the flight crew between the flights to larger latitudes and those near equator. CARI-6 program of FAA Civil Aerospace medical institute, USA could be used for this. Female crew members have to be educated on the possible hazards during pregnancy. Their exposure to cosmic radiation during pregnancy can be minimized by assigning short duration low latitude flights.

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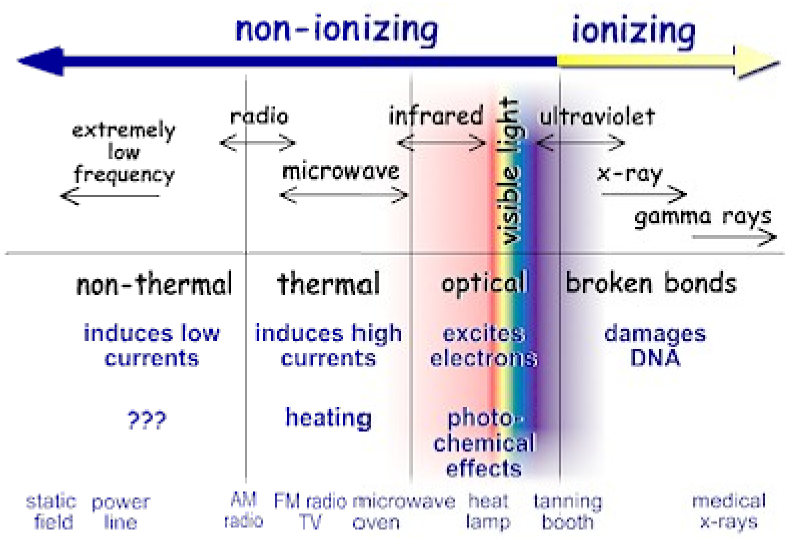

Figure 1. The electromagnetic spectrum

Radiation source	Global Average dose/year	Hazard
Natural : Radon	1.3 mSv	Low
Cosmic radiation	0.39 mSv	Very Low
Earth crust	0.46 mSv	Very Low
Consumer products: Tobacco	160 mSv	High
food and others	.05 – 0.3 mSv	Very Low
Medical: X-ray	0.3mSv	Very Low
Nuclear medicine	4.3 mSv	Low
CT scan (0.5 hour)	100 mSv	High

Table.1. Radiation exposure from various sources

Galactic Radiation Received In Flight

Flight Summary		
Date of Flight	**05/2006**	
Origin Code	**OKBK**	KUWAIT, KUWAIT
Destination Code	**EGLL**	LONDON, UNITED KINGDOM
Number of en route altitudes	**1**	
Minutes to 1st en route altitude	**30**	
En route altitude(s) and time(s)	Altitude (in feet): **35000**	Minutes at altitude: **360**
Minutes descending to touchdown	**30**	
Effective Dose	**24.87 microsieverts (0.02487 millisieverts)**	

Galactic Radiation Received In Flight

Flight Summary		
Date of Flight	**05/2006**	
Origin Code	**OKBK**	KUWAIT, KUWAIT
Destination Code	**KJFK**	NEW YORK, NY
Number of en route altitudes	**1**	
Minutes to 1st en route altitude	**30**	
En route altitude(s) and time(s)	Altitude (in feet): **38000**	Minutes at altitude: **660**
Minutes descending to touchdown	**30**	
Effective Dose	**76.12 microsieverts (0.07612 millisieverts)**	

Table.2. Sample outputs from CARI-6 for a flight from Kuwait to London and a flight from Kuwait to New York

Origin- Destination	Single non-stop flight				
	Highest altitude, ft	Air time, hours	Block hours	Milli-sievert	Milli-Sievert/ block hour
Kuwait- JFK, New York	38000	12	12.75	0.07612	0.00597
Kuwait - London	35000	6.5	7.25	0.02289	0.003157
Kuwait- Frankfurt	35000	6.5	7.25	0.02289	0.002924
Kuwait - Bangkok	38000	6	6.75	0.01974	0.002186
Bangkok - Manila	36000	2.5	3.25	0.0040	0.00123
Kuwait- Dhaka	33000	6.5	7.25	0.01237	0.001706
Kuwait - Cairo	36000	2.5	3.25	0.00514	0.00158
Kuwait- Doha	30000	2.5	3.25	0.00310	0.000954
Kuwait- Dubai	31000	4	4.75	0.00618	0.0013
Kuwait- Jeddah	30000	2.5	3.25	0.00344	0.001058
Kuwait- New Delhi	33000	5	5.75	0.00956	0.001662
Kuwait- Bombay	36000	3.5	4.25	0.00705	0.001659
Kuwait- Trivandrum	33000	4.5	5.25	0.00747	0.001423
Kuwait- Chennai	33000	5	5.75	0.00859	0.001494

Table. 3. Cosmic radiation exposure for various flights of KAC