Radiation Safety in Commercial Air Traffic

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When the possibility of high altitude supersonic commercial aviation was first seriously proposed, Foelsche (Fo61) brought to light a number of concerns with respect to atmospheric radiation. Subsequently, a detailed study of the atmospheric radiation components at high altitude was conducted by the Langley Research Center (Fo74). In it the major role of atmospheric neutrons in radiation exposure was uncovered. These studies utilized an instrument package consisting of tissue equivalent ion chambers, organic scintillator neutron spectrometers, and nuclear emulsion. A theoretical program to predict atmospheric radiation levels and to specifically extend the neutron spectrum into the range outside that measured by the scintillation spectrometer was also developed (Wi70). It was found that the neutron spectrum due to galactic cosmic rays was nearly independent of solar modulation. However, the neutron spectrum produced by solar cosmic rays was found to vary from event to event. An overview of that program is given by Foelsche (Fo77). It was the conclusion of this previous work that high altitude commercial aviation required special considerations for radiation protection while worst case flights for pre-1980 subsonic airlines were well within the exposure limits of the general population (Fo74, Fr80).

The previous work on atmospheric radiation used the quality factors, as defined by the International Commission for Radiological Protection (An64), which are currently undergoing considerable revision. With the recent recommendation of a new quality factor by the International Commission for Radiological Measure and Units (An86), it seems prudent to estimate the resulting changes in the radiation exposure rates in the Earth's atmosphere. It is found that worst case estimates of radiation exposure are now well above the exposure limits of the general population and a reassessment of radiation impact on commercial aviation is needed.

Contributions to the neutron dose equivalent rate were calculated (Fo74) in energy subintervals as shown in the first three columns of table I. The corresponding previous average quality factors (An64) for each subinterval are shown in column four. The newly recommended quality factors (An86) are averaged over each subinterval according to the neutron spectrum produced by the galactic cosmic rays and then applied to the neutron dose rates to obtain new estimates of the neutron dose equivalent rates, as shown in columns five and six. The resultant change in the total dose equivalent rate is an increase of 55 percent.

The neutron dose equivalent rates of Foelsche et al. (Fo74) were scaled according to the 55 percent increase to obtain the new rates shown in figure 1. The dose in extremities has been used since it most closely represents the neutron "maximum dose equivalent" which is recommended for use in ambient environments (An77). In addition to changes in neutron dose equivalent, the nuclear star quality factors were taken as 25, as recommended by the ICRU (An86), instead of 20 as used in the earlier calculations (An64, Fo74). The newly estimated total dose equivalent rate is shown in figure 1 as a function of altitude at high latitudes for different phases of the solar cycle. The curve labeled 1965 is near solar minimum and the curve labeled 1968 is near solar maximum.

It is clear from figure 1 that dose equivalent rates near 45,000 ft. are at the level of 1 to 1.6 m-rem/hr at high latitudes depending on solar activity. A crew flying at 45,000 ft. cruise altitude for 40 hrs. per month (Fo74) would receive exposure levels of 0.5 to 0.8 rem per year. Such crew members should be considered as radiation workers rather than as members of the general population at least if presently recommended levels of maximum permissible dose remain in effect (namely, 0.5 rem per year for the general population and 5 rem per year for radiation workers).

Although the preceeding argument suggests that crew members of high latitude commercial flights should be considered as radiation workers, there are several factors which could substantially alter the exposure for most flight crews. The 45,000 ft. altitude and high latitude assumptions are conservative and the specific flight patterns need to be more accurately modeled. At the same time, airline deregulation has forced commercial air carriers to use their flight personnel more efficiently so that a value of 40 hours per month at cruise altitude yields too low a dose estimate. Claims are made that flight crews currently spend up to 80 hours per month at cruise altitude (Ma86). The maximum permissible dose limits are currently under revision and the final limits are unclear. Finally, the estimates of new dose equivalent rates made herein are rather crude and should be made more accurately. Even so, errors in the present estimate are not worse than 20 percent due to energy variation in the average neutron quality factor. Clearly, such work needs to be done to clarify the work status of the commercial air crews.

In addition to the above uncertainties, the effects of galactic heavy ion collisions on the atmospheric neutron spectrum have never been resolved (see Fo74). This is especially important to developing a worldwide neutron dose equivalent rate map since the ratio of protons to heavy ions in the galactic spectrum is a function of geomagnetic cutoff. Also, the 45,000 ft. altitude is sufficiently high as to be adversely affected by solar cosmic ray events (Fo74,Fr80); therefore, a reevaluation of the projected solar cosmic ray dose rates is in order. This is especially important since the neutrons play an even more important role in solar cosmic ray exposures and the neutron spectrum varies considerably in different solar events.

Table I. Dose (ΔD,m-rad/hr) and Dose Equivalent (ΔH,m-rem/hr) Rates in Neutron Energy Intervals (ΔE,MeV) with the ICRP (Au64) and the New ICRU (Au86) Quality Factors ($\bar{Q}$).

ΔE	ΔD	ΔH_{ICRP}	$\bar{Q}_{ICRP}$	$\bar{Q}_{ICRU}$	ΔH_{ICRU}
0.1-1	.020	.234	11.7	19.4	.388
1-10	.032	.252	7.9	17.6	.563
10-100	.039	.272	7.0	7.0	.273
100-1000	.031	.104	3.4	3.4	.104
.1-1000	.122	.863	7.0	10.9	1.328

Figure Caption

Figure 1. Galactic cosmic ray dose equivalent rates for extremities at high latitudes for different phases of the solar cycle (cycle 20).

References

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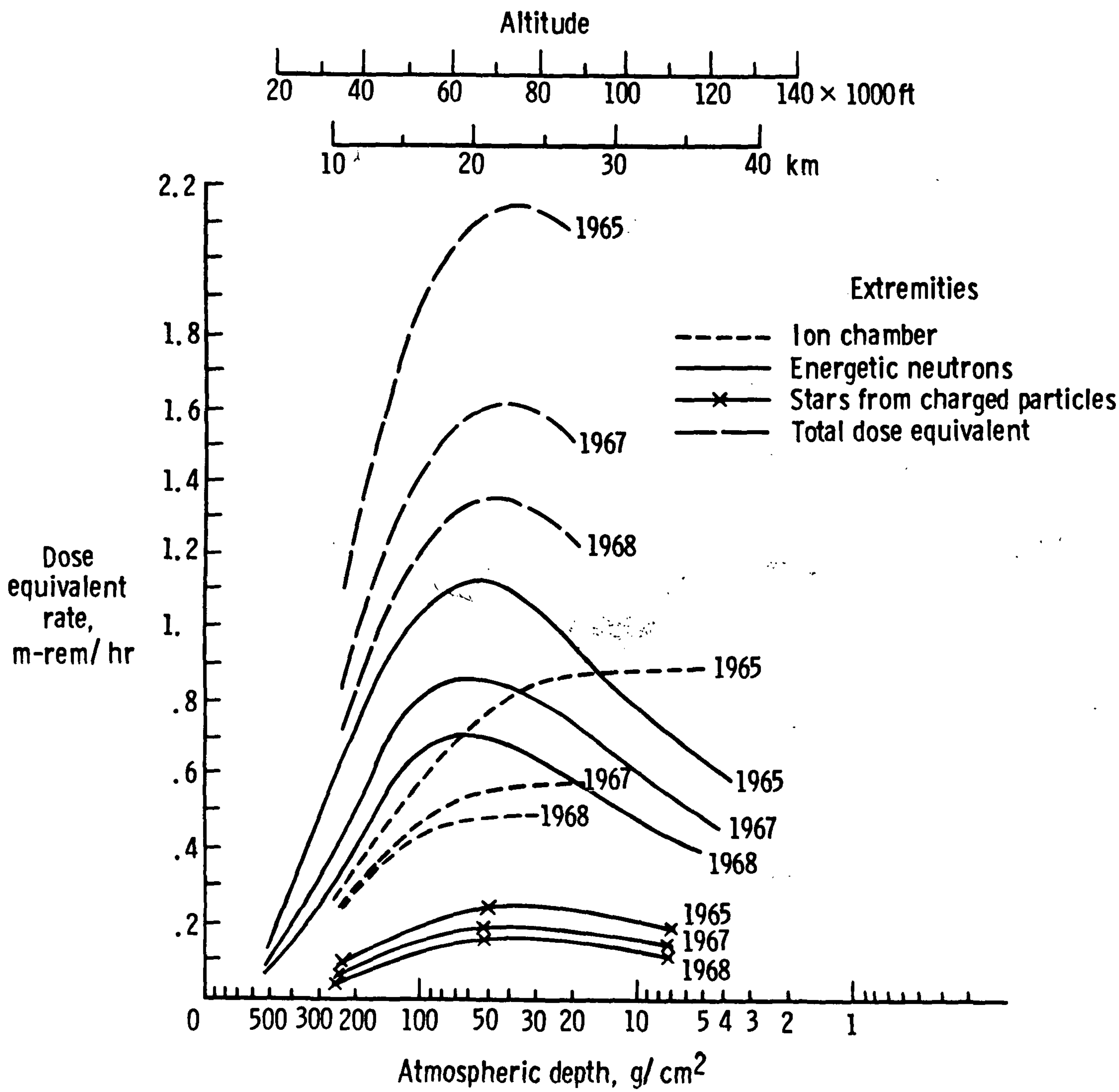
Altitude
20
40
60
80
100
120
140 × 1000 ft
10
20
30
40 km
Extremities
Ion chamber
Energetic neutrons
Stars from charged particles
Total dose equivalent
Dose equivalent rate, m-rem/hr
2.2
1.8
1.6
1.4
1.2
1.
.8
.6
.4
.2
0
1965
1967
1968
1965
1967
1968
1965
1967
1968
1965
1967
1968
500 300 200 100 50 30 20 10 5 4 3 2 1
Atmospheric depth, g/cm2