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## MAGNETIC FIELDS

In future space operations, astronauts may be exposed to a very wide range of magnetic field intensities and gradients. Figure 4-1 presents magnetic field intensities expected at several points in the solar system. It suggests that field intensities on the lunar surface will be several orders of magnitude less than the geomagnetic field. At a distance of more than 10 Earth radii, the solar wind is expected to have a magnetic field of only  $10^{-4}$  to  $10^{-5}$  gauss (16). Intricacies of the interaction between the solar

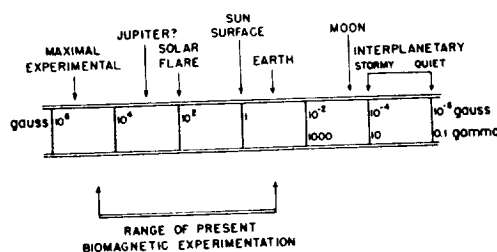


Figure 4-1

Range of Magnetic Field Intensities

(After Beischer<sup>(8)</sup>)

wind, magnetic fields, and trapped radiation belts around the Earth, are being unraveled ( 2, 26, 27, 29, 33 ). A neutral sheet or wedge of low field strength is present on the down-Earth side of magnetosphere. The surface of Venus probably has intensities of less than 0.05 gauss and Mars, even lower values. While the solar photosphere has a field strength of 1 gauss, the center of sunspots have been calculated to range from 1000 to 3500 gauss. The contribution of electronic equipment on board a space vehicle to the total magnetic field experienced by an astronaut both extra- and intra-vehicularly is not clear (15).

The high-gradient magnetic fields with intensities of several tens of thousands gauss suggested for anti-radiation shielding and electric propulsion systems may, in some instances, be involved in human exposure (14, 15, 25 ).

Relatively little is known about the specific effects of high and low intensity magnetic fields on man ( 1, 7, 8, 9, 11, 15, 22 ). Past studies in magneto-biology have been directed mainly at determining the effects of magnetic fields different from that of the geomagnetic field on sub-human species, plants, and simple chemical systems. Several reviews of these background materials are available (1, 3, 5, 7, 8, 9, 11, 15, 19, 22, 31).

Low Magnetic Fields

Very few human exposures to a magnetically quiet environment have been reported. A certain amount of experience has accumulated during ordnance

work inside degaussing coils. A health survey of personnel exposed to an almost magnetically quiet environment during most of their working day over several years revealed no ailment traceable to this unusual environmental exposure ( 11 ). A number of physiologic and psychologic studies on two men exposed for 14 days to a magnetic field of about 50 gamma (1 gamma =  $10^{-5}$  gauss) revealed no abnormal responses ( 9, 11 ). A similar study of low gauss in which six men were exposed to a magnetic field below 50 gamma revealed significant alterations in scotopic critical flicker fusion and brightness discrimination in five of the six subjects during the period of exposure ( 10, 13 ). Such limited observations suggest that some physiologic processes of the human may be altered in the geomagnetic and lunar magnetic fields, but more experimental work is required before the operational significance of these findings is known ( 15 ).

The view is generally held that during the millions of years life was evolving in our planet, the general magnitude of the Earth's magnetic field was no different from that measured at the present time ( 4 ), though its polarity and strength have detectably changed several times, the last major change occurring about  $7 \times 10^5$  years ago ( 20, 28 ). Accordingly, it is not unreasonable to assume that living creatures have become accustomed to the geomagnetic field as part of their natural habitat, and possibly that some biologic processes have actually become to some degree dependent on the presence of the geomagnetic field ( 4 ). It has been pointed out that normal magnetobiologic effects would take place on molecular and atomic levels ( 8 ). It is suggested that a turn of the human body in the geomagnetic field imparts a momentary precession, according to the Larmor theorem, of approximately 2000 cps to all hydrogen nuclei in the body. Other magnetic cell constituents should also precess with frequencies according to their mechanical and magnetic moments. One must consider that the near absence of precession movements in very low intensity magnetic fields may deprive living matter of spatial clues, and that very careful long-term physiologic and psychologic observations of man in such fields are necessary before predictions that human performance will be unaltered under such conditions ( 15 ).

Few data are available on the magnetic fields encountered within a typical spacecraft cabin. The induced magnetic fields at different distances from specific electronic components and the magnetic characteristics of representative spacecraft materials have been recorded ( 17 ). Such data are of value in design of magnetic field experiments in orbit or on the lunar surface.

### High Magnetic Fields

What is presently known of the effects of high magnetic fields on man is summarized in Table 4-2. These responses were obtained from personnel of a number of nuclear physics laboratories who are exposed occupationally to high magnetic fields.

This list should not be taken to mean that the performance of man will not be degraded in high magnetic fields. There is every indication from recent studies using spider monkeys as subjects that very high magnetic fields (up to 100,000 gauss for 24 hrs.) may affect neural and cardiac

Table 4-2

Effects of Magnetic Fields on Man

(After Beischer (9))

VISUAL SENSATIONS (PHOSPHENES) IN ALTERNATING FIELD.

NO SENSATION OBSERVED IN PART AND ENTIRE BODY EX-  
POSURE TO NON-CHANGING FIELDS UP TO 20 kilogauss  
FOR A DURATION OF 15 MINUTES.

NO AFTER-EFFECTS FOLLOWING EXPOSURE TO FIELDS OF  
5 kilogauss FOR LESS THAN 3 DAYS PER YEAR PER MAN.

TASTE AND PAIN SENSATION CAUSED BY INTERACTION WITH  
FILLINGS OF TEETH SOMETIMES DESCRIBED.

function ( 12, 13, 23 ). These studies demonstrated a shift of the frequency of the EEG to higher values and a considerable increase in intensity of the brain potential. The electrocardiogram showed a decrease in heart rate, an increase in sinus arrhythmia and an augmentation of the amplitude of the T wave. No gross pathology has been seen in these animals. The significance of such alterations to the general health and psychomotor performance of humans remains to be determined.

Exposure of animals, isolated organs, neoplastic and non-neoplastic tissue cultures and simple chemical systems to high magnetic fields has produced a great variety of biologic effects ( 15 ). To date, no definite magnetic dose-effect relationship has been established. Effects have been predicated on the basis of field strength alone ( 9 ), as well as on the inhomogeneity of the paramagnetic strength of the field ( 4 ).

The coupling of magnetic fields with biological systems has been hypothesized as due to ( 4, 6, 18, 24, 29, 32):

- 1) Generation of electromotive force in moving conductors.
- 2) Force exerted upon moving charge carriers at critical sites ( 24 ).
- 3) Torque exerted on permanent magnetic dipoles and non-spherical para- or diamagnetic particles ( 29 ).
- 4) Retarding effect on the rotational diffusion of large molecules, leading to a decrease in biochemical reaction rates.
- 5) Alteration of bond angles, which may influence chemical reaction rates ( 24 ).
- 6) Alteration of tunneling rate of protons in hydrogen bonds of macromolecular systems.

Any one of these basic factors could possibly alter human performance under very high magnetic fields. Much work is required to classify the mechanisms responsible for behavioral changes in animals exposed to these fields (15, 21 ).

There is a deficiency of data on electromagnetic fields in which the electro and magnetic components are strongly perturbed. Checklists of sources of different electromagnetic radiations are available (34 ).

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