Trapped Field Magnets for Radiation Shielding

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Overview

Problem: Long duration space flight requires adequate shielding due to astronaut exposure to radiation.

- Solar radiation (up to 100 MeV)
- Galactic (space radiation up to 1000 MeV)

Characteristics of Galactic Cosmic Radiation (GCR) and Solar Particle Emissions (SPE)

- GCR comes from all directions in deep space.
- Two kinds of SPE radiating from the Sun.
  - Coronal Mass Ejection (CME).
  - Solar Flares.
- For CME – a large plasma cloud is ejected from the Sun's surface: It's part of the solar mass.
  - Travel time to earth is one day.
  - An isotropic cloud of active particles.
  - An order of magnitude (x10) worst than a solar flare.
- For Solar Flares
  - Smaller events associated with sunspots.
  - Mainly protons traveling at the speed of light – Travel time is about 30 minutes.

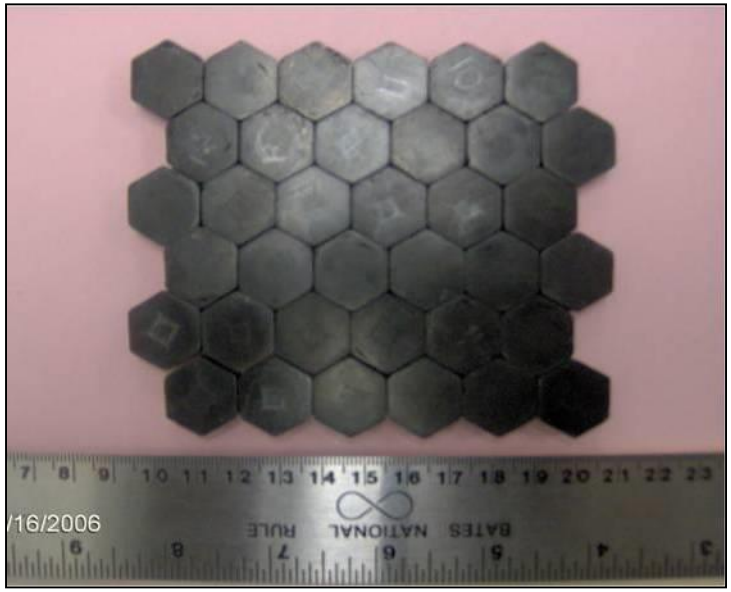
Methods for Shielding Astronauts

- Pharmaceutical countermeasures.
- Passive shields –
  - Water
  - Cryogenic fluids; liquid H_2, O_2
- High temperature (77° Kelvins) superconducting magnets.
  - Superconducting coils
  - Trapped field magnets
- Evaluation factors for superconducting magnets include:
  - Shielding protection
  - Angular coverage
  - Magnetic fields inside habitat
  - Magnetic forces on habitat
  - Mechanical stability/magnetic pressure between individual magnets

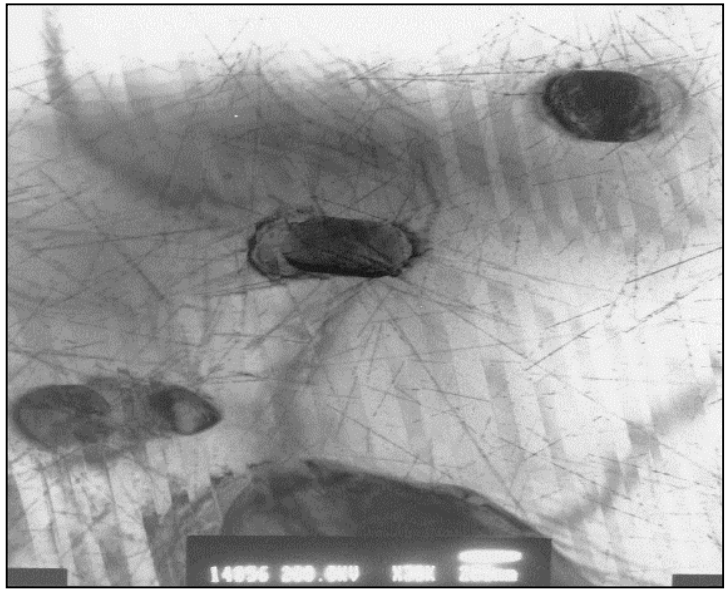
What is a Trapped Field Magnet (TFM)

- TFMs are magnets composed of single grain, low grade crystals of a high temperature superconductor YBa^2 Ca^3 O^{7-8} (YBCO).
- Induced currents set up in the TFM are persistent (do not die out). Resulting magnetic fields are retained in position by “pinning centers”.
- Pinning centers are imperfections in the crystal lattice structure and are non-superconducting. The success of a TFM is to have many good pinning centers, i.e., 10^{12} per square cm.
- Professor Emeritus Roy Weinstein, Univ. of Houston, head of the Beam Particle Dynamics Laboratory, holds the patents for creating high-quality TFM.
- See Figure 1

Trap Field Magnets



TFM Mosaic Array



Lattice with Pinning Centers

Characteristics of TFMs

- Capable of sustaining very high magnetic fields (2-7 Tesla) or 20,000 to 70,000 Gauss at each small TFM.
- TFM has a one inch diameter and .25 inch thickness.
- Each TFM is magnetically independent of the adjacent magnets in an array.
  - This means each magnet can be energized one at a time and the support structure should have minimal forces exerted on it by the magnets.
- Light-weight – 30 magnets per pound.
- Low cost - $300 per magnet.

Characteristics of TFMs cont.

- Highly stable once activated with an initial 15% loss of field strength over the first two years, then stable for many years.
- No superconducting wires.
- Cooling can be achieved by using the natural coldness of deep space (4° K) to cool the magnets below the required 77° K.
- Activation of the magnetic array can be done one magnet at a time. A 3 meter by 1 meter solar array can supply the power to energize one square meter of magnet array (1600 magnets) in one hour. De-activation is achieved by warming the magnets above 77° K.

Measured Fields of a Seven TFM Array

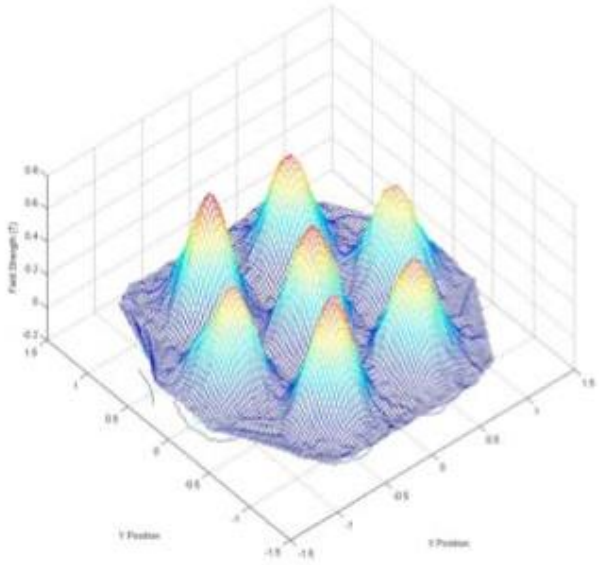


Figure 3

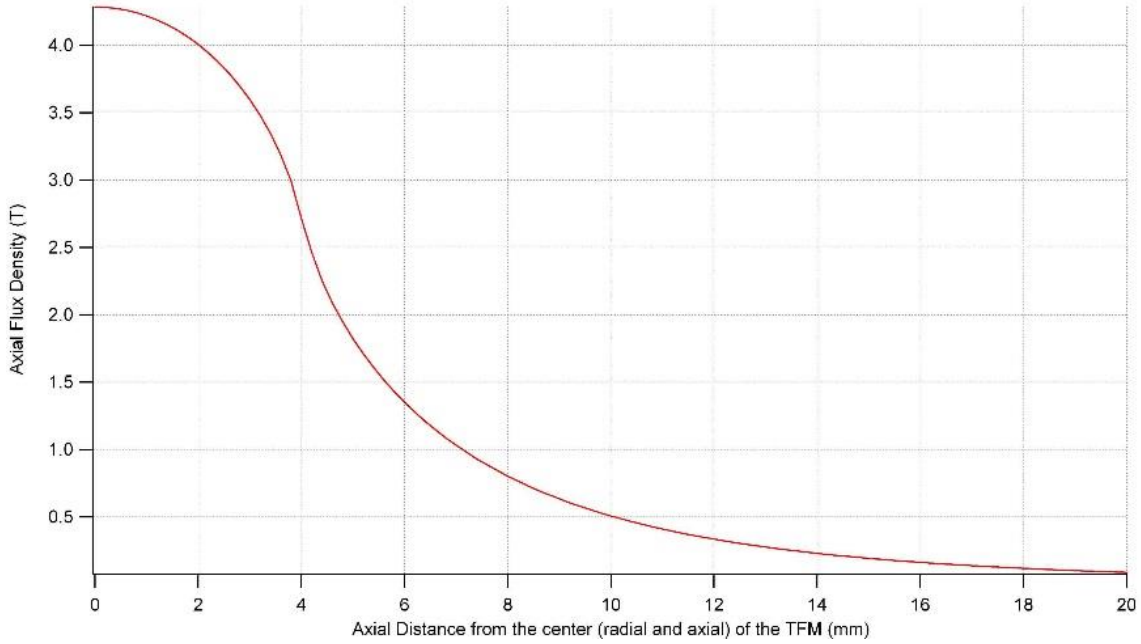


Figure 4

Magnetic Configurations

- A magnetic shield could consist of several layers of magnet arrays spaced several cms apart. Each layer would then be offset from the upper layer by approximately .5 inches (half the diameter of a single TFM) in order to fill the gaps in coverage as seen in Figure 3.
- Since the fields extend only a few inches above the top layer of the arrays, a thin layer of magnetic shielding can be achieved. Extra shaping of the fields may possibly be achieved by having a Halbach configuration.
- Both internal and external shield configurations are possible.