Artificial Radiation Belt Discussed in Symposium at Goddard Space Center

On 9 July at 0900:09 Universal Time a nuclear explosion of about 1.4 megatons occurred 400 kilometers above Johnson Island in the central Pacific Ocean. As a result of the explosion a new artificial radiation belt was formed. The new belt is composed principally of the electrons produced by the decay of fission fragments from the explosion. The electrons possess energies up to about 8 Mev, with about half of them being below 1 Mev. They are trapped in the earth's magnetic field in the same manner as the particles of the natural radiation belt. The probable existence of the belt was predicted before the explosion. A general description of the distribution in space of these electrons is illustrated by the drawing on the front cover of this issue.

A large number of scientists made observations on the phenomena related to the event, and many data were obtained from satellite observations. In order to collect these data, a symposium was held at the Goddard Space Flight Center 10 and 11 September on the artificial radiation belt. This was a special effort to bring together people from various fields to get a general picture of the energetic particles trapped in the earth's magnetic field. Material presented at the meeting covered several related subjects: satellite detector measurements of the particle fluxes, solar cell damage on satellites, measurements and calculations of the synchrotron radiation coming from the trapped particles, a model of the currently trapped radiation, and information on particle lifetimes. A summary of this information is presented here. Details of many of the observations and calculations will be presented in a forthcoming issue of the *Journal of Geophysical Research.*

In the session on satellite measurements, data were presented on four vehicles, Ariel, Injun, Telstar, and Traac. The first indication that there was a new belt of high intensity came from Ariel, which 3 days after the explosion stopped transmitting useful data because of reduced voltage from the power supply. By that time Ariel had lived for several months, and the cause of the system failure was complex; it was not obvious that the failure was induced by radiation, although the possibility was immediately mentioned. A few days later when data had been reduced, however, it was apparent that Ariel had encountered large particle fluxes. The existence of such fluxes was indicated by a 302 Geiger-Müller counter (E. Elliott, J. J. Quenby, and A. C. Durney) and by an ionization chamber for x-rays (R. L. F. Boyd, A. P. Willmore, and K. A. Pounds). Willmore reported on the Ariel results at the meeting and included a very interesting history of the early period of the trapped radiation and its low-altitude time decay.

The SUI satellite, Injun, had already lived about a year before the explosion on 9 July and had collected many useful data (*1*). Many of the detectors on board went into saturation, but the SpB detector (a 213 Geiger-Müller counter with lead shielding of 3½ grams per square centimeter) worked well, and other detectors on Injun are expected to be productive in the future. Van Allen reported on the data from Injun and presented information on the spatial distribution and time decay of the electron flux. Some of these data have already been published (*2*).

Telstar, the Bell Telephone Laboratories' communication satellite, provided a very important part of the data now available on particle fluxes at high altitudes. Telstar ascends to about 6000 kilometers, while the other satellites reported here do not rise much above 1000 kilometers. Brown reported on the solid-state particle detectors on Telstar which give information on electron fluxes in several different energy regions. This information shows that the spectrum up to ~ 2 Mev is quite similar to a fission electron energy spectrum and indicates that there are total fluxes above 10^9 electrons per square centimeter per second in some regions of space.

Pieper reported on the data from the Traac satellite. A 302 Geiger-Müller counter with shielding of about 0.7 gram per square centimeter (supplied by Frank of SUI) counts electrons of energy above about 1.5 Mev. Traac failed because of damage to the power supply about 1 month after the nuclear explosion. During this month, it collected data on the electron flux and its time decay at low altitudes. One point of interest reported was that a local hot spot of flux is seen in the Pacific at late times by the Traac detector.

Data on solar cell damage were presented on four satellites. Bourdeau reported that from 1 to 3 $\times$ 10^{13} electrons per square centimeter would be required to give the damage observed at +4 days on the Ariel satellite. Fischell showed very interesting damage curves for Traac and Transit 4B and showed that about 4 $\times$ 10^{14} electrons per square centimeter were needed to give the failure at about +30 days. Brown said that about 6 $\times$ 10^{13} electrons per square centimeter per day inside the protective covering would give the observed degradation of the Telstar solar cells.

Although it is not a trivial problem, solar cell power supplies can be designed so that they will live a long time in this radiation flux. Telstar is expected to live longer than a year in this flux. The satellites that failed had not been designed in this manner because it was not expected that they would encounter very large fluxes.

Although magnetically trapped energetic electrons are expected to radiate energy through the synchrotron radiation process, such radiation has not been observed from the natural radiation belt. However, synchrotron radiation from the artificially trapped electrons was observed in the 18 to 120 Mcy/sec range at observatories near the geomagnetic equator.

Dyce, Pannell, and Slutz presented reports on equipment and measurements. Time delays between the injection of electrons and the initial increase in signal were well correlated with longitudinal drift times from the longitude of injection to the field of view of the antennas. Effective source temperatures were highest at the geomagnetic equator, decreased to one half of equatorial values at about 10° geomagnetic latitude, and were just measurable at 20° geomagnetic latitude. The variation with wavelength of effective source temperatures in this frequency range was found to be proportional to λ^3; galactic radio noise is proportional to $\lambda^{2.32}$. The mid-August equatorial source temperature at 30 Mcy/sec was about 1.5×10^4 degrees Kelvin, a value comparable to that of galactic radio noise. The time decay of the synchrotron radiation appeared to be correlated with particle loss from the lower edge of the artificial radiation belt. At 30 Mcy/sec, the decay rate was about 10 percent every 2 weeks during August.

Peterson reported on calculations of the spectral distribution and intensity of synchrotron radiation from the observed spatial distribution of the artificial radiation belt. An energy spectrum of electrons similar to that from the decay of fission products was found necessary to explain the spectral distribution of the synchrotron radiation. Observed electron fluxes at the lower edge of the artificial belt showed good agreement between calculated and observed intensities of radio emission. Calculations were insensitive to fluxes at higher latitudes because of the strong dependence of emission on magnetic field.

Hess reported on the composite model of the radiation belt that was developed by combining data from the Ariel, Injun, Telstar and Traac satellites. After a fission spectrum had been assumed, the fluxes from the different detectors were converted to total fluxes of electrons of all energies. These were compared in terms of the magnetic coordinates (B and L), and showed good agreement where direct comparisons were possible. The electron flux map shown on the cover was obtained in this manner. This is an idealized dipole representation of the electron fluxes. The actual flux distribution is somewhat different, especially at low altitudes. At an altitude of a few hundred kilometers significant fluxes are measured only in the south Atlantic, because of irregularities in the earth's magnetic field. The fluxes in the map on the cover at most places in space are probably reliable to a factor of 2 or 3. This flux map is for 1 week after the explosion; some decay has taken place since then.

Van Allen expressed doubt that the summary contour diagram shown on the cover should be accepted as representing the intensities of artificially injected electrons. This doubt arises from two separate considerations: (i) The Injun 1 counting rate contours at low altitudes curl away from the earth at latitudes of 35° to 40° in such a way as to suggest that the artificial belt is limited effectively to a radial extent of less than 2.7 earth radii. (ii) Much of the summary diagram has a striking resemblance in both form and absolute intensities to those of the natural radiation belts found with Explorer XII and with other satellites by the Iowa group. A central experimental difficulty is that Telstar was fired after the Johnston Island burst, and hence no direct subtraction of pre-burst data with the same detectors can be made for these data. It appears that most of the radiation damage data and the synchrotron noise are consistent with either a limited or an extended artificial belt. Several other members of the audience felt quite strongly that the flux plot as presented did represent artificial electrons out well past the field line $L = 2$. Further study is being given to this question.

Kaufmann presented calculations on the expected time decay of the electron flux. These calculations were based on the assumption that coulomb scattering is the dominant loss process. The times agree qualitatively with observations at low altitudes. On the field line of $L = 1.25$, Van Allen reported that a decay of about 2 times was observed on Injun from 100 hours to 1000 hours after the explosion. The calculated characteristic time of decay on this field line is a few months, that is, in moderately good agreement. For the field line of $L > 1.3$ the characteristic times became very long—years. At high altitudes processes other than coulomb scattering may contribute to the loss of particles.

This symposium was organized by Col. McCormac of the Defense Atomic Support Agency and Dr. Hess of the National Aeronautics and Space Administration. Proceedings of the conference will be published in the near future.

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References

1. B. J. O'Brien, C. D. Laughlin, J. A. Van Allen, L. A. Frank, *J. Geophys. Res.* **67**, 1209 (1962); B. J. O'Brien, *ibid.*, **67**, 1227 (1962).
2. B. J. O'Brien, C. D. Laughlin, J. A. Van Allen, *Nature*, in press.

Forthcoming Events

November

1–2. Alkaline **Pulping** Conf., Savannah, Ga. (Technical Assoc. of the Pulp and Paper Industry, 360 Lexington Ave., New York 17)

1–2. **Chemtronics**, conf., New York, N.Y. (E. C. Torkelson, Bell Telephone Laboratory, 463 West St., New York)

1–2. **Educational** Conf., annual, New York, N.Y. (A E. Traxler, Educational Records Bureau, 21 Audubon Ave., New York 32)

1–2. **Kidney**, annual conf., Princeton, N.J. (National Kidney Disease Foundation, 145 E. 35 St., New York 16)

1–2. **Medical Practice** Management, 1st annual conf., Las Vegas, Nev. (Soc. of Professional Business Consultants, 420 Madison Theatre Bldg., Detroit 26, Mich.)

1–2. **Product Engineering** and **Production**, natl. conf., San Francisco, Calif. (H. R. Traver, Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif.)

1–3. American **Chemical** Soc., annual southeastern regional meeting, Gatlinburg, Tenn. (F. A. Griffitts, Maryville College, Maryville, Tenn.)

1–3. Delayed Effects of **Captivity**, intern. medical congr., Brussels, Belgium. (R. Laumond, Intern. Confederation of Former Prisoners of War, 46 rue Copernic, Paris 16^e^, France)

2–3. American **Geophysical** Union, regional meeting, Seattle, Wash. (F. A. Richards, Dept. of Oceanography, University of Washington, Seattle)

2–3. **Fat** as a Tissue, intern. research conf., Philadelphia, Pa. (Division of Research, Medical Science Bldg., Lankenau Hospital, Philadelphia 51)

4–7. **Engineering in Biology and Medicine**, annual conf., Chicago, Ill. (Program Committee, P.O. Box 1475, Evanston, Ill.)

4–9. American Acad. of **Ophthalmology** and **Otolaryngology**, Las Vegas, Nev. (W. L. Benedict, 15 Second St., SW, Rochester, Minn.)

4–10. Interamerican **Red Cross** Conf., San Juan, Puerto Rico. (American Natl. Red Cross, 17 St. between D and E Sts., NW, Washington, D.C.)

5–7. American Soc. for **Cell Biology**, annual, San Francisco, Calif. (ASCB, Box 2982, Duke Univ. Medical Center, Durham, N.C.)

5–7. Protection against **Radiation** Hazards in Space, symp., Gatlinburg, Tenn. (E. P. Blizard, Oak Ridge Natl. Laboratory, P.O. Box X, Oak Ridge, Tenn.)

5–9. American Inst. of Mining, Metallurgical, and Petroleum **Engineers**, fall meeting, Chicago, Ill. (Executive Secretary, AIME, 345 E. 47 St., New York 17)

5–9. German **Ceramics** Soc., annual, Baden-Baden. (Deutsche Keramische Gesellschaft, Menzenbergerstr. 47, Bad Honnef am Rhein, Germany)

5–9. **Metallurgical** Congr., intern., Chicago, Ill. (C. Wells, American Soc. for Metals, 7301 Euclid Ave., Cleveland, Ohio)

5–9. Practical Applications of Short-Lived **Radioisotopes** Produced in Small Research Reactors, seminar, Vienna, Austria. (Intern. Atomic Energy Agency, 11 Kärntner Ring, Vienna 1)