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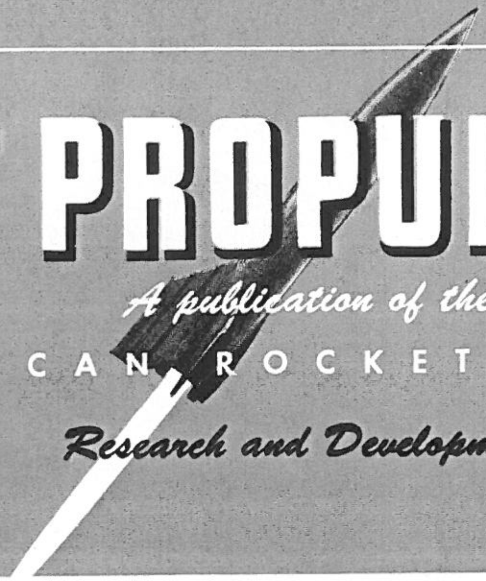

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SURVEY ARTICLE

Some Recent Advances in the Mechanics of Terrestrial Flight . . *Angelo Miele* 581

CONTRIBUTED ARTICLES

Observation of High Intensity Radiation by Satellites 1958 Alpha and Gamma . . . . . . *J. A. Van Allen, G. H. Ludwig, E. C. Ray and C. E. McIlwain* 588

Flame Stabilization in the Boundary Layer of Heated Plates . . . . *Richard W. Ziemer and Ali Bulent Cambel* 592

Erosive Burning of a Colloidal Solid Propellant . . . *Jean A. Vandenkerckhove* 599

Supersonic Aerodynamic Experiments Using Very High Temperature Air Wind Tunnels . . . . *D. E. Bloxsom Jr.* 603

Use of Capacitor Discharges to Produce High Temperature, High Pressure Air . . . . *D. E. Bloxsom Jr.* 609

Measurement of Turbulent Heat Transfer Rates on the Aft Portion and Blunt Base of a Hemisphere Cylinder in the Shock Tube . . . . . *Josef Rabinowicz* 615

TECHNICAL NOTES

A Comparison of Turbojets and Ramjets for High Speed Flight. . . . . *M. Arens* 620

Simulation of Free Flight Structural Characteristics by Captive Missile I. Computer Analysis. . . . . *P. Lieberman* 622

DEPARTMENTS

New Patents 626 Book Reviews 630 Technical Literature Digest 634

Observation of High Intensity Radiation by Satellites 1958 Alpha and Gamma[1]

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Introduction

THIS is a preliminary report of results obtained concerning radiation intensities measured with a single geiger tube carried by the artificial earth satellites 1958 α and 1958 γ.[6]

The counting rate of the counter in 1958 α was transmitted continuously, and the data were recorded only when the satellite was quite near one of the 16 receiving stations distributed over the earth.

The data collected by 1958 γ were also telemetered continuously. In addition, a small magnetic tape recorder stored the data obtained during each entire orbit. Then, as the satellite passed near one of the receiving stations, a radio command from the ground caused these data to be read out.

A preliminary study of the data obtained from 1958 α and several interrogations of 1958 γ has been carried out, with the following results.

Reasonable cosmic ray counting rates have been obtained for altitudes below about 1000 km. In particular, we have obtained a plot of omnidirectional intensity vs. height in the vicinity of California for the first two weeks in February. This curve, extrapolated down to altitudes previously reached by rockets, agrees with earlier data.

At altitudes greater than about 1100 km, very high counting rates were obtained. This conclusion is the result of a somewhat lengthy analysis. Geiger tube output rates up to about 140/sec have actually been observed. In addition, periods have been found during which the geiger tube put out less than 128 pulses in 15 min. (We have a scaling factor of 128.) The considerations detailed in section 3 cause us to conclude that this is not due to equipment malfunction, but is caused by a blanking of the geiger tube by an intense radiation field. We estimate that if the geiger tube had had zero dead time, it would on these occasions have been producing at least 35,000 counts/sec.

We surmise that the radiation we have found is closely related to the soft radiation previously detected during rocket flights in the auroral zone.[7]

The radiation intensity necessary just to blank the geiger tube is equivalent to 60 mr/hr. In this connection the recommended permissible dose for human beings is 0.3 r/week.[8] The present radiation is 0.3 r in 5 hr or less.

Several geophysical effects of this radiation seem possible. It is very likely closely related to aurorae and geomagnetic storms. In addition, a rough calculation suggests that the radiation may be sufficiently intense to contribute important heating to the upper atmosphere. It will be important to investigate the amount of atmospheric ionization, light and radio noise which would be produced, under various assumptions as to the nature of the radiation.

1 Instrumentation for 1958 α and 1958 γ

The instrumentation for 1958 α consisted essentially of a single Geiger Mueller tube, a scaling circuit for reducing the number of pulses to be worked with, and telemetry systems for transmitting the scaler output to the ground receiving stations. The system contained in 1958 γ was identical, with the addition of a miniature tape recorder for storing the data for the duration of each orbit and a command system to cause the telemetry of the stored information over a ground receiving station (Fig. 1).

Identical G.M. counters, scaler input circuits and scaling circuitry were used in the two cases. The G.M. counters were Anton halogen quenched counters having approximately 0.050 in. thick stainless steel walls. In addition, the counters were surrounded by the stainless steel cases of the payload, which were 0.023 in. thick. Thus the total absorption was approximately 1.5 gm cm^{-2} of stainless steel (approximately

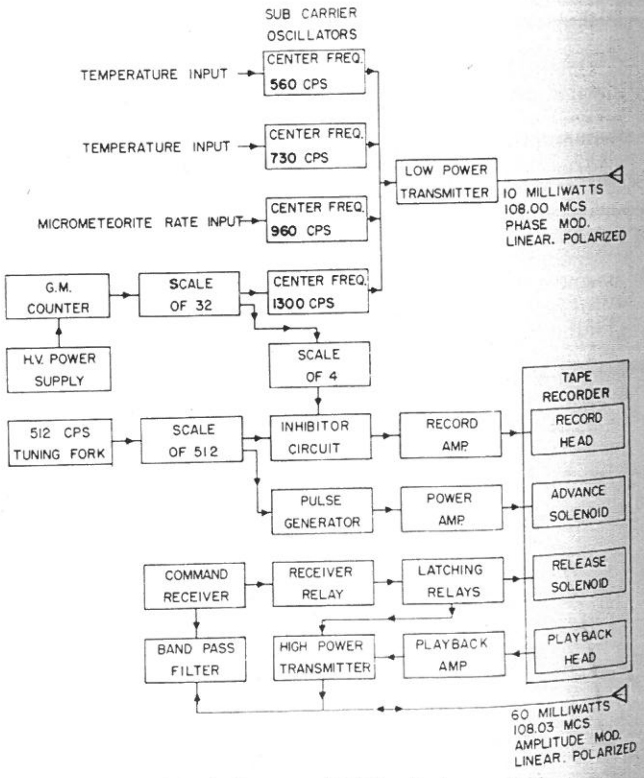

Fig. 1 Block diagram of 1958 γ instrumentation

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[5] Research Assistant, Department of Physics.

[6] These satellites are sometimes called Explorer I and Explorer III, respectively.

[7] Meredith, Gottlieb and Van Allen, J. A., *Physics Review*, vol. 97, 1955, p. 201.

[8] Kinsman, S., "Radiological Health Handbook," U.S. Dept. of Health, Education and Welfare, 1955, p. 292.

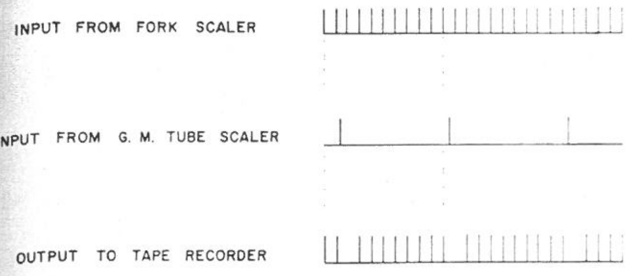

Fig. 2 Illustration of the function of the inhibitor circuit

75 per cent iron, 25 per cent chromium). The G.M. tubes had essentially infinite lives, small variation in counting efficiency over the range −55 to 175 C, approximately 85 per cent counting efficiency for cosmic rays, and about 0.3 per cent counting efficiency for photons of energy 660 kev. The dead time of the counters was approximately 100 microsec. The length of the counter wire was 4 in.; the inside diameter of the counter was 0.781 in.

Following the counters were current amplifiers, which directly fed the first scaler stages. The scalers were bistable transistor multivibrators, which operated over a wide range of supply voltage and over a temperature range of −15 to 85 C. This limitation was caused by the supply batteries. The scaler resolving time was 250 microsec. If input pulses at higher rates than 4000 per sec periodic were received, the scaler simply indicated a constant rate of 4000 per sec. That is to say, the scaler would not go out of operation if this rate was exceeded. It did, however, have an input pulse amplitude discrimination level, so that counter pulses of amplitude less than approximately one eighth normal were not counted.

In each of the satellites, the output of a scale of 32 was telemetered directly by the low power transmitter. In addition, it was transmitted by the high power transmitter in 1958 α. In all cases, the shift of state of the output scaler stages caused a discontinuous shift in the frequency of the subcarrier oscillators, of which the outputs were transmitted by the appropriate transmitters. The data telemetered in this manner have been readable when the rates of input pulses to the scalers were between 0.14 pulses per sec (16 pulses or one change of state per 2 min pass) and 80 pulses per sec (limited by the bandwidth of the receiving and data reduction systems).

In 1958 γ additional scaling circuits were included to provide a total scaling factor of 128 for the data to be stored. It was also necessary to include a time base, in order that a proper correlation could be established between the data and the satellite position. These two bits of information were combined in such a way that they could both be stored and telemetered on a single channel. Fig. 2 indicates the manner in which an inhibitor circuit effected this combination. The time base input was a train of pulses at the rate of one each sec. These pulses appeared at the output of the inhibitor, and were recorded, unless one was preceded by an output from the scale of 128, in which case it was suppressed.

The tape recorder was advanced in a discontinuous manner at the rate of one step per sec. As the tape advanced, it wound a spring for the eventual return of the tape to the starting point.

Upon receipt of a properly coded interrogation signal by the command receiver in the satellite, a relay system was activated which caused the higher power transmitter to be turned on and the tape to be released, so that the spring was free to return it to zero. The return tape speed was controlled by an eddy current damping system, so that the playback time was approximately 5 sec. As the tape returned, the information was read off the tape, telemetered, and the tape was erased. Upon completion of the cycle, the relays were reset, the transmitter turned off, and the next recording begun.

The information thus telemetered to the ground was the train of pulses emanating from the inhibitor circuit, except that it was much compressed in time. It can be seen then that scaler input pulse rates between 0 and 128 per sec were properly passed on, and that all rates above 128 per sec appeared as a rate of 128 per sec, that is, all pulses missing.

2 Summary of Preliminary Observations

Table I is a list of the stations receiving data and reporting them to us. The stations labeled JPL are operated under the auspices of the Jet Propulsion Laboratory at Pasadena, Calif. Those labeled NRL are operated by the Naval Research Laboratory in Washington, D. C. Data were obtained from 1958 α only when it was reasonably near one of these stations, since it had no provision for storing data for a later readout. We have already analyzed most of the data from the JPL stations, and some of that from the NRL stations as well. This work is continuing.

A small magnetic tape recorder in 1958 γ stored the cosmic ray information for an entire oribit, and then played it into a transmitter on command from the ground. Data from nine of these orbits have been reduced in a preliminary way. We already have on hand many more of these passes, and are reducing the data from them in a routine way.

It is evident from the above summary that the present report is a very preliminary one. The nine cases from 1958 γ occur during the last four days of March, and we expect ultimately to have data obtained during several weeks after those days. In addition, we have so far reduced the data from 1958 γ only in a rather rough way, as explained in the following paragraphs. Finally, we do not yet have highly accurate data on the satellites' orbits. We do have the position of 1958 α as a function of time tabulated in 1 min intervals as supplied by the Vanguard computing center for the month of February. These data seem to be in error by several minutes in time, but apparently are sufficiently accurate for the purposes of the present report. So far for 1958 γ, we have only a set of orbital elements for March 26 and position vs. time for one orbit on April 1, together with estimates of the various perturbations. This information, supplied to us by the Vanguard Computing Center, has made it possible for us to estimate the orbit during the last days of March with reasonable accuracies. In particular, we estimate that our error in determining the time of passage through perigee is not more than about 5 min on March 31, and is less on earlier dates. Our errors in estimating latitude and longitude may amount to 10 deg in some cases.

Accurate orbital data will ultimately be supplied to us by the Vanguard Computing Center.

Table I Receiving stations

Blossom Point, Md.	NRL
Fort Stewart, Ga.	NRL
Antigua, Br. W. Ind.	NRL
Havana, Cuba	NRL
San Diego, Calif.	NRL
Quito, Ecua.	NRL
Lima, Peru	NRL
Antofagasta, Chile	NRL
Santiago, Chile	NRL
Woomera, Aus.	NRL
Patrick Air Force Base, Fla.	JPL
Earthquake Valley, Calif.	JPL
Singapore	JPL
Ibadan, Nigeria	JPL
Temple City, Calif.	JPL
Pasadena, Calif.	JPL

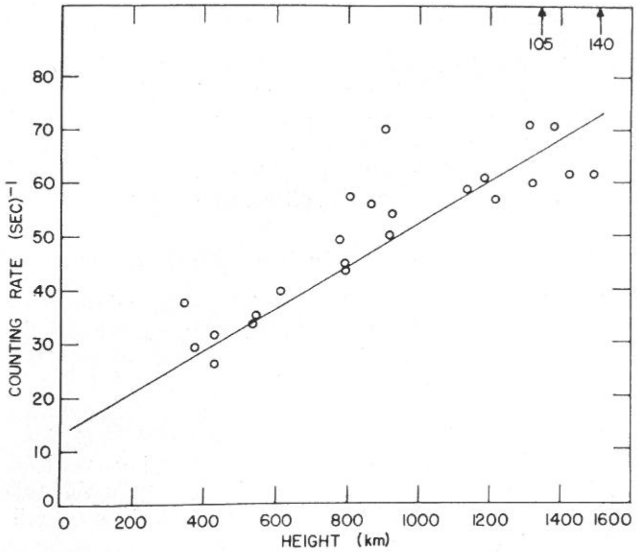

Fig. 3 Counting rate vs. height near California for 1958 α

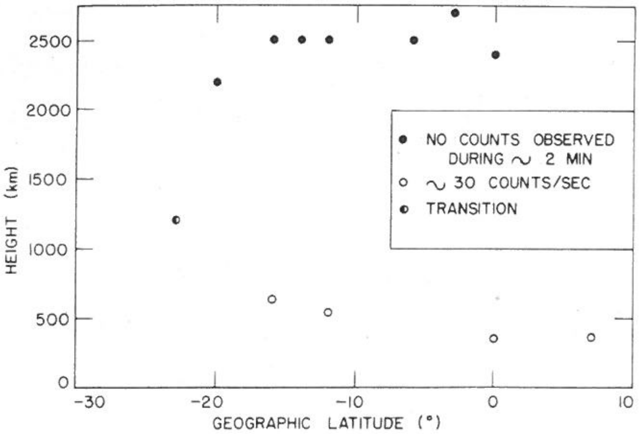

Fig. 4 Positions in altitude vs. latitude for telemetry of data from 1958 α over South America

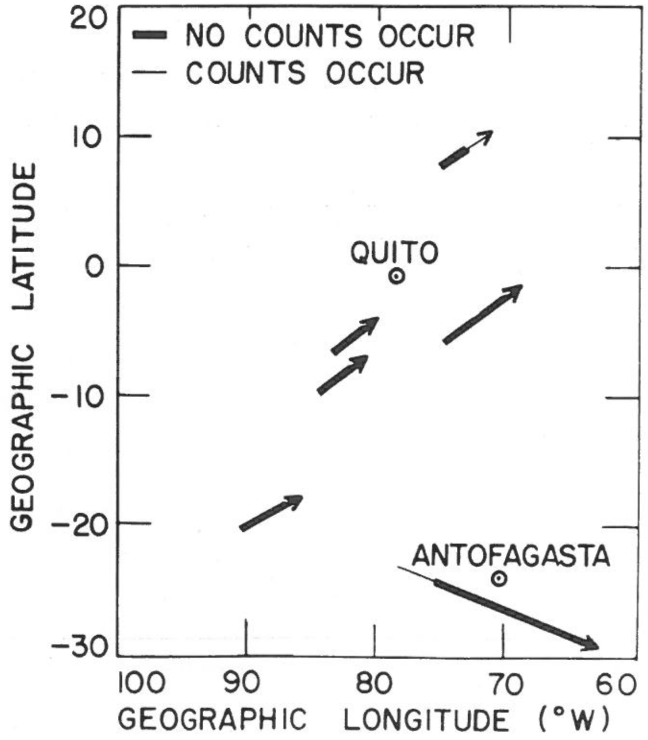

Fig. 5 Positions in latitude vs. longitude for telemetry of data from 1958 α over South America

We discuss first the data obtained from 1958 α.

Fig. 3 is a plot of height against counting rate near the California coast. All of the passes recorded by JPL stations in California are included in this graph. There is some variation in latitude, which presumably accounts for some of the scatter of the points. In addition, as explained above, the orbital data are not yet known with good accuracy, and this presumably contributes significantly to the scatter. A linear extrapolation down to a height of 100 km yields a value of omnidirectional intensity of 1.22 (cm^2-sec)$^{-1}$, in adequate agreement with values we have previously obtained from rocket flights, considering the crudity of the extrapolation. The data shown in this figure were nearly all taken before Feb. 11.

The data obtained by the NRL stations in South America during the first two weeks of February are altogether different from those just discussed. The passes fall into two classes. In the first case, one obtains a counting rate of about 30/sec, a roughly reasonable value. In the second case, the telemetered signal fails to show a single scaler output pulse during the approximately 2 min of clean signal. This represents an input rate to the scaler of less than about 0.1/sec. There are, in addition, a few cases showing a strong change in counting rate during the pass.

For reasons discussed in section 3, we believe that the extremely low output rate of the scaler is caused by very intense radiation which "jams" the geiger tube so that it puts out pulses of such low height that they are below the threshold of the counting circuits. Laboratory tests show that this first happens for the present equipment when the radiation reaches such an intensity that a counter of the same effective dimensions and efficiency as the present geiger counter but with a zero dead time would produce 35,000 counts/sec.

Fig. 4 is a plot of height vs. geographic latitude in the vicinity of 75 W longitude. The positions of 1958 α during reception of its telemetering signal by various of the NRL stations are marked. A code designates the kind of information received. It is at once evident that the extremely low counting rates observed all occur at a high altitude, while the more or less normal rates occur at a low altitude. Transitional cases occur at a low altitude. Transitional cases occur at intermediate altitudes.

Quite similar behavior is observed near Singapore, and probably also Ibadan. In these two cases no thorough study has been made, mostly because of the lack of trajectory data for the dates on which extremely low telemetered counting rates occur. In the one case at Singapore where such a rate occurred on a date for which orbital data were available, the extremely low counting rate observed occurred at an altitude of about 2000 km.

Fig. 5 is a plot of geographic latitude vs. geographic longitude for various orbits. Only the high altitude cases are plotted on this figure. The fact that the segments of data do not correspond to positions of closest approach to the interrogating stations is due to our so far inaccurate knowledge of the trajectory.

These data already suggest a picture of the geophysical phenomenon being measured. The data from 1958 γ are much more explicit. Fig. 6 is a plot of the scaler output as a function of time as given by the tape recorder readout for the pass ending near San Diego on March 28, 1748 UT. Since the tape recorder can only record one scaler output pulse each second (see section 1) the maximum indication on the tape recorder output corresponds to 128 counts/sec for the geiger tube output rate. (Our scaling factor is 128 in this case.) It is evident from the figure that reasonable counting rates occur near the two ends of the pass. These ends correspond to the most northern latitudes and the lowest heights above the earth. The section where the counting rate indication is zero corresponds to a portion of the magnetic tape where no tuning fork pulses were missing, and hence no scaler output pulses occurred. This condition lasted 15 min, and 128 pulses were fed to the scaler during this time. This is an average counting rate for the interval of 0.14/sec, to be compared with the usual cosmic ray rate for a geiger tube of this sort of about 50/sec. The counter goes through the transition from putting out essentially no counts to putting out a great many very quickly, and we presume that most of the 128 counts observed during this 15 min interval occurred near the ends of the interval. There is, of course, no real evidence for this.

As discussed in detail in the next section, we believe that if we had had a detector with zero dead time, and a storage mechanism of unlimited capacity, Fig. 6 would begin where it does now, and at about 13 min would have begun rising rapidly to a peak near 25 min at which point the counting rate would have been greater than 35,000 counts/sec. After this time, the rate would gradually have subsided, returning finally to about the value actually recorded near the end of the pass.

Fig. 7 is a plot of geographic latitude vs. geographic longitude of those orbits for which the tape recorder readout data have so far been analyzed. We have simply identified the transition points between portions of the record where no tuning fork pulses are missing, all tuning fork pulses are missing, or some tuning fork pulses are missing. These three different kinds of regions are identified on the graph as >15,000/sec, 128 to 15,000, and <128, respectively. The dashed portions of the various curves represent regions where the identification as to counting rate range is uncertain. Since these passes all occurred during March 28 through March 31, the orbit did not have time to precess appreciably. Since perigee was near the most northern latitude, a given latitude corresponds closely to a given altitude. It is evident that at high altitudes and low latitudes, mostly in a certain range of longitude, the counting rate is very high. Near perigee the counting rate is low. Elsewhere intermediate counting rates occur. Possible interpretations of this result will be discussed in section 3.

3 Interpretation of Observed Data

We now propose to justify our claim that when essentially no scaler output pulses occur, the apparatus is, in fact, exposed to very intense radiation.

Three possibilities are immediately evident. The apparatus may have some simple malfunction. This possibility can immediately be rejected except for the scalers, geiger tubes, and geiger tube voltage supplies, since the subsequent treatment of the information is completely different in the 1958 α and 1958 γ. Some effect of temperature seems the only reasonable possibility here. The temperature of the geiger tube was measured in 1958 γ and telemetered on the continuously operating transmitter. The observed temperatures range from zero to about 15 C. As discussed in section 1, the operating range of the circuitry is −15 to 85 C. In addition, the frequencies of the continuously telemetering channels which carried the cosmic ray information are significantly temperature sensitive. These showed that no extreme temperatures occurred at the location of the corresponding subcarrier generators.

Another possibility might be that the satellite passed through regions which very few cosmic rays could reach. This is extremely unlikely. A magnetic field of the order of one gauss extending over thousands of kilometers and remaining unbelievably free of local irregularities would be required to exclude a sufficient fraction of the cosmic radiation.

The possibility that we firmly believe is correct is that the geiger tube encountered such intense radiation that dead time effects reduced the counting rate essentially to zero. In order to explore this possibility, we have carried out the following experiments.

A spare flight unit for 1958 α was placed in an X-ray beam which was hardened by a $\frac{3}{8}$ in. thick, brass absorber. The voltage on the X-ray tube was varied between 50 and 90

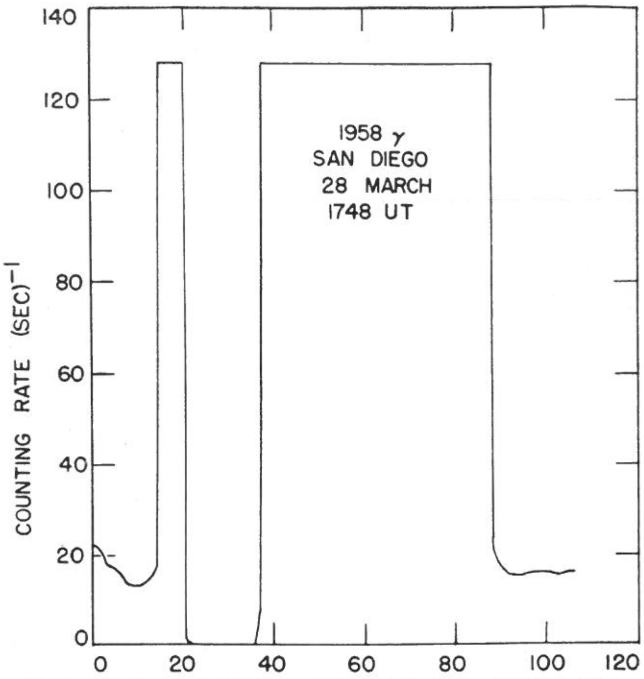

Fig. 6 A sample of the results of a tape recorder readout near San Diego on March 28, 1748 UT

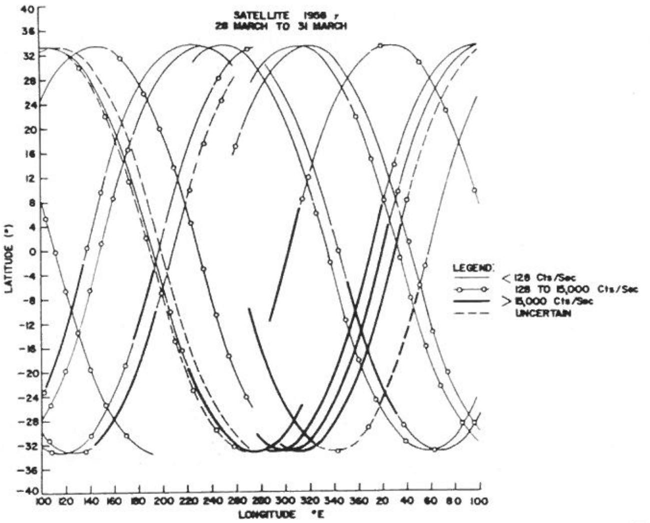

Fig. 7 A plot of various orbits of 1958 γ showing the range of counting rates as a function of position

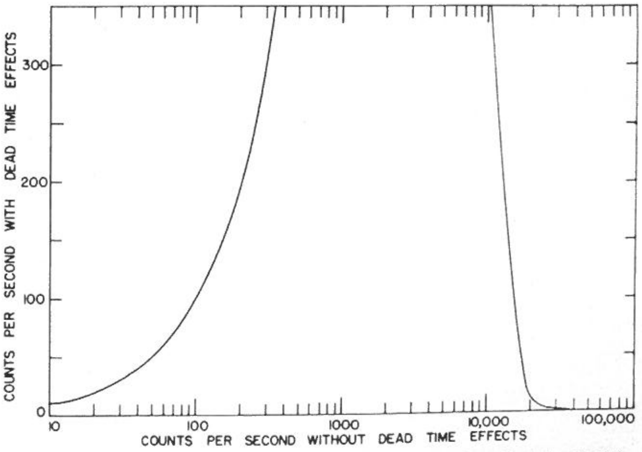

Fig. 8 Observed counting rate of a counter like that in 1958 α and γ vs. the counting rate of a similar counter but with zero dead time

kev to vary the flux over a wide range. The counting rate was measured with and without lead shields which permitted only part of the beam to reach the geiger tube. In this manner the counting rates with and without the dead time effects were determined. As shown in Fig. 8, the dead time effects are negligible up to highest rates which can be handled by the telemetering systems. At high fluxes few of the pulses from the geiger tube have sufficient amplitude to operate the scaling circuit, and the counting rate returns to the range which can be telemetered. At very high fluxes no pulses have sufficient amplitude, and the counting rate is zero.

An ion chamber placed in the position of the satellite apparatus measured an intensity of 60 milliroentgens per hr at the minimum flux required to reduce the counting rate to zero. The ionization produced by different energy X-rays or by charged particles producing this effect would of course be different from this measurement. The X-rays used for this measurement had energies in the range 50 to 90 kev.

We have little concrete evidence concerning the nature of this radiation. Apparently, however, it is not electromagnetic. It makes its effects felt through the 1.5 g/cm^2 of absorber which constitute the hull of the satellite and the walls of the counter. Photons with such energy should then be seen down to the lowest altitudes our equipment reaches. The radiation can presumably be either protons or electrons. If it is electrons, we then are probably detecting bremsstralung formed in the satellite shell.

4 Implications

Any reasonable identification of this radiation strongly suggests several geophysical consequences. It is unlikely that the particles have several Bev of energy each. Then in order to reach such low heights through the geomagnetic field they must at least initially be associated with plasmas which seriously perturb the magnetic field at an earth radius or so. We presume that this plasma is closely related to geomagnetic storms and aurorae.

Secondly, at heights only a little above 1000 km, there is still some atmosphere. Crude quantitative estimates suggest that the energy loss in this residual atmosphere of the radiation we detect may contribute significantly, if not dominantly, to the heating of the high atmosphere. In addition to considering this heating effect, it will be important to calculate, on various assumptions as to the nature of the radiation, the amount of visible light, radio noise, and ionization produced.

Finally, there are obvious biological implications of these results. As discussed in section 3, if photons are being detected directly by the geiger tube, and if these photons are in the energy range 50 to 90 kev, then the radiation field inside the satellite corresponds to about 0.06 r/hr. The maximum permissible dose for human beings is 0.3 r/week. Other assumptions as to the nature of the radiation would obviously lead to different results.

Acknowledgments

We owe a large debt of gratitude to many individuals and agencies. We are indebted to the Jet Propulsion Laboratory at Pasadena, Calif., for the high speed rocket cluster and for assembly of the satellite payload. The Army Ballistic Missile Agency at Huntsville, Ala., supplied the booster stage and conducted the launching. Project Vanguard of the Naval Research Laboratory assisted in the early design phases of the instrumentation. They also set up and operated the minitrack tracking and telemetering stations, with cooperation and assistance from the countries in which the stations are located. They supplied us with orbital information for both satellites. The Jet Propulsion Laboratory set up the microlock stations for telemetry reception and operated all of them except those at Ibadan and Singapore. These last two were operated by students at University College, Ibadan, and the University of Maylaya, Singapore, as a part of the British IGY effort.

Flame Stabilization in the Boundary Layer of Heated Plates

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This paper describes studies conducted with flames stabilized in the boundary layer of a heated flat plate. A graphical analysis of boundary layer flame stabilization is proposed and is verified by an experimental investigation of propane-air flames. The free stream flow was laminar with a turbulence intensity of 0.4 per cent, and the approach mixture velocity was 25 and 50 ft per sec. The maximum Reynolds number encountered, based on the length of the heated plate, was 122,000. Surface temperatures up to 2025 R were investigated.

Introduction

IN TURBOJET afterburners and ramjets, it is necessary to anchor the flame and prevent it from being blown out by the high velocity gases. One method which has been suggested is the stabilization of the flame on a high temperature surface. Such a surface may have the form of a circular cylinder or a flat plate, aligned parallel with the flow. The phenomenon whereby a flame anchors itself within the boundary layer of the surface as a result of boundary layer configuration and surface temperature is called boundary layer flame stabilization. No flow separation occurs, and, in addition, the surface upon which the stabilizing boundary layer is created need not obstruct the flow stream. No turbulence is created by the body other than that from the transition from the laminar to the turbulent regime.

Previous Investigations

Probably the use of heated bodies to stabilize flames was first proposed in 1950 by Tsien (1)[3] who suggested a flameholder in the shape of a streamlined body. Such an airfoil would first be internally heated until combustion was initiated. Once the flame was started, it would be stabilized on

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Presented at the ARS Semi-Annual Meeting, San Francisco, Calif., June 10–13, 1957.

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[2] Professor and Chairman, Department of Mechanical Engineering. Fellow, ARS.

[3] Numbers in parentheses indicate References at end of paper.