for example by a telescope tube L, the corresponding rate observed by the other telescope tube R probably be larger than the average if the former deviation is due to an anisotropy. Fig. 1 shows the distribution of D observed by R or L in the sections corresponding to those where $D>2$ in the observation by the other telescopes. As seen from the figure, almost all of the deviation can be attributed to the statistical fluctuations with the standard deviation of 6%.

After adding two independent observations by L and R tubes, the intensity distribution of the cosmic ray over the celestial sphere of unit section $10°\times10°$ were obtained. In this distribution, the parts of the sky which gave counting rates as large as $|D|>2.5$, *i.e.*, $|N-N_0/N_0|>5\%$, were marked in the map shown as Fig. 2. The maximum of observed D values in the map was 3.5 for the first series.

Apart from the scanning, observation with higher statistical accuracy has been made in several regions of the sky containing astronomical objects of special interest, such as *Tau.* A, *Cas.* A, *Cyg.* A. At present, any significant results were not yet obtained.

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INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part III

III-2-18. A Gas Cerenkov Cosmic-Ray Telescope

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A cosmic-ray telescope was built based on an idea to detect high energy cosmic-ray charged particles by observing gas Cerenkov radiation emitted by them in a closed vessel without aid of any other particle detectors. Individual μ-meson ($E>10^{10}$ eV) was detected with sufficiently high efficiency ($\sim$95%) and with narrow angular resolution ($7°\phi$) in a wide scope ($15°\phi$). The telescope was built on an alt-azimuth mounting (azimuthal angle $0°\sim360°$, zenith distance $0°\sim90°$), and has a large detection area (20 m^2), so it can be used to observe the intensity of cosmic rays coming from nearly horizontal direction with appreciable accuracy.

This telescope was planned and constructed for the study of the anisotropy of primary cosmic rays. It can be used also for the study of the time variation of cosmic ray intensity and for any other experiments to detect high speed charged particles of very low flux density.

§ 1. Introduction

Two cosmic-ray telescopes were built at Nagoya. Telescope No. 1 in 1951 and Telescope No. 2 in 1955, respectively[1]. They are G. M. counter telescopes mounted on alt-azimuth mountings, with thick iron absorbers. These telescopes were used for the study of the anisotropy of primary cosmic radiation.

In the course of this study, a new telescope with larger detecting area became necessary. Since the detecting area of Telescope No. 2 is 0.5 m^2, it was hoped that the

This paper was combined with III-2-16 and III-2-17, and presented by Y. Sekido in III-2-20.

new telescope has an area larger than 10 m². In 1956–58, preliminary experiments were made to solve several problems relating to the construction of new telescope. After careful examination of the results of these experiments, it was decided to use the Cerenkov radiation emitted by single high speed charged particle passing through a closed vessel as the only mean to detect it.

Based on this idea, Telescope No. 3 was constructed during 1958–60, and observation by this telescope was started from February 1961. In the following, outline of this telescope will be described.

§ 2. Structure of the Telescope

The Cerenkov radiation emitted by a cosmic-ray particle passing through the telescope tube (12 m effective length) is reflected by a concave parabolic mirror (4 m in diameter, 2 m focal length). The telescope tube is filled by air at normal atmospheric pressure as the radiator of the Cerenkov radiation. At the focal plane, 19 phototubes (5″ ϕ, DuMont 6364) are placed to convert these lights into electric pulses

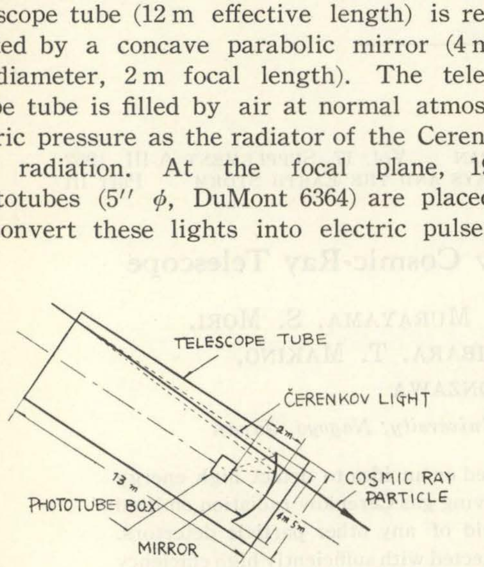

Fig. 1. Principle of the Gas Cerenkov Cosmic-Ray Telescope.

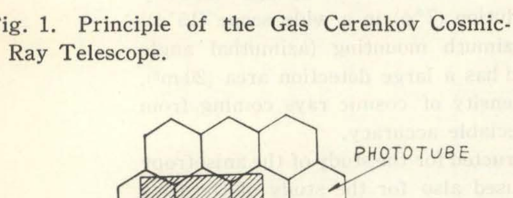

Fig. 2. Arrangement of Phototubes at the Focal Plane and the Image of Cerenkov Light.

(Fig. 1). The concave mirror consists of about 1200 small convex surface mirrors of ~100 cm² each. The curvature of the convex mirror and its shape were so designed that the image produced by the Cerenkov light at the focal plane covers at least 4 phototubes (Fig. 2). The pulses from the anode of the phototubes are amplified and shaped by a pre-amplifier and sent to the electronics room through co-axial cables.

In the electronics room, these pulses are amplified again by a linear amplifier and discriminated from amplifier noises. Then the pulses due to the Cerenkov light emitted by cosmic-ray particles are picked up by selecting coincident pulses among adjacent 4 phototubes. These cosmic-ray pulses are then mixed into 12 channels and scaled down by scaler circuits before sent to the recording room.

In order to record the number of pulses during a certain interval, a memory circuit made of 3000 Parametron units is used.

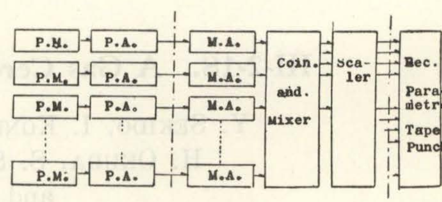

Fig. 3. Block Diagram of the Electronic Circuits:
P. M.: Phototube, P. A.: Preamplifier.
M. A.: Main Amplifier and Discriminator.
Coin.: Coincidence circuit.
Rec.: Recording System.

This memory circuit can accumulate the pulses one by one in 36 channels. The accumulated number of pulses are then punched out on a paper tape by codes once every ten minutes. These codes are then converted to numerals by telecommunication printer and are used for the further analysis (Fig. 3).

The telescope has duplicate telescope tubes which are set in parallel on an alt-azimuth mounting (Fig. 4). Each telescope tube is octagonal cylinder of 5 m diameter and 13 m length. In order to change the zenith distance of the axis of the telescope, telescope tubes are rotated around the horizontal axis at the middle of the tube with a speed of

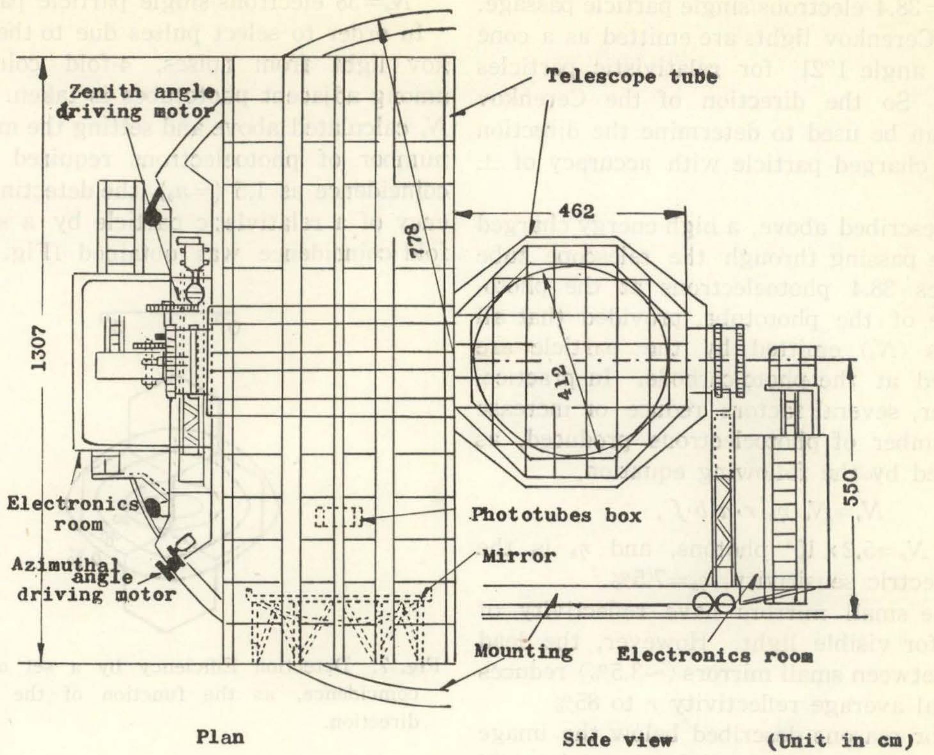

Fig. 4. Telescope Tubes and Alt-Azimuth Mounting.

Table I. Cerenkov Radiation in Air.

Refractive Index: n	Threshold Velocity: β	Threshold energy E			Maximum Angle: θ	Photon Yield/cm
		e	μ	P		
1.00029	0.99971	21 MeV	4.2 GeV	39 GeV	1° 21′	0.43

90°/25 min. Azimuthal angle of the telescope is altered by driving the telescope mount along a circular rail of 15 m diameter with a speed of 360°/30 min. The total weight of the telescope is about 70 tons including the alt-azimuth mounting.

§ 3. Selection of Cerenkov Light Pulses from Noise

The number of photons emitted by a relativistic particle along unit path length in normal air, and having frequencies sensitive to the phototube was estimated as

$N_{air}^{max}=0.43$ photons/cm track length.

The dependence of N_{air} to the energy of the cosmic-ray particle is also calculated and shown in Fig. 5. and Table I.

The number of the electrons emitted from the photocathode of the phototube can be derived by multiplying the photoelectric sensitivity to the number of photons emitted by the particle. As the effective length of the telescope tube is 12 m this calculation leads to

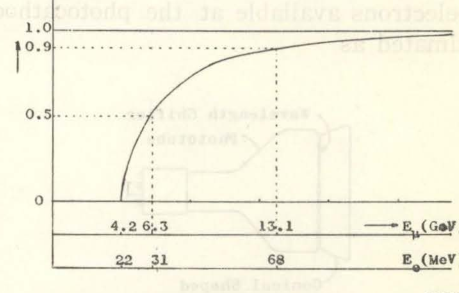

Fig. 5. Number of Photons relative to N_{air}^{max} as the Function of the Charged Particles Passing through Air.

$N'_e=38.4$ electrons/single particle passage.

The Cerenkov lights are emitted as a cone of half angle 1°21′ for relativistic particles in air. So the direction of the Cerenkov light can be used to determine the direction of the charged particle with accuracy of ± 1.3°.

As described above, a high energy charged particle passing through the telescope tube produces 38.4 photoelectrons at the photocathode of the phototube, provided that all photons (N_0) emitted by the particle are collected at the photo-cathode. In practice, however, several factors reduce or increase this number of photoelectrons produced, as indicated by the following equation,

$$N_e=N_0\cdot\eta_k\cdot r\cdot a\cdot b\cdot f\ ,$$

where $N_0=5.2\times10^2$ photons, and η_k is the photoelectric sensitivity, $\eta_k=7.5\%$.

r: The small mirrors have reflectivity of 89.5% for visible light. However, the dead space between small mirrors (~3.5%) reduces the total average reflectivity r to 85%

ab: For reasons described below the image of the Cerenkov light covers at least 4 phototubes at the focus, so the space between the sensitive area of phototubes occupies 46% of the image. Some of the light falling on the dead space is recovered by a conical shaped auxiliary mirror attached on the phototube surface. These two yield a reduction of the light by a factor $ab=0.65$.

f: Ultraviolet light with wavelength between 2000 and 3000 Å in the Cerenkov radiation is converted to visible light by a wavelength shifter coated on the phototube surface. Using *para*-4-*phenyl* as the wavelength shifter,[2], the number of photoelectrons is increased by a factor $f=1.8$ (Fig. 6).

Considering these factors, the number of photoelectrons available at the photocathode is estimated as

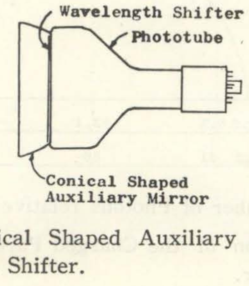

Fig. 6. Conical Shaped Auxiliary Mirror and Wavelength Shifter.

$N_e=38$ electrons/single particle passage.

In order to select pulses due to the Cerenkov light from noises, 4-fold coincidence among adjacent phototubes is taken. Using N_e calculated above and setting the minimum number of photoelectrons required for the coincidence as 1.5 ($=n_b$), the detecting efficiency of a relativistic particle by a set of 4-fold coincidence was obtained (Fig. 7). At

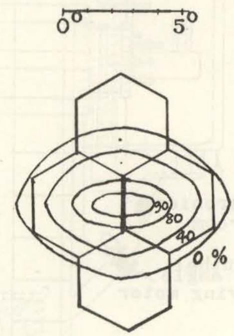

Fig. 7. Detection Efficiency by a set of 4-fold coincidence, as the function of the particle direction.

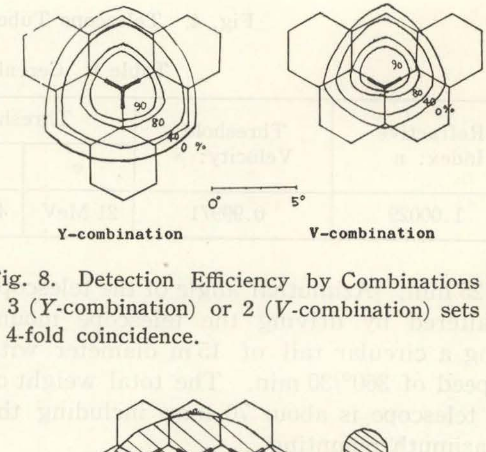

Fig. 8. Detection Efficiency by Combinations of 3 (Y-combination) or 2 (V-combination) sets of 4-fold coincidence.

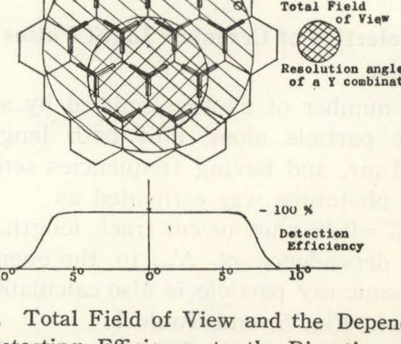

Fig. 9. Total Field of View and the Dependence of Detecting Efficiency to the Direction of the Particle.

present, two or three 4-fold coincidence sets are grouped into one channel in order to reduce the number of recording channels. For these combined coincidences the dependence of the efficiency becomes as shown in Fig. 8.

The field of view of the telescope was also estimated and illustrated in Fig. 9. Taking into account of the coma aberration of the parabolic mirror, the total field of view can be represented by a circle of 15° diameter. And the efficiency of recording a relativistic charged particle is uniform and higher than 95% in a circle of 13° diameter.

§ 4. Test Observation

Main parts of the telescope were completed in September, 1960, since then test observation of cosmic-ray particles was carried out. This observation was made to determine the efficiency of the telescope for cosmic-ray detection and its resolution angle and the field of view. Also check was made on the background counts which arise not from single cosmic-ray particle passage through the tube.

a) Counting rate of the telescope

The detecting efficiency of the telescope derived above and the effective area of the telescope can be used to derive the estimated counting rate of the telescope. Assuming the effective area of the telescope as 10 m², (geometrically 13 m²) for a relativistic particle, the efficiency was calculated as the function of N_e for $n_b=1.5$.

Observed counting rates under three different conditions agree with the estimated values as shown in Fig. 10.

b) Zenith distance dependence of the counting rates

Zenith distance dependence of the counting rate was measured. The background pulses were measured by putting a black curtain on the face of the phototubes and are probably due to local shower particles which hit the phototube windows simultaneously. Accidental coincidences among phototube noises were found to be less than 0.1/min., which is negligible with the cosmic-ray flux. After substracting these backgrounds, the counting rate of the telescope is plotted in Fig. 11, together with theoretical estimation.

The theoretical expectation curve was derived by taking into account the followings: i) The number of Cerenkov radiation depends on the energy of the cosmic-ray particles. ii) The energy spectrum of μ-mesons at various zenith distance estimated by Murayama *et al*[3] was used. For the electron component, decay from π^0-mesons and μ-mesons are considered, and electrons

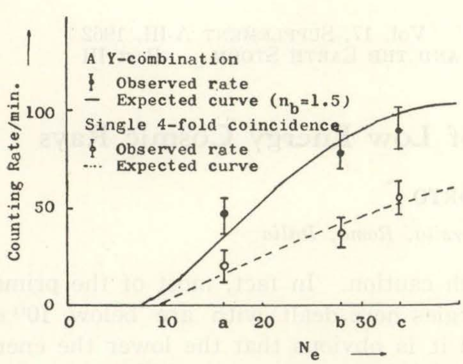

Fig. 10. Counting Rate as the Function of the Total Number of Photoelectrons available at Photocathode, N_e. *a*: Phototube only. *b*. With wavelength shifter. *c*. Both with wavelength shifter and auxiliary mirror.

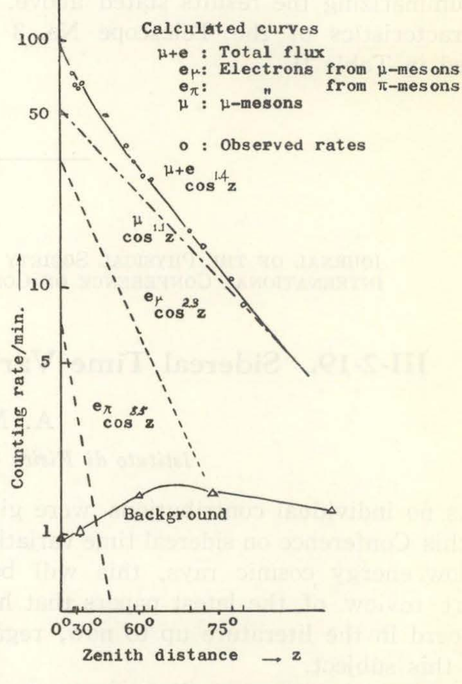

Fig. 11. Zenith Distance Dependence of the Counting Rate of a *Y*-combination.

Table II. Characteristics of the Telescope

Detecting Area (Sum of two tubes)		~20 m^2	
Total Field of View		A circle of 15° dia	
Resolution Angle	(for a Y-combination)	A circle of 7° dia.	
〃	(for a V-combination)	5°×7°	
Minium Energy of the Particle	(μ-meson)	5 GeV	
observed by the Telescope	(electron)	200 MeV	
		Z=0°	Z=75°
Mean Energy of the Particles	(μ-meson)	18 GeV	40 GeV
observed by the Telescope	(electron)	500 MeV	600 MeV
Mean Energy of the Particles at the Top of the Atmosphere	(μ-meson)	20 GeV	50 GeV
Mean Energy of the Primary Protons which produce μ-mesons observed.		90 GeV	300 GeV
Counting Rate of a Y-combination		90/min.	15/min.
Total Counting Rate of the Telescope (Sum of two tubes)		2000/min.	300/min.

of energies lower than 200 MeV are assumed to be absorbed by 1 cm Pb fixed on the front face of the telescope tube. As seen from Fig. 11, the observed dependence is in good agreement with the theoretical curve.

Summarizing the results stated above, the characteristics of the Telescope No. 3 are listed in Table II.

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INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part III

III-2-19. Sidereal Time Variation of Low Energy Cosmic Rays

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As no individual contributions were given in this Conference on sidereal time variations of low energy cosmic rays, this will be a short review of the latest papers that have appeard in the literature up to now, regarding this subject.

It should be first of all stressed that the expression "sidereal" has to be taken with much caution. In fact, most of the primary energies here dealt with are below 10^{11} eV. And it is obvious that the lower the energy of the cosmic ray particles, the stronger is the mixing action of intergalactic magnetic fields: so that the least one would expect these particles to provide information about possible anisotropies, either real or apparent,