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— RESTRICTED DISTRIBUTION —

FOR CALIBRATION PURPOSES, THE RELATIVE ANODE EFFICIENCY OF SAMPLE PMTs FROM BURLE, HAMAMATSU, PHILIPS AND THORN-EMI WERE MEASURED USING TWO CERENKOV SOURCES DEVELOPED AT QUEEN'S UNIVERSITY. THESE PMTs WERE SENT BACK TO THE MANUFACTURERS AS STANDARDS. QUEEN'S UNIVERSITY HAS SENT ONE CERENKOV SOURCE TO EACH MANUFACTURER SO THAT THEY CAN MEASURE THE RELATIVE ANODE EFFICIENCY OF THEIR OWN PMTs; THUS CAN PROVIDE A REASONABLE ESTIMATE OF THE MINIMUM VALUE OF RELATIVE ANODE EFFICIENCY THAT THEY CAN GUARANTEE IN THEIR PROPOSAL.

MEASUREMENT OF RELATIVE PHOTOMULTIPLIER (PMT) ANODE EFFICIENCY

1. The PMT was placed inside a copper box, 78cm wide by 78cm deep by 87cm long. The inside walls of the box are covered with dull black paint.

2. Helmholtz coils were used to compensate the earth's magnetic field.

3. Two Cerenkov sources were used. Each source contains approximately 1 Ci of ^{90}Sr at the centre of a 1cm diameter by 2cm long clear plastic rod mounted on a Hamamatsu R1635 PMT.

   SOURCE 1; the clear plastic is U.V. transmitting acrylic, same as sources delivered to PMT manufacturers. This source is mounted on PMT WA1126.

   SOURCE 2; The clear plastic is lucite. This source is mounted on PMT RX6208.

4. Only one Cerenkov source was used for each measurement. The Cerenkov source was placed along the axis of the PMT inside a pyramid. The inside walls of the pyramid are covered with dull black paint.

5. Only the minimum projected photocathode area quoted by the manufacturer was used. A black collimator with a circular hole was mounted on the PMT to cover the photocathode area outside the quoted projected area.

6. For all PMTs with a diameter less than 30cm, the Cerenkov source was placed at a distance d from the collimator so that the half angle subtended by the exposed photocathode area was 7 degrees, corresponding to a solid angle of 0.0468 sr. Fot the 50cm Hamamatsu PMT (R3600), the room spca available is limited and a half angle of 9.1 degree was used. Results were quoted for half angle of 7 degree as requested by LANL. Corrections for difference in solid angles are applied if needed.

7. The width of the discriminator pulse from the monitor PMT was set at 120ns. The coincidence window was approximately 155ns wide.

8. The anode pulses were amplified by a x10 amplifier before the constant fraction discriminator and QDC.

9. The charge (Q) and time (T) spectra were accumulated simultaneously.

10. The relative anode efficiency was measured with the PMT operated at two High Voltages; corresponding to 2 PMT gians. The relative anode efficiency is for a gain of 10^7.

11. Corrections for reflection from the inside walls of the box and pyramid were measured by placing a black disc 3.9cm in diameter at a distance of 7.3cm in front of the Cerenkov source. The disc subtends a half angle of 15 degrees at the Cerenkov source.

12. Corrections for small deviation of the timing discriminator threshold from the 1/4 single photoelectron value are applied when required.

13. The discriminator threshold for the PMT was set according to the instructions given in the request for quote from Los Alamos Nuclear Laboratory (LANL).

14. The timing resolution and relative anode efficiency were measured in accordance with instructions given in the request for quote from LANL

15. After a set of initial measurements, some manufacturers improve their PMTs, and the relative anode efficiencies of these new models were measured uncer the same conditions.

16. The anode uniformity scan, the point source s.p.e. response of the PMTs, were measured with one of the Cerenkov source mounted on a movable arm which travels in arc in front of the PMTs. The earth's magnetic fields were compensated in these measurements (external field less than 1 microtTesla.

17. The magnetic field sensitivity of the PMTs, were measured with one of the Cerenkov source at distance d from the PMTs such that the exposed photocathode subtended a half angle of 7 degree. Collimators were used to limit the photocathode to the quaranteed minimum diameter.

18. The geometries used for these measurements were shown in figures 1 to 5.

19. The s.p.e. of the following PMTs were measured.

Burle;	H10456, Blue cathode sensitivity	= 6.9 microAmp.
	H00063,	= 7.8
	H10462,	= 6.8
	V21119,	= 8.3
EMI;	6424,	= 10.2
	6403,	= 12.7
	7121,	= 11

Hamamatsu	CA91,	= 6.3
	ZW217,	= 6.5
	ZW262,	= 6.3
	ZW274,	= 7.0
	LA152,	= 8.2
	LA159,	= 7.6
Philips	378,	= 10.3
	372,	= 9.4

20. All PMT manufacturers used photocathode scan and magnetic field scan data from Queen's University in their proposal. In general, there is no substantial difference between data from Queen's and from manufacturers.

21. H.B. Mak visited Burle, Hamamatsu, Philips and Thorn-EMI in late May and June to discuss the relative anode efficiency measurement and to check equipments used. In general, the manufacturers have the electronics and expertise to do such measurements. In that trip H.B. Mak carried one of the Cerenkov source from Queen's University. This was used to cross check the Cerenkov source at each manufacturer using one of the standard PMTs sent to the manufacturer. This operate quite well and can be used to establish the calibration between Queen's Cerenkov source and the Cerenkov source at the manufacturer. There were some minor problems with Burle and Hamamatsu and these were resolved later with more trips to the manufacturer.

22. Queen's University sent one Burle PMT, one Hamamatsu 20cm PMT and one Philips PMT to University of Penn. for verifications of data obtained at Queen's University.

23. Queen's University has been studying the effects of implosion on neighbouring PMTs. The PMTs are mounted in a frame and placed in a tank of water. The pressure can be adjusted externally. Implosion is induced by a hammer with can be activated from outside of the tank. This system can be used to study the rigidity of reflectors, mounting devices and the protective systems. Queen's University has requested one PMT manufacturer to provide dummy PMTs (these are PMTs that have very poor characteristics, but still have vacuum inside) for further studies, and have been promised that some will be delivered at no charge.

24. At LANL request, H.B. Mak visited one PMT manufacturer to clarify some technical specifications in August. Report of that visit has been distributed to members of the PMT group. In summary, H.B. Mak did not find any major problem with the data provided by the manufacturer.

25. Electronics for acceptance tests have been delivered to Queen's University. Design for light source has started. Construction of darkroom will begin within the next two months.

26. System for checking water proof enclosure is in early stage development. Once the tests parameters (duration and pressure) are established, final design will start in October.

27. Guelph University and LBL have measured the U and Th concentrations of internal components of Burle, Hamamatsu, Philips and Thorn-EMI PMTs. These data were used in their proposal.

28. The U, Th and K concentrations of samples of furnace liner materials to be used by Schott have been measured at Guelph University. The concentrations are quite acceptable; about the same as earlier samples from liner used in the pot melt for SNO.

29. Queen's University bought 10 PMTs from one manufacturer; 3 will be delivered to Oxford University, 2 to University of Penn., 2 to LANL and 3 to Queen's University.

APRIL 1993

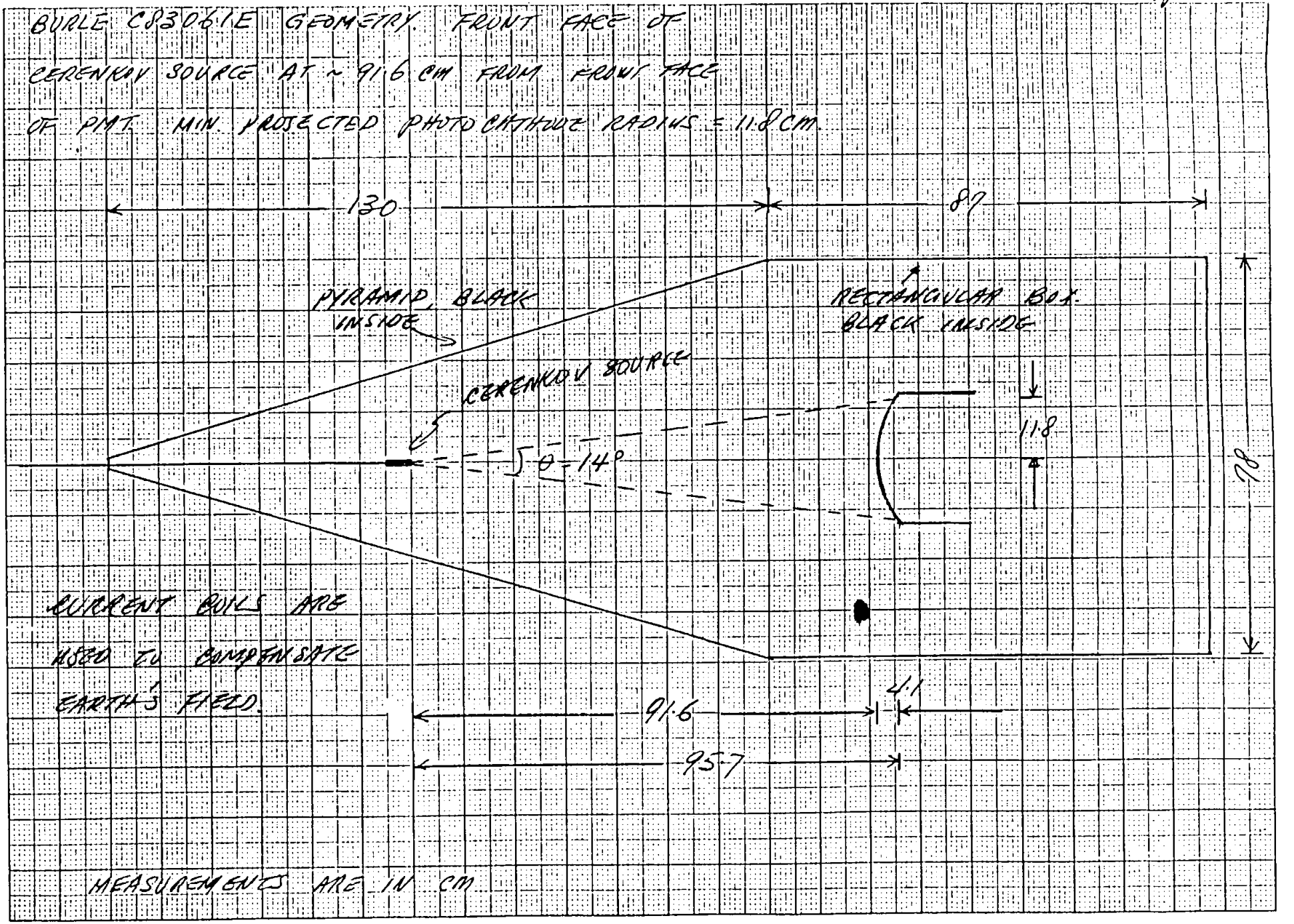

FIG 1.

DATA TO EMI

PMT 6424.

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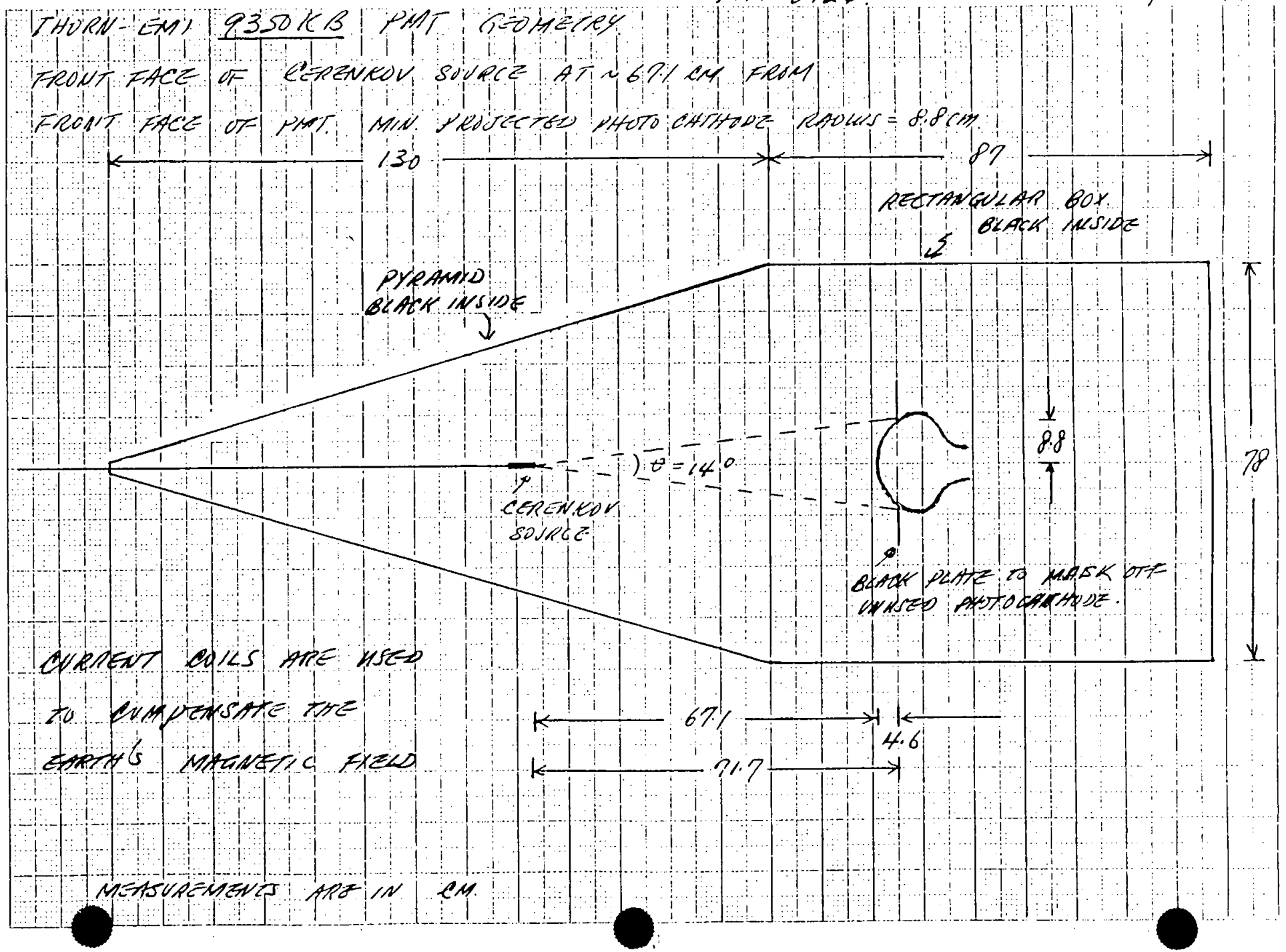

FIGURE 1