NAL PROPOSAL No. 202

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Search for Tachyon Monopoles in Cosmic Rays Above 15 Foot Bubble Chamber

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January 30, 1973

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ABSTRACT

Two of the most speculative hypothetical particles are the magnetic monopole and the tachyon. We conjecture that these particles exist as a combined "tachyon monopole" and propose using the fringing field of the 15 ft. bubble chamber as a detector. Such an experiment would lower the existing limit on tachyon monopoles in cosmic rays by a factor of 100.

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PHYSICS JUSTIFICATION

All the known particles which travel at velocities less than that of light are electrically charged or neutral. Those which travel at the velocity of light are neutral. We speculate that particles which travel faster than light (if they exist) will be neutral or magnetically charged.

There has already been one search[1] explicitly designed to detect such a "tachyon monopole" (TM). This search looked for the Cherenkov radiation which a tachyon monopole should emit even in vacuo. No TM's were detected near an intense ^{60}Co source. The article enumerated, however, four ways in which TM's could exist but have escaped detection:

" i) The calculation of the energy lost to Cherenkov radiation is wrong.

ii) The TM pair recombines immediately after its production.

iii) Tachyons obey Fermi statistics, but the sea of such particles is already filled to a level above an MeV.

iv) Tachyons are coupled strongly to nuclear matter rather than to electromagnetic radiation."

This proposal aims at removing the last three of these four loopholes.

We propose looking for tachyon monopoles that might be produced in the upper atmosphere by extremely energetic primary cosmic rays. We assume that at this point of production,

electromagnetic or strong forces transfer sufficient energy to each member of the TM pair to enable it to escape recombination or a filled Fermi sea.

Two searches for "conventional" monopoles (the accelerator search of Fidecaro et al.[2] (1962) and the cosmic ray search of Carithers et al.[3] (1966)) would also have been sensitive to tachyon monopoles. (See Appendix of ref. 1.) In proposing to extend the search for tachyon monopoles to higher energies, we clearly have to choose between an accelerator search and a cosmic ray search. We think a cosmic ray search is more promising for the following reasons:

i) Neither the monopole search of Fidecaro et al. nor indirect evidence from Serpukov or the ISR show any anomalies which even suggest the existence of tachyon monopoles.

ii) In contrast the unexplained Schein events[4] in cosmic rays could be related to monopoles.[5]

Only the scintillation counters but not the spark chambers of the experiment of Carithers et al. would have been sensitive to TM's. Viewed as a search for tachyon monopoles, this experiment had an unexplained counting rate of one-half count per day. By using the large magnetic field on top of the bubble chamber, we could lower this limit on the flux of tachyon monopoles in cosmic rays.

We are not aware of any competing or planned experiments. However, the monopole search of Fleischer et al. (NAL expt 74) could conceivably be made sensitive to tachyon monopoles.

EXPERIMENTAL ARRANGEMENT

Unfortunately there is a basic ultraviolet catastrophe in the expression for the Cherenkov radiation from a tachyon[1,6]. For the purposes of this proposal, we assume that the tachyon's energy in the lab cannot become negative. Thus the tachyon can only emit photons having less energy than the tachyon itself possesses. We further assume that the tachyon gains energy from a longitudinal magnetic field in an amount predictable from the Lorentz force law:

$$\Delta E/\Delta s = ZgH$$

where $\Delta E/\Delta s$ is the energy gained per unit length, g is the strength of the Dirac monopole (69 e) and H is the magnetic field (Oersted).

Granted these two assumptions, it is readily shown that the TM attains an equilibrium energy E_o at which the rate of energy gained from the magnetic field just equals the rate lost to Cherenkov radiation. The number of photons having energy between $\varepsilon + \Delta\varepsilon$ emitted per centimeter is

$$\frac{\Delta N}{\Delta s} = \frac{137}{4}\left(\frac{\Delta\varepsilon}{\hbar c}\right) Z^2 \quad , \quad \varepsilon \leq E_o$$

$$E_o = \frac{4}{137}\sqrt{\frac{2Hg^3}{Z}} \quad .$$

In these formulas, Z is the number of Dirac charges possessed by the TM. (See eqns. 1-8 in ref. 1).

There is at present no complete theory for the motion of a radiating tachyon in an arbitrary field. Two extreme cases are the following:

i) The tachyon monopole is similar to a thermalized monopole and is thus trapped on a magnetic field line that pierces the earth's atmosphere.

ii) The TM has sufficient inertia to ignore the magnetic field and arrive at the detector isotropically.

In describing the proposed apparatus, we shall emphasize alternative (i). It should be noted, however, that in either case (i) or (ii) the sensitivity of the proposed experiment is about 100 times that of the experiment of Carithers et al.

The basic detecting region is simply the large air space on top of the bubble chamber cameras. Four photomultiplier tubes will look for Cherenkov radiation which is emitted in a direction perpendicular to the TM motion. These phototubes will be mounted directly to the columns which support the sliding roof above the bubble chamber. The tubes will be placed 17 ft. above the median plane of the bubble chamber; the axis of each tube will point towards the axis of the bubble chamber. Finally, the tubes will accept near ultraviolet light but will be shielded from visible light, thus permitting them to be operated with the room lights on (see fig. 1). Let us examine some features of this arrangement.

Sensitivity

The area over which an aligned magnetic dipole gathers the earth's flux is $3\pi R_o^2$. Here R_o is the distance in the median plane from the dipole to the radius where the return field from the dipole exactly cancels the earth's field.[3] In the experiment of Carithers et al., R_o was 13 m. For the 15 ft. bubble chamber, R_o is about 70 m. Thus the increase in collecting area is $(70/13)^2 = 30$. We have tested phototubes in the proposed configuration and find the background to be less than 0.15/day.[7] Accordingly, we expect an overall increase in sensitivity of (30) x (0.15/d)/(0.5/d) = 100. In this test the gain of the phototubes was adjusted so that a TM having a charge as low as 0.5 Dirac monopoles would be detected. On the other hand, the fringing field of the bubble chamber is sufficiently strong that a TM having a charge less than 3 Dirac monopoles would still radiate in the near ultraviolet ($3000\text{Å} < \lambda < 4000\text{Å}$).

Magnetic Field at the Phototubes

The magnetic field at the phototubes is 800 Oersted. We are confident that this field can be reduced to an acceptable value by using heavy iron and mu metal shielding. We plan to test possible shielding configurations soon. However, if passive shielding is not satisfactory, we can resort to active shielding.[8]

Spectral Sensitivity of Photomultipliers

Using photomultipliers to selectively record ultraviolet radiation in the presence of copious visible radiation is an

old technique. Indeed space physicists use "solar blind" phototubes which can find uv photons in sunlight. But these tubes are generally small, costly, and slow. We propose instead to shield a fast bialkali phototube from visible light with a black filter. Correspondingly, the uv light from the fluorescent lamps in the room of the bubble chamber building would be shielded by a light yellow plastic of the kind storekeeprs use to protect their wares from the sun. While waiting for the necessary filters to test this scheme, we have successfully operated a blue-shielded phototube (56AVP) in the presence of red light.

Running Time

The set-up of the experiment should require only a week. The expected running times are one month with the magnetic field off and one month with a magnetic field of the proper polarity (the South pole of the bubble chamber magnet should be up).

APPARATUS

The heart of the experiment is four fast, bialkali phototubes. We have good 2 in tubes (Amperex 56DVP and RCA 8575). A 5 in tube (58DVP) would permit us to be sensitive to TM's having a charge as low as 1/4 that of a Dirac monopole. If the background of these larger tubes is low enough and they can be adequately shielded from the magnetic field, we will use them. We plan to conduct tests during the winter of 1973 to determine which tube diameter is most satisfactory.

Standard NIM electronics will identify coincidences between 3 out of the 4 phototubes. The output of all 4 phototubes will then be recorded on 2 oscilloscopes. (The shape of these pulses will identify specious electrical breakdowns, the timing will indicate whether the triggering particle had a unique path.) The apparatus required is summarized below:

	Cost $	Status
4 photomultiplier tubes with shields & bases	4,000	On hand
Iron photomultiplier tube shielding 800 pounds @ 30¢/lb.	300	
Fast electronics	4,000	On hand
2000 ft. low loss signal cable	1,000	
Camera box to record oscilloscope traces	2,000	
2 Tektronix 517 oscilloscopes	5,000	On hand
8 ft.x10 ft. work space (enough for desk, 2 chairs, 1 relay rack, 3 scopes)	-	-

Safety

We are aware of two aspects of the proposal which are relevant to the safe operation of the bubble chamber.
(i) The high voltage applied to the photomultiplier tubes could spark. Normally this problem would not be of particular concern, but if the sparking occurred during an unplanned leak of hydrogen from the bubble chamber, ignition could occur.[9]

We plan to forestall this possibility by three expedients:

a) All parts of the phototube and base will be enclosed in a nitrogen filled, air-tight enclosure.

b) The high voltage of the t ubes will be interlocked with hydrogen detectors.

c) The cathode of the tubes will be grounded, thus minimizing electrical stress near the phototubes. (This procedure generally improves the signal to noise ratio anyway.)

ii) The iron shielding of the phototubes will be pulled by the fringing field of the bubble chamber. However, at the mounting position of the shields, this force is only equal to the weight of the shields[10] and should be overcome in a properly designed mount.

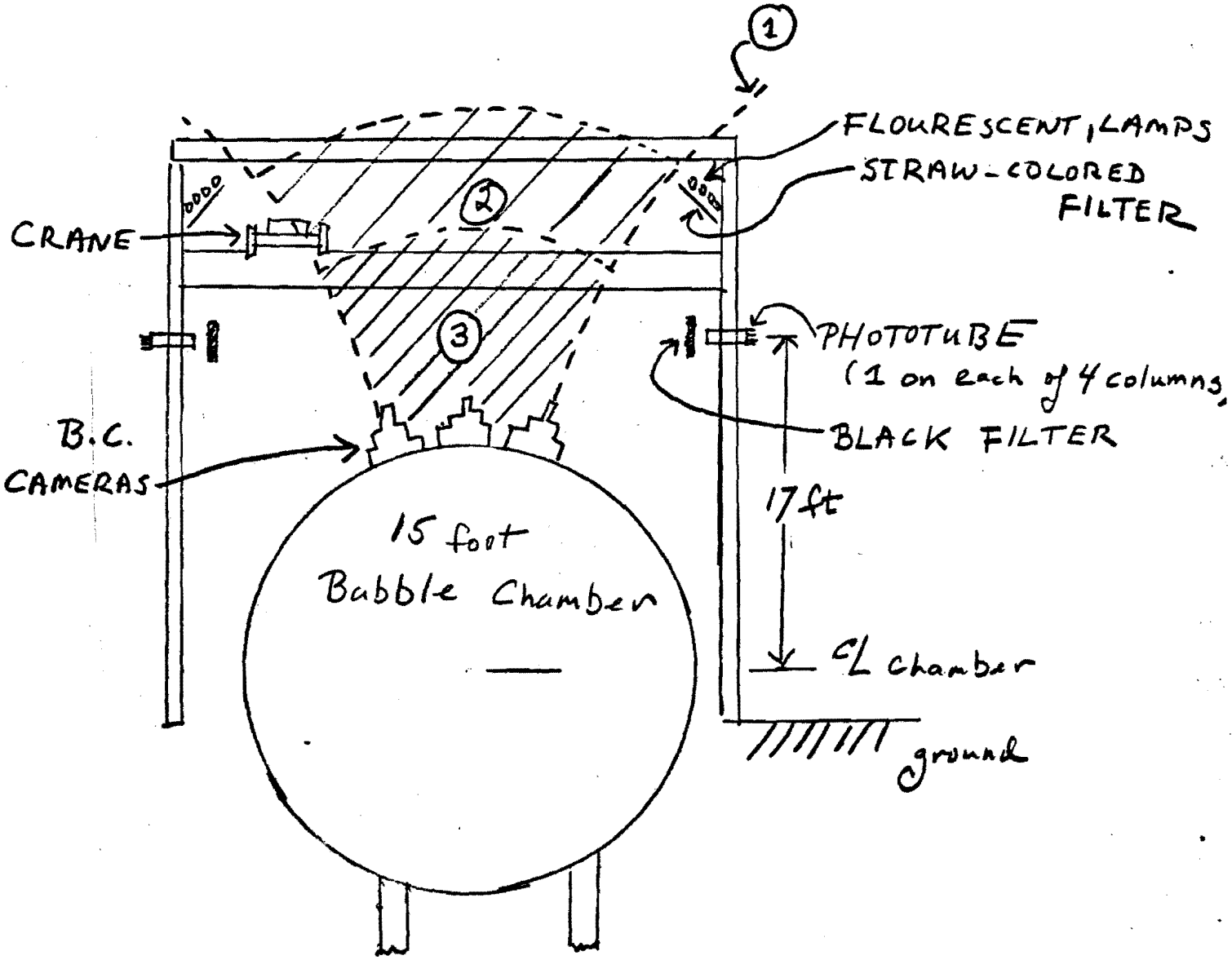
Time to Prepare Experiment

The proposers of this experiment have no major commitments on their research time. We plan to prepare the experiment during the winter of 1973. If approval is granted, the experiment could be installed and run during the spring and summer of 1973.

REFERENCES

1. D. F. Bartlett and M. D. Lahana, Phys. Rev. D 6, 1817 (1972).
2. M. Fidecaro, G. Finocchiaro, and G. Giacomelli, Nuovo Cimento 22, 657 (1961).
3. W. C. Carithers, R. Stefanski, and R. K. Adair, Phys. Rev. 149, 1070 (1966).
4. M. Schein, D. M. Haskin and R. G. Glasser, Phys. Rev. 99, 643 (1955).
5. M. Ruderman and D. Zwanzinger, Phys. Rev. Letters 22, 146 (1969).
6. F. C. Jones, Phys. Rev. D 6, 2727 (1972).
7. This test was done with the photomultipliers optically shielded from one another. One might worry that extensive air showers could give sufficient Cherenkov radiation or scintillation light in the air space above the bubble chamber to constitute a background. Calculations show, however, that this background is negligible.
8. L. Lavoie and R. Winston, Rev. Sci. Instrum. 40, 1350 (1969).
9. Safety Report, 15 Foot Bubble Chamber, v. 3, p. 64 (July, 1972).
10. ibid, v. 3, pp. 266-269.

figure 1

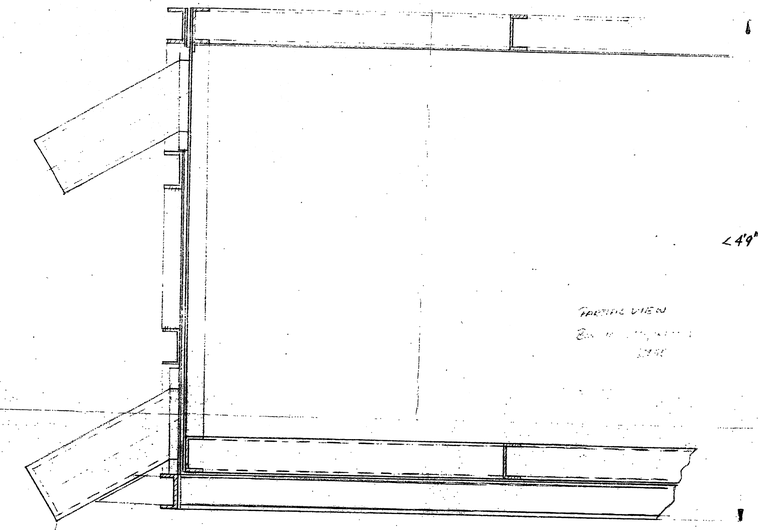


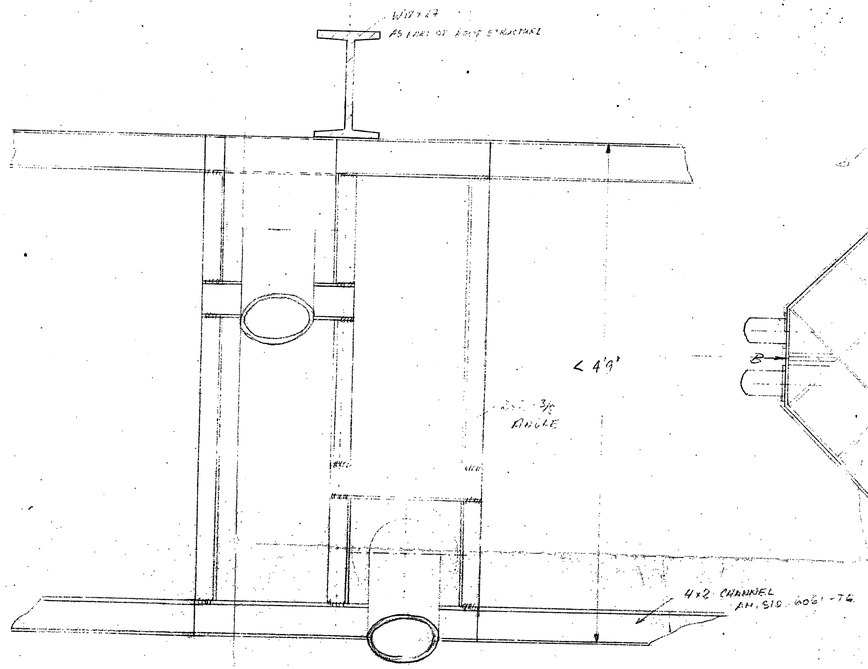
NOTE (1): Curve represents line of $\vec{H}$ field which just reaches upper atmosphere.

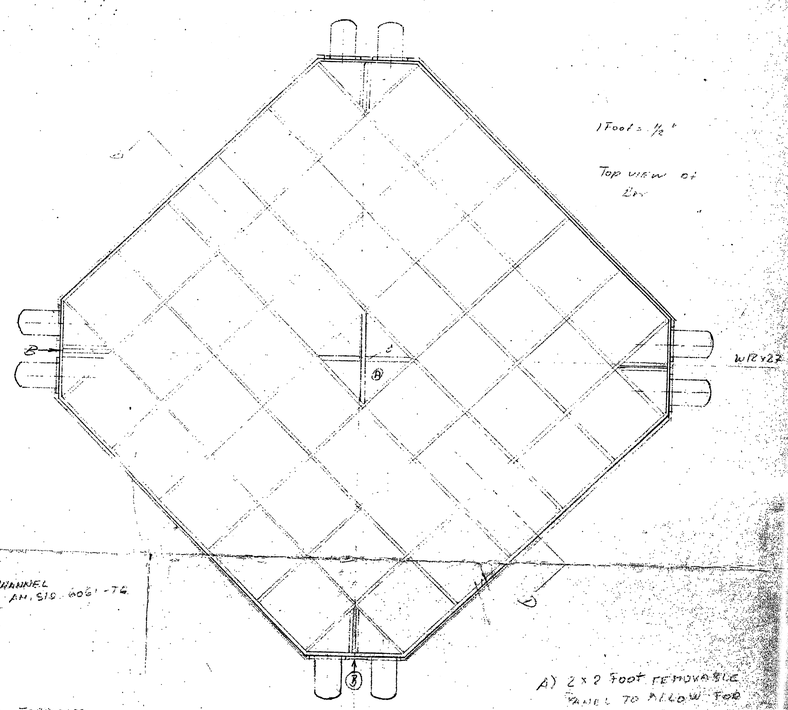
(2): TM having strength $\leq$ 1 Dirac monopole will radiate in near uv.

(3): TM having strength $\leq$ 2 Dirac monopoles will radiate in near uv.

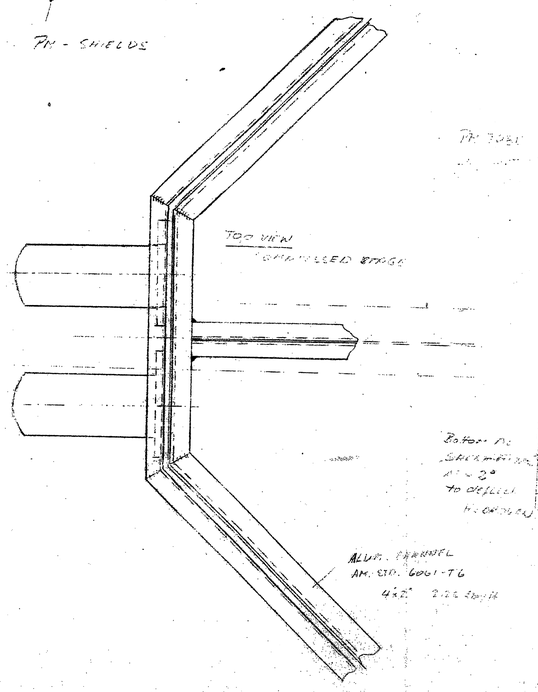
(3) = Sensitive region if TM's follow field lines

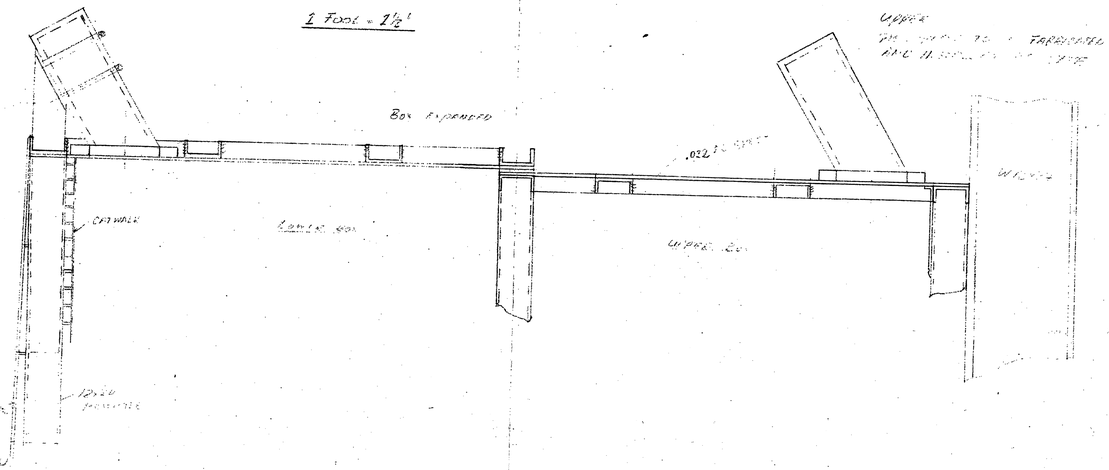






1 Foot = 1½'





A) 2 x 2 Foot removable panel to allow for rigging.

B) Hooks in 4 places to lift box with 4 wires from top of C.C. to roof truss.

C) Cross Brace removable during shipping purposes

D) Break line for upper and lower box to be fastened at nail

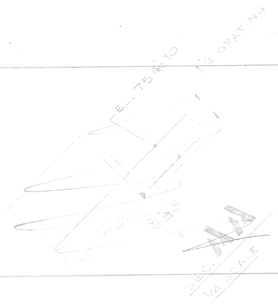
ALL MATERIALS EXCLUDING
Photo Multiplier Shields
will be 6061-T6 Aluminum

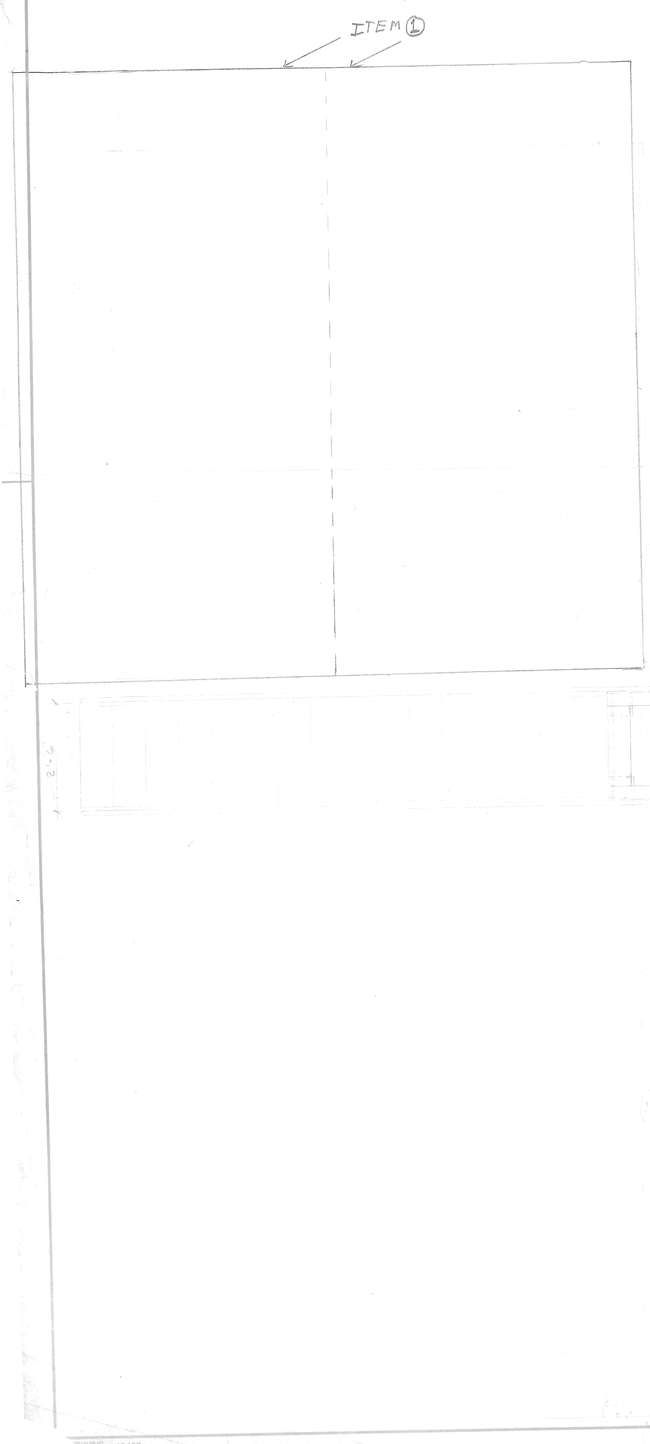
EXPERIMENT 202
2/18/70

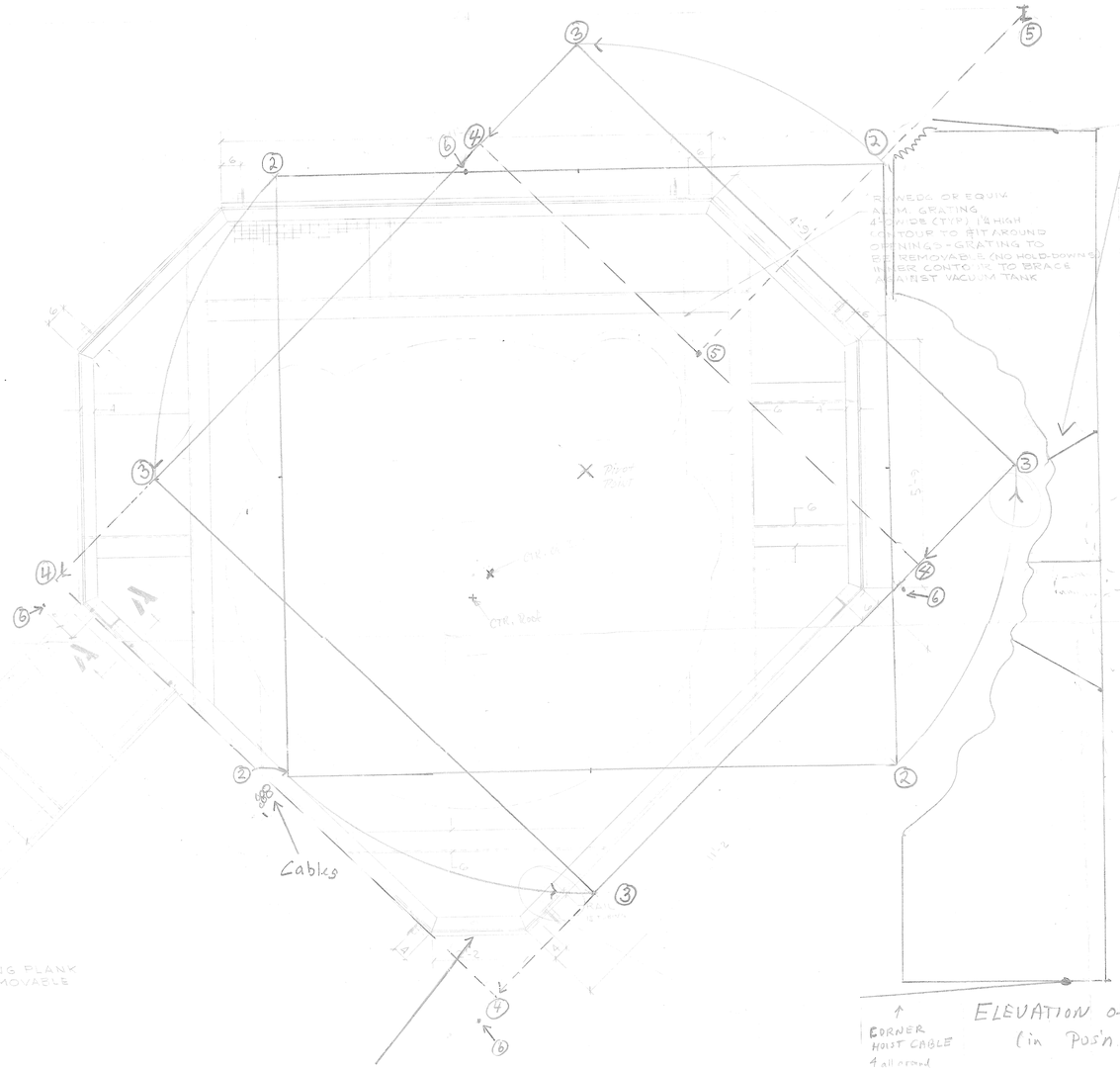
Appendix I

REVISIONS			
SYM	DESCRIPTION	DRAWN APPD.	DATE DATE
A	NUMBER WAS 2627ME-25008		6-14-72

SUGGESTED METHOD OF ATTATCHMENT FOR REMOVABLE RAILS (OPTIONAL)
1/4 SCALE







PLAN VIEW
3/4" = 1'-0

Note: Two meters mounted above handrail to be removed during installation.

ELEVATION of BOX (in Posn (4))

ELEVATION VIEW
1/2" = 1'-0

(6) Box raised to roof by 4 corner winches, Top corners of box home to posns indicated

(5) "Come-a-long" Attached between Box and NE corner column (To prevent box from hitting cables)

(4) Box Translated SW by Crane and set on posts. Crane Removed

(3) Box Rotated 45° by Crane

(2) Box Lifted by Crane placed Above B.C. (L.P. Box ≈ 5in Above handrails)

(1) TWO HALVES JOINED (on top of 1:4t)

Appendix II - "Agreement"

RIGGING PLAN for BOX

Expt 202

Feb 22, 1974 (Colorado - Princeton)

ITEM NO.	PART NO.	DESCRIPTION	QTY. REQ.
		PARTS LIST	

UNLESS OTHERWISE SPECIFIED			ORIGINATOR		
FRACTIONS	DECIMALS	ANGLES	DRAWN	ANGERENOS	4-5-72
±	±	±	CHECKED		
1. BREAK ALL SHARP EDGES 1/64 MAX.			APPROVED		
2. DO NOT SCALE DWG.			APPROVED		
3. DIMENSIONING IN ACCORD WITH USASI Y14.5 STD's.			USED ON		
√ MAX. ALL MACHINED SURFACES			MATERIAL-		

NATIONAL ACCELERATOR LABORATORY
U.S. ATOMIC ENERGY COMMISSION

30K LITER HYDROGEN B.C. CAMERA PLATFORM

SCALE	FILMED	DRAWING NUMBER	REV.
NOTED		2627ME-26008	

TUNING 40-107