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HYPERFRAGMENTS PRODUCED BY K^o MESONS FROM K^+ CHARGE EXCHANGE*

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ABSTRACT

Stacks of C-2 emulsion were exposed to neutral K mesons. These were produced by the charge exchange, in dense material, of K^+ mesons from the Berkeley Bevatron. Hyperfragments were found in these stacks.

It is concluded that the hyperfragments were produced by K^o_2 mesons in the $\bar{K}^o$ mode. These were generated by the decay of the K^o_1 component of the K^o beam as would be expected from the Gell-Mann Pais scheme. Other possible mechanism of production of the hyperfragments have been considered and shown to be unimportant.

I. INTRODUCTION

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It has been pointed out[1,2,3] that the time dependence of the $\overline{K}^0$ amplitude, in a K^0 beam of definite initial strangeness, can show interference effects due to the mass difference of the K^0_1 and K^0_2. A possible method of detecting this interference is to utilize the charge exchange of a K^+ beam in a dense target which then produces a pure beam of K^0 mesons of strangeness +1. By monitoring the amplitude of the $\overline{K}^0$ at different distances from the K^+ target, it should be possible to detect the interference. An exposure has been made to test the feasibility of such an experiment. Preliminary data, although insufficient to give information on the mass difference, do show that the double change in strangeness does occur[4].

II. EXPOSURE

Crude estimates of the background of stars and charged particles indicated that it would be very difficult to monitor, in G-5 plates, the $\overline{K}^0$ mode by detecting the interactions which would lead to the production of charge hyperons and K^- mesons. The principal background comes from the very high ratio of minimum ionizing pions to $\overline{K}^0$ interactions. However, the nonmesonic decays of hyperfragments can be detected with reasonable probability in much less sensitive emulsions which do not register the minimum ionizing pions. For this reason C-2 emulsions were chosen with the intention of detecting the K^0_2 mesons interactions in the $\overline{K}^0$ mode which ultimately lead to hyperfragment formation.

The geometry of the exposure is shown in Figures 1 and 2. The momentum of the K^+ mesons at the position of the hevimet target was found from the ranges of protons in Al wedges placed in the position of the target. It was found that there was a variation of the momentum across the face of the target due to the dispersion of the magnet. The momentum interval involved was found to be 640 ± 30 to 750 ± 30 Mev/c. The ratio of pions to K^+ mesons in this beam is not accurately known, but is of the order of 70 to 1.

A total flux of 7×10^{14} protons of 6.2 Bev struck the internal proton target, which gave about 2×10^7 K^+ mesons on the K^+ target. The target for the K^+ mesons was hevimet, an alloy of tungsten, with a density of 17.2. The high density was chosen to minimize the volume in which charge exchange would take place. Two stacks (B and C) were placed at different distances below the K^+ target. A third stack A was placed ahead of the K^+ target and below the K^+ beam in order to study the spray of particles from the magnet and shielding.

It would have been desirable to have used a separated K^+ beam, but estimates of beam intensity requirements excluded this possibility, for an exposure of reasonable duration.

Because of their low energy (< 650 Mev) the pions which also came down the channel produced few strange particles in comparison to the K^+ mesons. The threshold for Λ^0 production by positive pions on free nucleons is 760 Mev, and with Fermi momentum 580 Mev. The estimated ratio, of K^0 produced by charge exchange of the K^+, to those produced directly by pions is about 30.[5] Furthermore, the K^0 produced by these pions will be very forward and miss the B and C stacks. For these reasons we believe that the contribution to the total number of K^0 incident on the emulsion stacks from pion production is negligibly small.

III. EXPERIMENTAL RESULTS

The C-2 emulsions were scanned with an oil immersion objective (55 x 10) for all types of double stars. Aside from the usual problems of distinguishing hyperfragments from other classes of double stars; there are additional problems introduced by the insensitivity of the C-2 emulsions. Except in extraordinary cases, all mesonic decays of hyperfragments are unrecognizable as hyperfragments in C-2 emulsions. This particular aspect is not important because the mesonic decays comprise a small fraction of the total[6]. It is known[7] that fast protons are ejected in about 50 percent of the nonmesonic decays. These fast protons would not be observed in C-2 plates. For this reason the total charge of the observed particles from the secondary star may not be the same as that of the connecting track. Also those events which consist of a fast proton and a recoil or in general one slow particle, will not be recognized as a fragment, but probably classified as a scattering. Because of these factors the true number of hyperfragments is undoubtedly greater than the number recognized by as much as a factor of two. The results of the scanning are given in Table I.

In Table I, only the events which showed definite evidence that the fragment stopped, such as thin down or small angle scattering near the secondary star, were included in the category of "sure hyperfragments". In the category "probable hyperfragments" were those events with saturated connecting tracks and without evidence for interaction in flight. It should be pointed out that pions and proton tracks have numerous gaps up to the very end of their range in these C-2 emulsions.

IV. DISCUSSION

In order to conclude that the hyperfragments observed in stacks B and C originate from the K^+ by a double change in strangeness, we must exclude the possible production of hyperfragments by other mechanisms. Such mechanisms could be the following:

(1), pions, neutrons or protons of high energy could scatter from the pole faces of the magnet and come down the channel and produce strange particles either directly in the hevimet or subsequently scatter into stack B and C and produce strange particles. We shall call these particles "energetic spray particles".

(2), strange particles, either neutral or charged, could originate from the pole faces of the magnet either by associated production, charge exchange or scattering and impinge on the hevimet and lead to eventual hyperfragment production in stacks B and C. We shall call these particles "strange spray particles".

Particles which originate from the jaws of the magnet will have a wider angular distribution than the beam particles and will have about the same or larger probability of striking stack A as the hevimet, while nearly all of the beam particles miss stack A. For this reason stack A is a good monitor of radiations capable of producing hyperfragments other than the K^+ beam.

If one assumes all hyperfragments in stacks B and C to be due to causes (1) or (2) one can calculate (See Appendix I and II), that the expected density of hyperfragments in A is ~ 700 or ~ 150 respectively. This is to be compared with ~ 3 observed, indicating that the contribution of process (1) and (2) to hyperfragment formation is unimportant.

The calculations shown in the Appendix are of an extremely crude nature, indeed it would be difficult to make them otherwise in view of the very scant data available on the processes involved. However, we feel that the arguments we indicate above are nevertheless valid, in view of the fact that the estimated densities differ from the observed one by factors of 300 and 50 respectively.

On the other hand, if one assumes that the hyperfragments are due to the charge exchange in the hevimet target, one obtains estimates that agree (Appendix III) to within a factor of 3 with the experimental observations.

We conclude that the hyperfragments were produced by the nuclear interaction of neutral K mesons in the $\overline{K}^0$ mode, which originated from the charge exchange of the K^+ mesons incident on the hevimet target. This represents a change of strangeness of two units since the strangeness of the incident K^+ beam was +1 and that of the Λ hyperon -1.

We greatly appreciate the help and advice of Drs. L. Kerth, M. Whitehead, R. Birge and R. E. Lanou who were also responsible for setting up the K^+ channel. The continued cooperation of Dr. E. J. Lofgren is greatly appreciated. Discussions with Professor R. G. Sachs and Professor G. A. Snow were helpful and stimulating.

APPENDIX

We take the following quantities to be

λ_g = collision mfp of pions in emulsion

= mfp of $\overline{K}^o$ in emulsion = 30 cm

λ_{pb} = geometric collision mfp of pions in lead = 14 cm

λ_{K^+} = collision mfp of K^+ in hevimet[8,9,10] = 20 cm

ω = solid angle subtended by 1 cm^2 in stack B as seen by the target = $\frac{1}{200}$

$P_{E\theta}$ = probability of K^o production in collisions of the "energetic spray particles" $\approx$ 1/100.

P_{EF} = probability of hyperfragment production by the "energetic spray particles" $\approx$ 1/1000

P_{ES} = probability of an "energetic spray particle" scattering with sufficient energy after scattering to produce strange particles $\lesssim \frac{1}{3}$

$P_{\theta S}$ = probability of ${K^o}_2$ scattering in hevimet = $\frac{1}{4}$

$P_{\theta F}$ = probability of hyperfragment formation by interaction of $\overline{K}^o \approx 1/40$[11,12]

$P_{K^+\theta}$ = probability of K^+ charge exchange in hevimet $\approx \frac{1}{2}$ [8,9,10]

L = effective length in hevimet for charge exchange = 4 cm.

ℓ = length of stack A = 7.5 cm

R = ratio of pions to K^+ in beam $\approx$ 70

S = frontal area of hevimet target = 31 cm^2

I. If it is assumed that all of the hyperfragments in stack B were due to K^o production in the hevimet target by energetic pions, or by scattered pions which directly produced hyperfragments in stack B we estimate that the density of hyperfragments in stack A to be:

$$\text{No. of hyperfrag (A)/cm}^3 = \text{No. of hyperfrag (B)/ cm}^3 \quad X$$

$$X \; \frac{\frac{1}{S}\,\frac{5.9}{7}\left(\frac{1}{\lambda_g}\cdot P_{EF} + \frac{\ell}{\lambda_{pb}}\cdot P_{E\theta}\cdot\frac{1}{\lambda_g}\cdot P_{\theta F}\cdot\frac{1}{2}\right)}{\left(P_{E\theta}\cdot\omega\cdot\frac{1}{2}\,\frac{1}{\lambda_g}\;P_{\theta F} + P_{ES}\,\omega\,\frac{1}{\lambda_g}\;P_{EF}\right)} = 700$$

The first term in the numerator corresponds to the direct production of hyperfragments by pions in stack A; the second term to hyperfragments due to K^0 produced in the lead near stack A. The first term in the denominator corresponds to K^0 production in the hevimet; the second term corresponds to hyperfragment production in stack B by spray particles of sufficient energy to produce hyperfragments.

II. If it is assumed that all hyperfragments in stacks B and C were due to neutral K mesons in the beam which scatter and subsequently interact in stacks B and C, we estimate the density of hyperfragments in stack A to be

$$\text{No. of hyperfragments (A)/cm}^3 = \text{No. of hyperfragments (B)/cm} \quad X$$

$$X \; \frac{\frac{5.9}{7}\cdot\frac{1}{S}\left(\frac{1}{\lambda_g}\cdot P_{\theta F}\cdot\;\frac{\ell}{\lambda_{pb}}\cdot P_{\theta S}\cdot\frac{1}{\lambda_g}\cdot P_{\theta F}\cdot\frac{1}{2}\right)}{P_{\theta S}\cdot\omega\cdot\frac{1}{\lambda_g}\cdot P_{\theta F}} = 150$$

III. If we now assume that all hyperfragments in stacks A, B and C were due to the charge exchange of the K^+ on the hevimet, we can estimate the number of hyperfragments expected.

From electron sensitive test plates placed in front of the hevimet target we find that the total number of pions incident on the target was 2.6 x 10^9. The number of hyperfragments/cm^3 is estimated as follows:

Number of hyperfragments (B)/cm^3

$$= \frac{2.6 \times 10^9}{R} \cdot \frac{L}{\lambda_K} P_{K\theta} \frac{1}{\omega} \frac{1}{2} \frac{1}{\lambda_g} P_{\theta F} = 7.7$$

Number of hyperfragments (A)/cm^3

$$= \frac{2.6 \times 10^9}{R} \cdot f \cdot \frac{5.9}{7} \frac{\ell}{8} \frac{1}{\lambda_g} P_{\theta F} \left(\frac{1}{\lambda_g} + \frac{1}{\lambda_{Pb}} \right) = 7.3$$

where $f = \frac{1}{10}$ is the ratio of the intensities of minimum ionizing tracks at the positions of stack A and of the hevimet target respectively.

The value of f was determined experimentally by means of G-5 test plates.

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3. W. F. Fry and R. G. Sachs, Phys. Rev. 109, 2212 (1958).

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5. W. D. Walker, (Private Communication) finds ~ 10^{-3} strange particles per collision in carbon by 750 Mev pions.

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11. Fry, Schneps, Snow, Swami, Wold, Phys. Rev. 107, 257 (1957).

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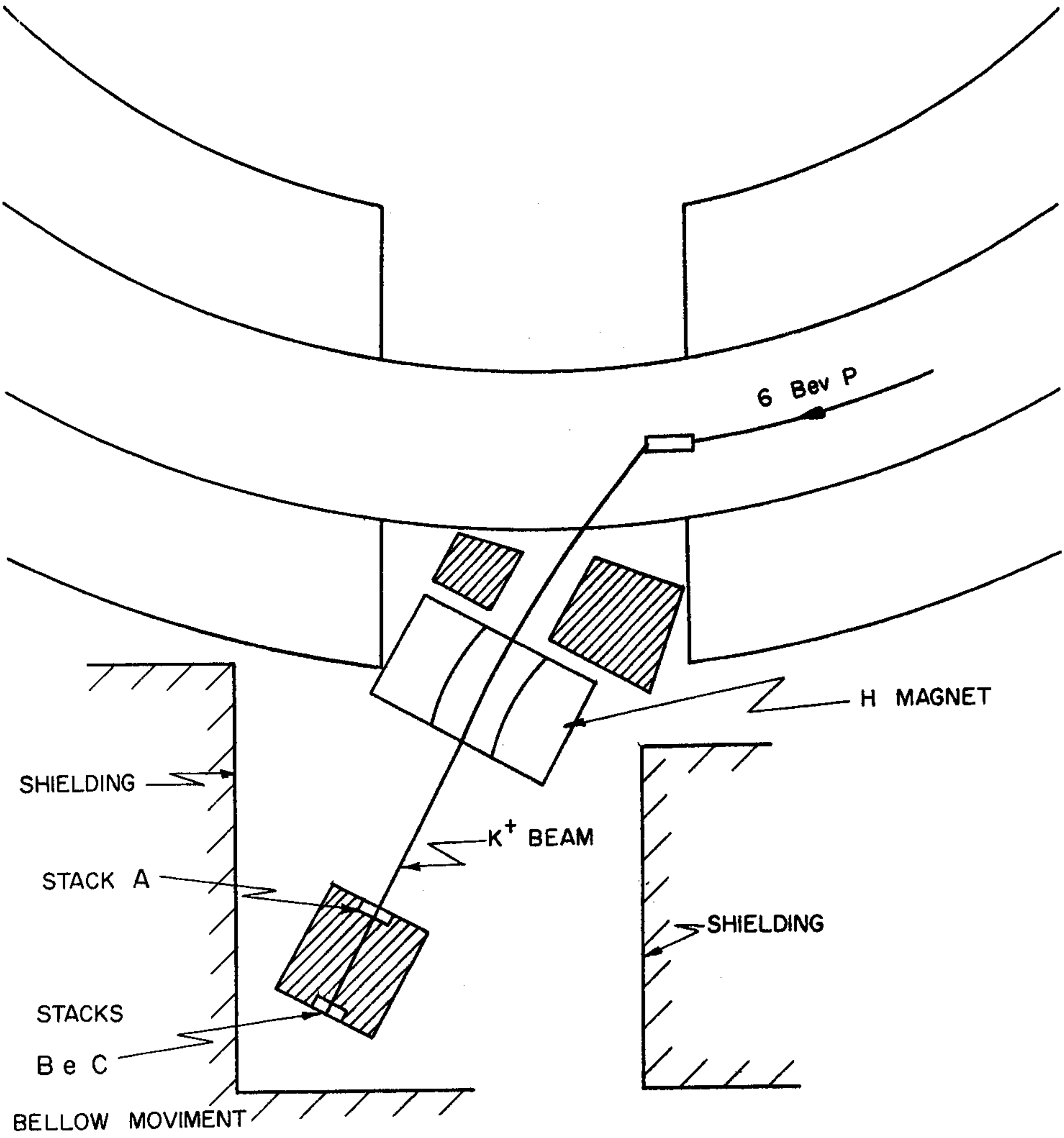
TABLE I

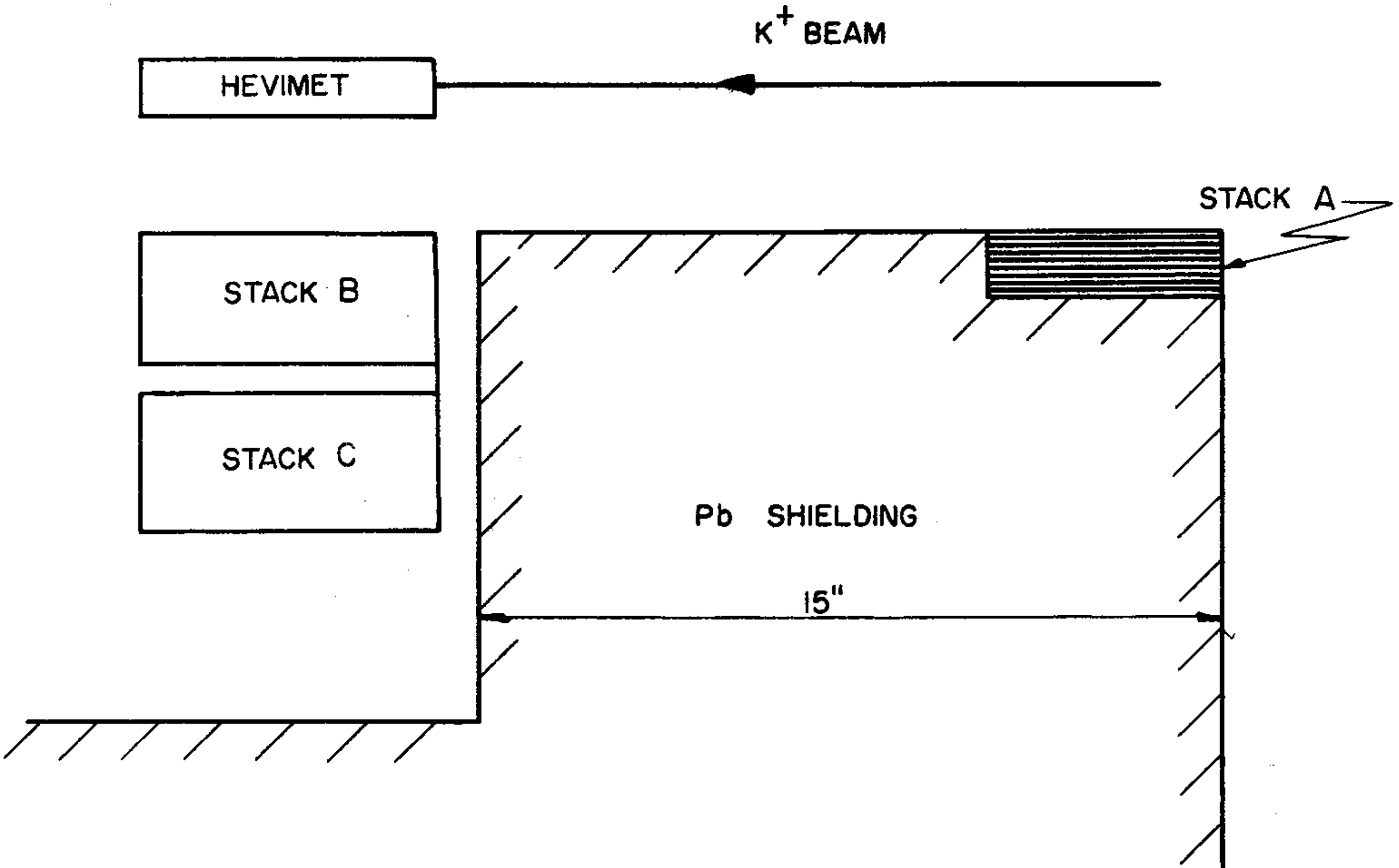
Summary of Data

			Hyperfragments					Stars		
Stack	Protons on target	Volume Scanned cm^3	Sure		Probable	Total	Per cm^3 per 10^{14} p	per cm^2	per cm^3 per 10^{14} p	per HF
			$R > 10$	$R < 10$						
A	5.9×10^{14}	3.18	1	1	5	7	0.4	780	4.4×10^3	1.1×10^4
B	7×10^{14}	3.3	5	9	4	18	0.8	390	1.9×10^3	2.4×10^3
C	7×10^{14}	2.25	1	3	1	5	0.3	380	1.8×10^3	6×10^3



TOP VIEW OF GEOMETRY OF EXPOSURE

FIG. 1



SIDE VIEW

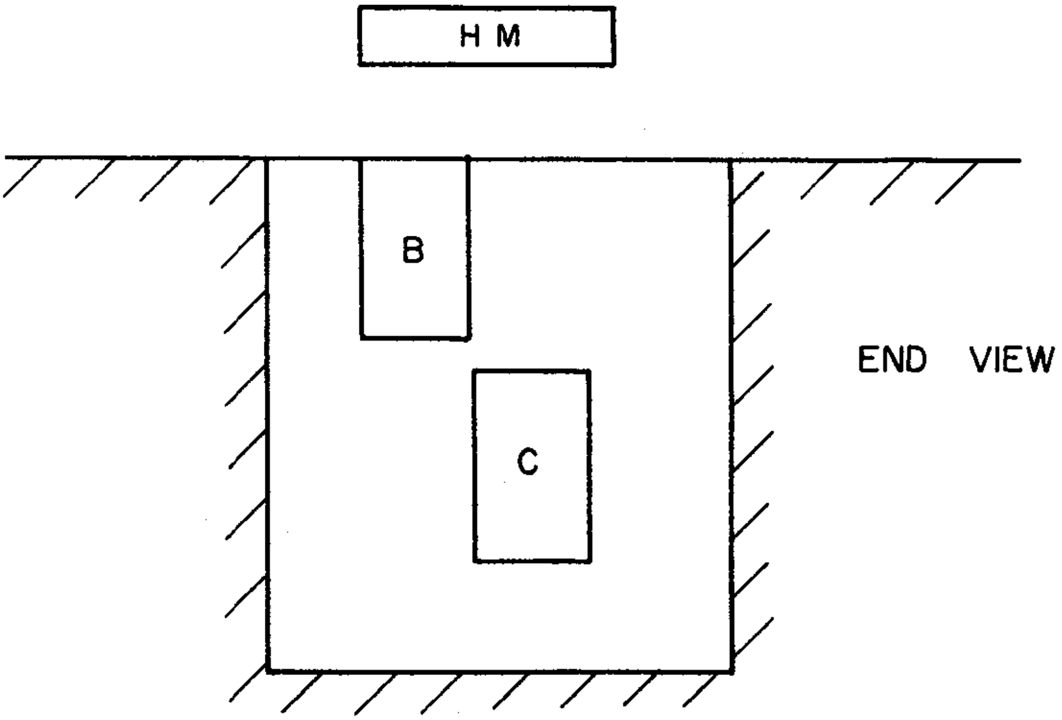


FIG. 2