Design of a Support Stand for Large Plastic Scintillation Bars for Nucleon Detection

Craig Sapp

REU

University of Virginia

August 1989

Advisor: Richard A. Lindgren

Supported in part by a grant
from the National Science Foundation
and the Commonwealth Center for
Nuclear and High Energy Physics.

I. Abstract

This REU project consists of designing a frame to support large scintillation bars for the detection of protons and neutrons. The device will be used in studying the photodisintegration of ^3He. Nucleons will be kicked out of the nucleus by a polarized 300 MeV photon beam, and will be observed by the detector both as singles and *pn* coincidences simultaneously.

The experiment using these bars and stand will be conducted in the LEGS facility at Brookhaven National Labratory this fall, and the computer-designing program AutoCAD is being used to design and draw the frame for the detector. The main feature of the support frame is two arcs eight feet long and one inch thick that will support 32 10×10×160 cm Bicron model BC-408 scintillating bars and 16 0.6×11×160 cm veto paddles of the same material in 16 slots between 20° and 140° from the horizontal plane of the incoming photon beam. Outside this pair of arcs is another pair that will support the photomultipliers attached to light pipes at the end of each bar. These four arcs will be positioned over the target and supported by 5-1/2′ legs enabling Phoswich detectors to rest underneath the target.

II. Introduction

This project report describes the designing of a detector support stand to be used in an experiment this fall conducted at the LEGS (Laser Electron Gamma Source) facility of Brookhaven National Laboratory (BNL). The experiment is being undertaken by a large collaboration including the University of Virginia, Rensselaer Polytechnic Institute, Tel Aviv University, Brookhaven National Laboratory, Institute of Physics in Rome, and the University of South Carolina. The goal of the experiment is to study nucleon structure and nucleon interactions in the nucleus by the photodisintegration of ^{3}He. Photon-induced nuclear reactions in ^{3}He will be measured at intermediate energies where the $\Delta(1232)$ resonance plays a major role.

The National Synchrotron Light Source (NSLS), which the LEGS facility is a part of, provides synchrotron radiation for experiments in a variety of fields from Nuclear Physics to Biology. This particlar experiment requires a 300 MeV polarized photon beam to hit a target of ^{3}He. The LEGS facility utilizes Compton back scattering at NSLS to produce these polarized photons. Ultra-violet light with an energy of 3.5 eV collide at 180° with 2.5 GeV electrons traveling in a storage ring 27 meters in radius. The UV photons are produced by a laser and then polarized either linearly or circularly (nearly 100%) by filters before being aimed at the electron ring by mirrors. If a UV photon then collides with an electron and recoils back exactly the way it came, it will retain its polarization and pass through the UV positioning mirror into the target area. The energy, E, of the γ rays produced at the angle θ between incoming laser photons and outgoing photons is

$$E = \frac{4\gamma^2 L}{1 + \frac{4\gamma L}{mc^2} + \theta^2\gamma^2}$$

where L is the energy of the laser photon, γmc^2 is the electron beam energy and γ is the Lorentz factor. A useful beam is obtained by collimating the outgoing photons within an angular range of 10^{-4} radians. γ for 2.5 GeV electrons is 4.9×10^3. Thus the range of γ ray energies is:

$$\frac{4(4.9\times10^3)^2 3.5\ \text{eV}}{1 + \frac{4(4.9\times10^{3)}3.5}{2.5\times10^9} + (10^{-8} — 10^{-10})(4.9\times10^9)^2} = 270 — 335\ \text{MeV}.$$

The final beam passing through the target has an intensity of about 5.2×10^6 photons per second which is 2.5×10^{-4} Joules of energy per second. Particles from the target will enter the detectors at a rate of about one per second.

The reason for having the incoming γ-rays polarized is that the assymetry of the neutron can be calculated by measuring the cross-section from photons polarized in one direction and comparing this to the cross-section from photons polarized in the opposite direction using the relation $A = \frac{\sigma_\uparrow - \sigma_\downarrow}{\sigma_\uparrow + \sigma_\downarrow}$, where σ stands for the cross-section.

In the ^{3}He target, several reactions will occur. A comprehensive observation of the following reactions is planned at LEGS using this detector: $^3\text{He}(\vec{\gamma},d)p$, $^3\text{He}(\vec{\gamma},p)\text{X}$, $^3\text{He}(\vec{\gamma},pn)p$, $^3\text{He}(\vec{\gamma},pp)n$, $^3\text{He}(\vec{\gamma},\vec{\gamma})^1\text{H}$, and $^3\text{He}(\vec{\gamma},\vec{\gamma})\text{X}$. Particles leaving the nucleus will have a combined momentum of almost 300 MeV since nucleon binding energy is only about 8 MeV per nucleon in ^{3}He. 20 cm of scintillating material can stop protons of energies up to 175 MeV which will be adequate for this experiment. Neutron detection efficiency will be about 20% however.

The part of the experiment on which I am working is designing the support stand for the array of 16 paddles and 32 bars of scintillator plastic as well as their attached electronics and photomultipliers that will rest above the target at LEGS. The detector below the target is already in place for other experiments (see appendix A picture). The bars are 10×10×160 cm in dimension, while the paddles are 0.6×10×160 cm.

The veto paddles are an important part of the detector because they will provide ΔE-E particle identification, allowing the detector to distinguish between protons and neutrons. Neutrons lose their energy in the scintillators all at once by reacting via scattering with a hydrogen nucleus in the H-C-H chains of the plastic while protons lose their energy gradually by ionization of the atoms in the chains. Therefore, nearly all the neutrons will pass through the paddles undetected while the protons will lose energy creating a signal that will be detected by the phototubes.

III. *Methods and Materials*

The detector-stand designing was done using a computer-assisted design system called AutoCAD running on the μVAX Born. AutoCAD (version 9.0) has minimized the time required for revisions to the drawings. The design for the inner pair of arcs has required the most revisions. Originally these arcs were planned to be made of 3/4″ aluminum plate but now are to be made of 1″ UHMW (ultra-high molecular weight) polyethylene — mainly because UHMW is lighter and cheaper than aluminum. Also, background will be less from the neuclons passing through the arcs since UHMW is less dense than aluminum.

These arcs (shown in the *Results* section) go out to a radius of 150 cm from the target and the paddles and bars start cyndrically at one meter from the target. Sixteen slots are cut in each of the arcs to support the ends of one paddle and two bars in each slot. Only these details have remained constant while the exact shape of the arc has been changing (see appendix B picture). Though only two bars will be used, the arcs are being designed for three in anticipation of future additional bars.

An important detail to consider for the stand is the positioning of the detectors once in place at LEGS. Positioning in three dimensions requires three places for adjustment in the detector. The height of the detector will be regulated by screws in the feet of the stand. Positioning in the horizontal plane will be done by two different groups of slots 2″ long that will allow bolts to slide the upper part of the stand to the desired location.

The most challenging part of designing the detector stand has been how to place it on the floor at Brookhaven. The detector must straddle two different floor heights as well as rest partially on a false floor. Not until last week were feet to the stand considered when I had an opportunity to visit Brookhaven and look at the room in the LEGS facility where the experiment will be held.

Adjustments will be made to the design shown in the *Results* section owing to conflicts seen in the detector's surroundings. Where to place the posts has been a particular problem: one end of the detector must rest on the false floor and be supported across I-beams running under the floor while the other end must be extended to pass over a break between the two floors that is about a foot deep.

Lately, a stress analysis is being done on the stand to predict how it will behave when fully laden with all of the scintillators and electronics. The total weight of the scintillating material is 530 kg or 1200 lb. The total weight supported above the four posts is estimated to be 3,000 lb., so for saftey, the base of the stand will be checked carefully to see if it can withstand a load of 6,000 lb. The base itself will weigh less than 400 lb.

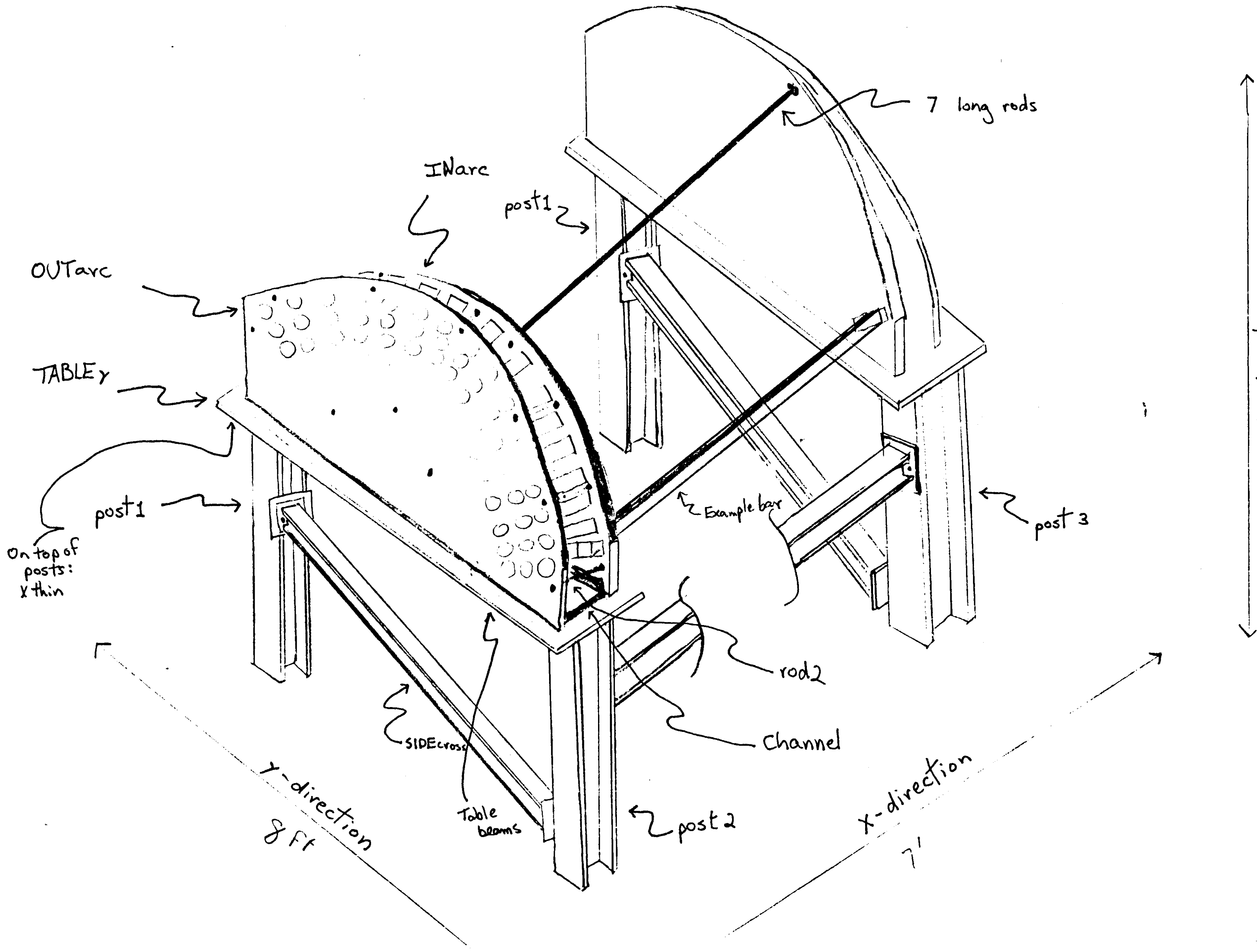
Final drawings are being made with AutoCAD to build the stand starting with the arcs this week, so some familiarity with standards in mechanical drawing was necessary for me to produce understandable blueprints. The help of George Plum in the Machine Shop and professor Richard Sealock has been helpful in giving my drawings some semblance of style.

IV. Results

Currently, the 4′ by 8′ UHMW plates that cost $382.72 apiece (as opposed to about $850 for equivalent aluminum plate) have arrived from AIN Plastics in New York, and other pieces will be ordered soon. The four arcs are now being machined at RWA Machining in Ruckersville, Virginia and the resr of the stand will be started on in a few weeks. The total cost for material will be around $4,000 and labor for building it will cost an additional $5,000.

The following pages show the currently designed pieces to the support stand for the detector and their relative position on the stand. Slight revisions will be made in the design so that it will no conflict with its surroundings at Brookhaven.

Position of the pieces on the stand

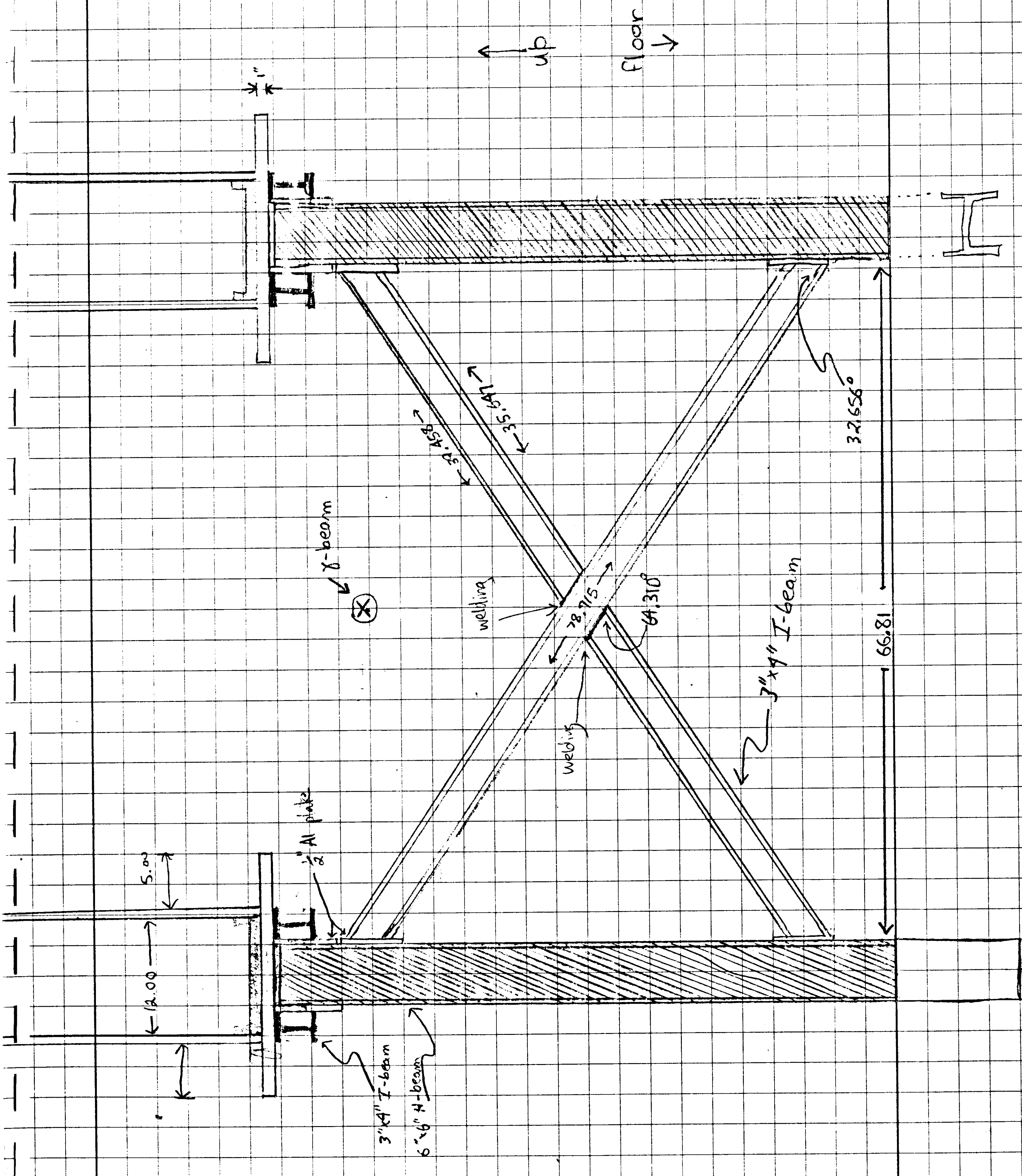


10

BACK VIEW OF DETECTOR STAND

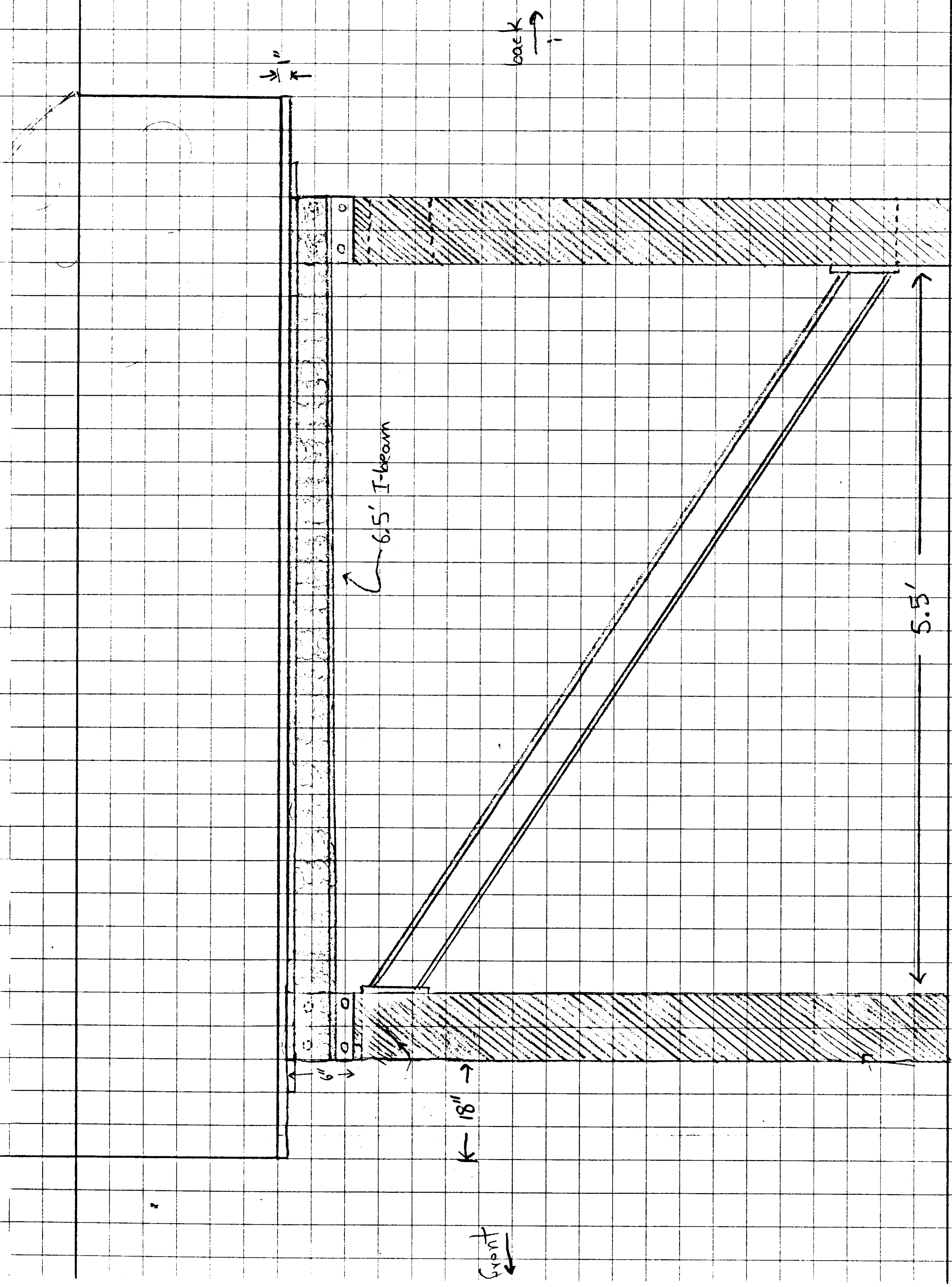
18 JUL 89

units in inches

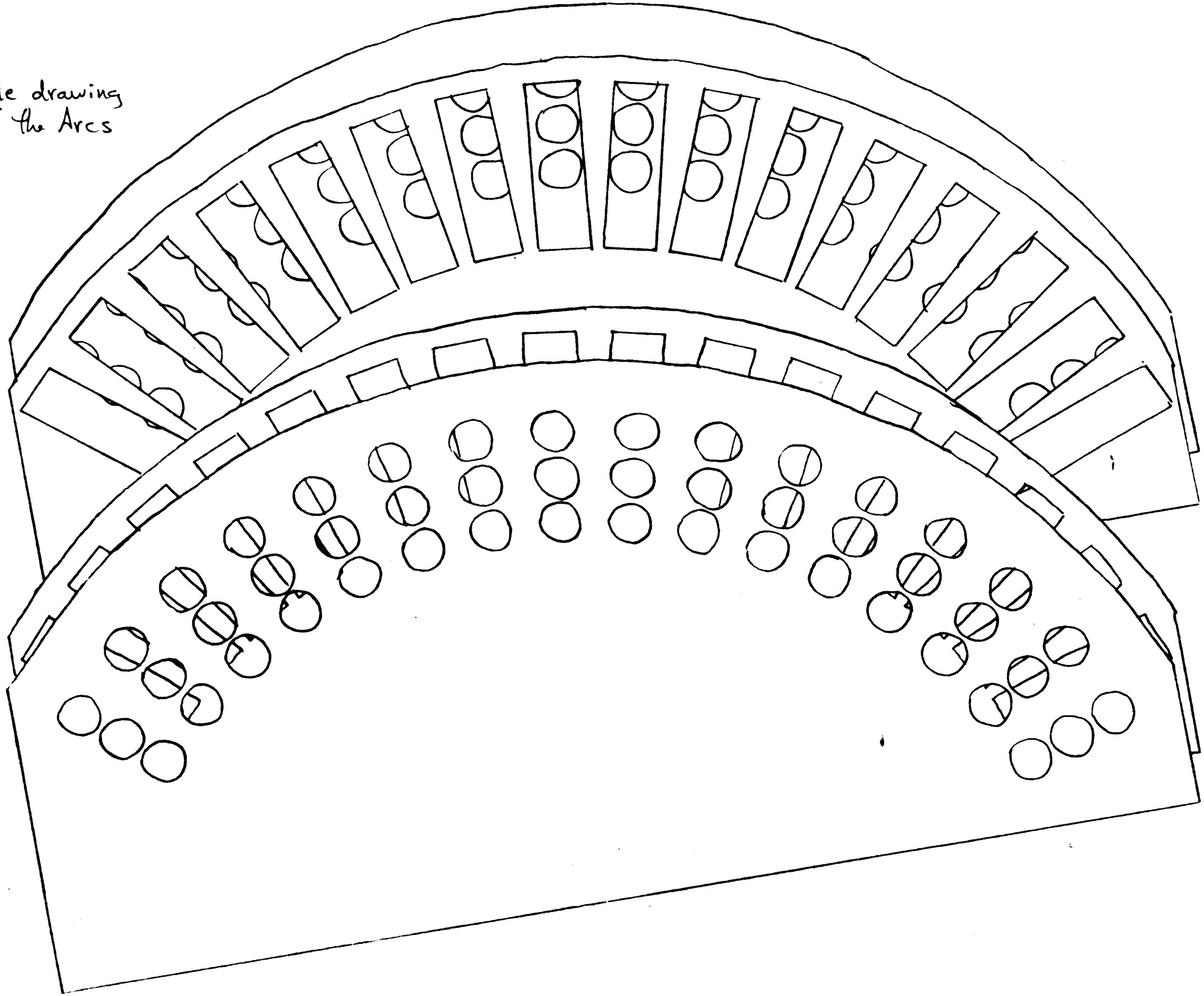


LEFT SIDE VIEW OF DETECTOR STAND

18 JUL 89



Scale drawing
of the Arcs



inARC.dwg -- 25JUL89

quantity: 2

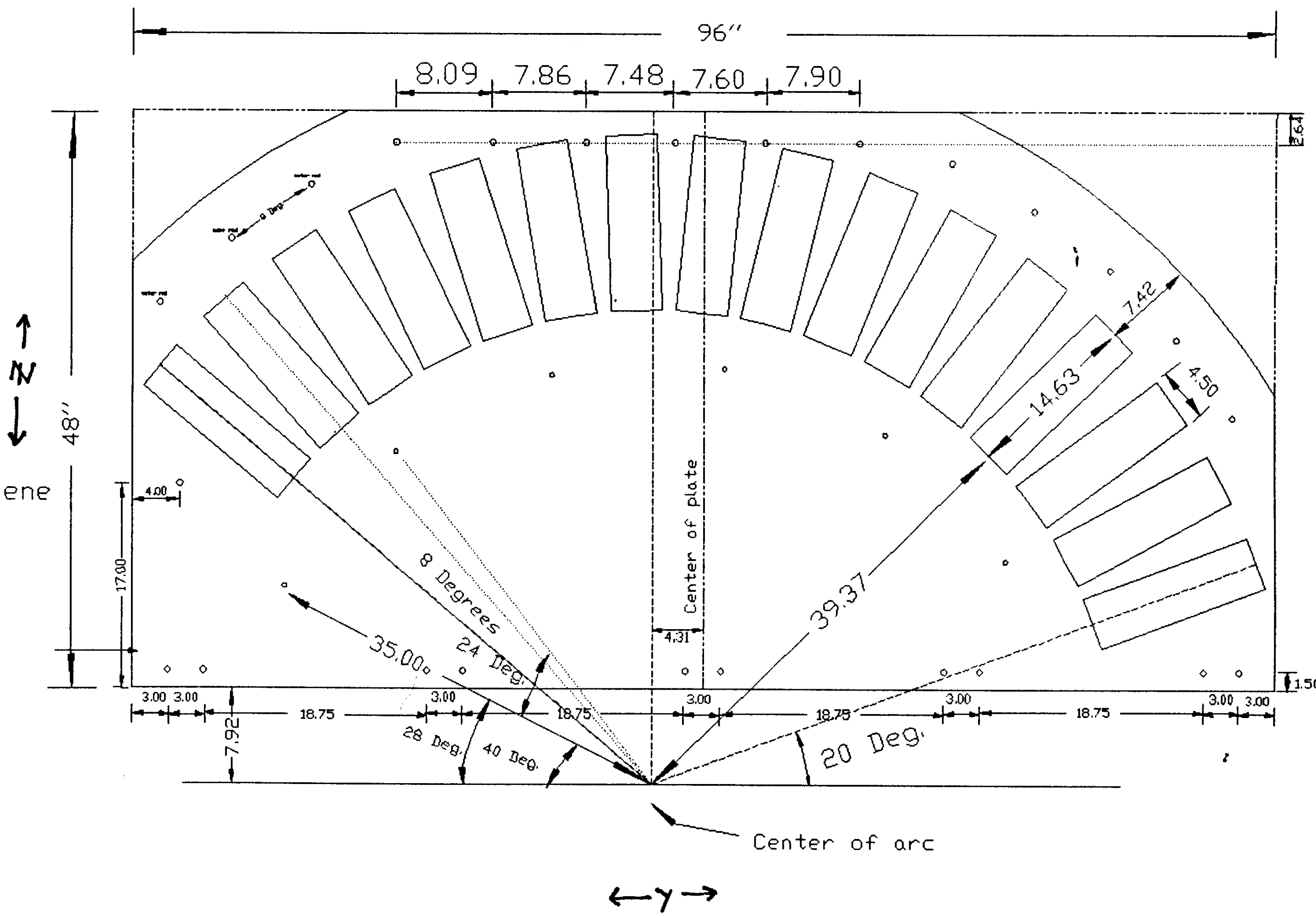
units: inches

tolerance: 0.01

material:1" plate UHMW polyethylene

holes for rods: 3/8"

holes for channel: 1/2"



OUTarc.dwg -- 25JUL89

material:1" plate UHMW polyethylene

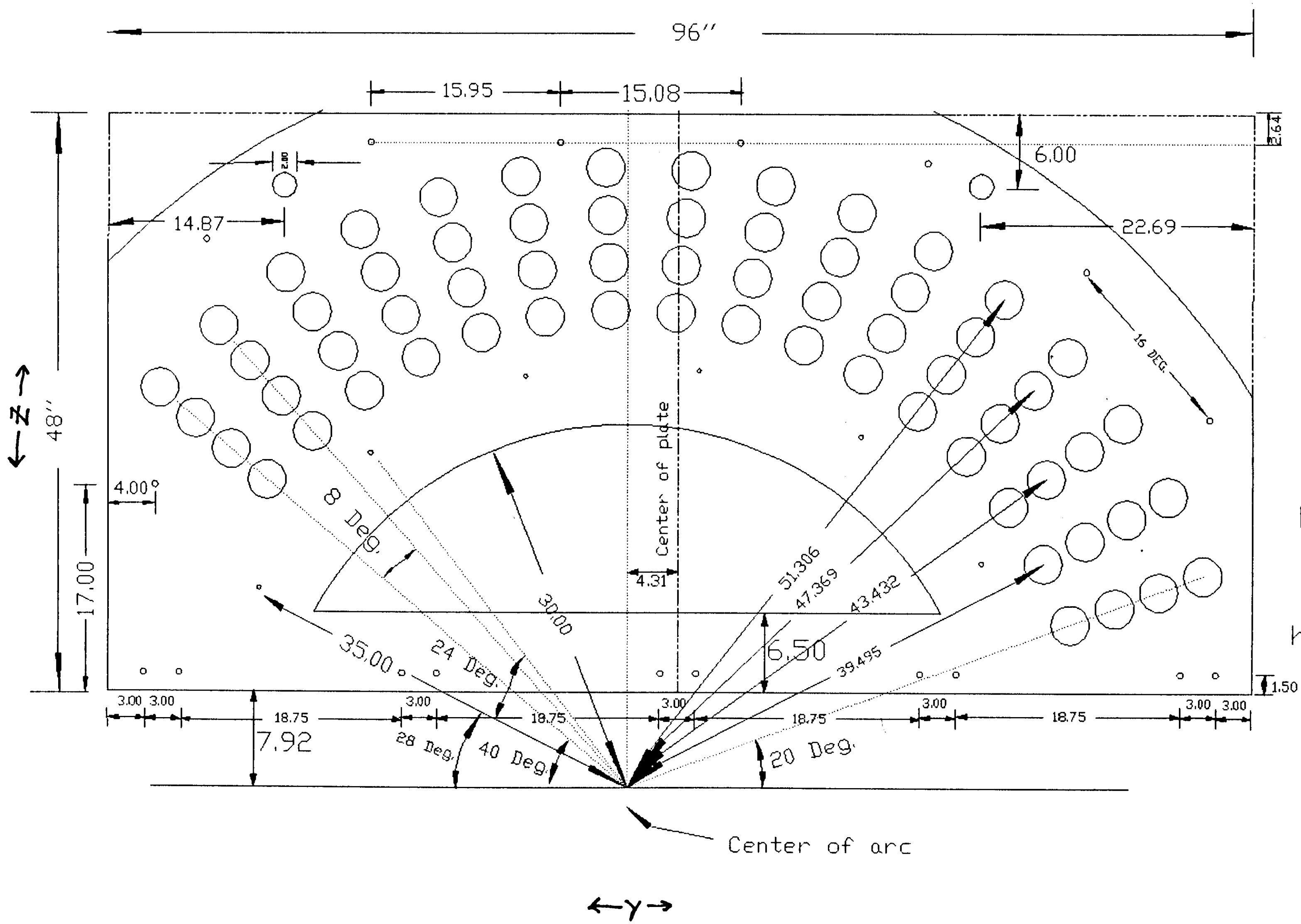
units: inches

tolerance: 0.01

quantity: 2

holes for rods: 3/8"

holes for channel: 1/2"



Circles on the Outer arcs

13 JUL 89

diameter of circles: 3 3/16" (3.1875 in)

diameter of tubes to be placed around phototubes: 6.4 cm

diameter of iron casings around tubes:

inside diameter: 2.7510

outside diameter: 3.1505

extra radial space left by circles: $\left(\frac{3.1875-3.1505}{2}\right) = 0.0185\,in = 0.47\,mm$

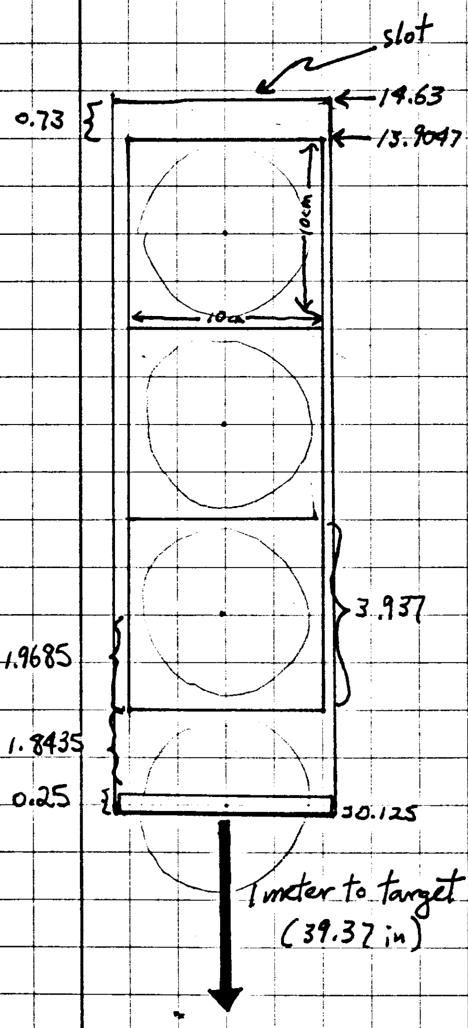
Coordinates in inches of first four circles at 20°

#1 – 39.495 (cos 20°, sin 20°)
(37.11316006, 13.50808556)

#2 – 43.4322 (cos 20°, sin 20°)
(40.81291784, 14.85468727)

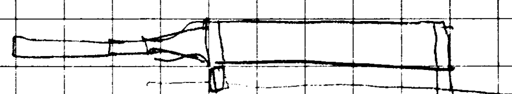
#3 – 47.3692 (cos 20°, sin 20°)
(44.51248769, 16.20122057)

#4 – 51.3062 (cos 20°, sin 20°)
(48.21205754, 17.54775388)



Spacing between circles: 0.75 in = 1.9 cm

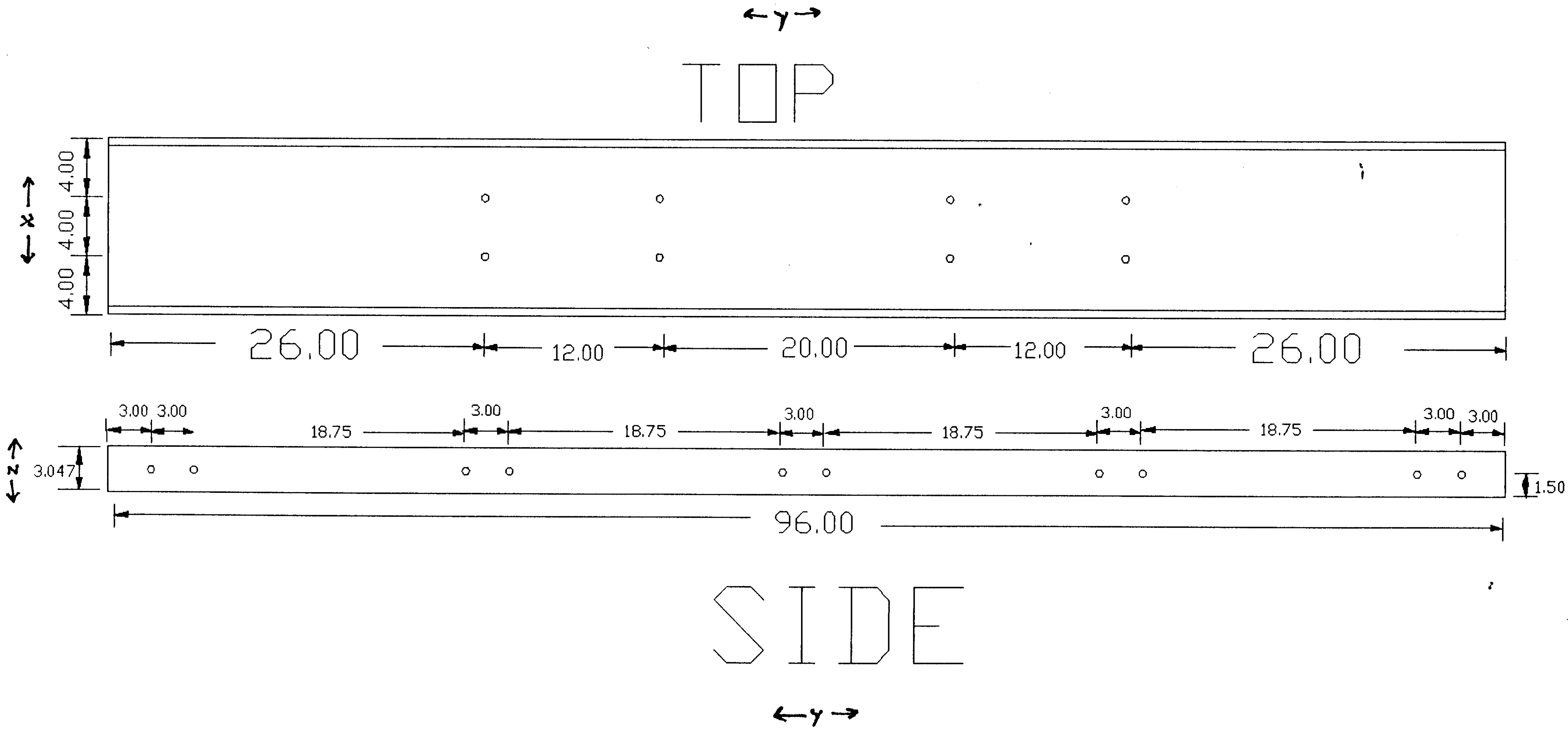
gap between paddle and first bar: 1.8435 in.



CHANNEL.dwg -- 24JUL89

quantity: 2 tolerance: 0.01

units: inches material: 12" Al channel



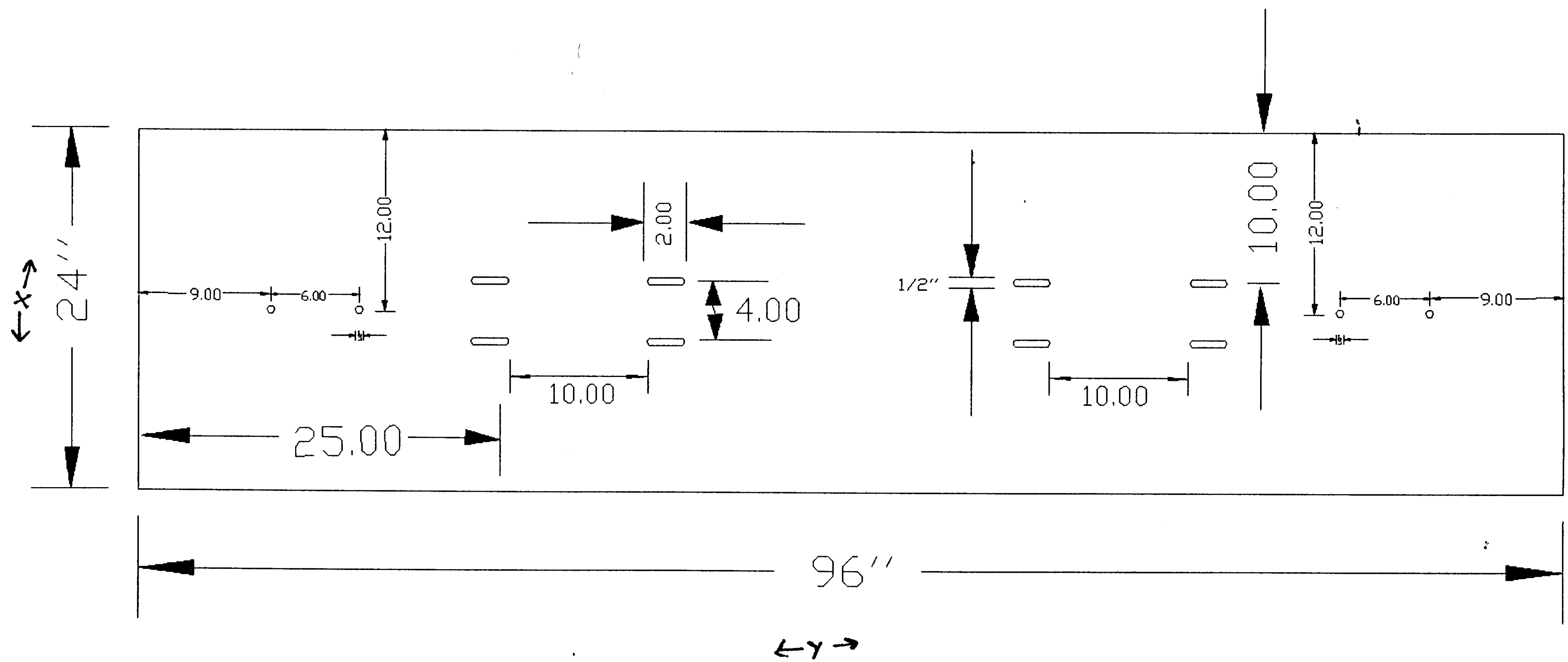
tableY.dwg -- 19JUL89

quantity: 2

units: inches

material: 1'' UHMW plate

tolerance: 0.01''



Xcorrect.dwg 19JUL89

quantity: 4

units: inches

material: 1/2" Al plate

tolerance: 0.01

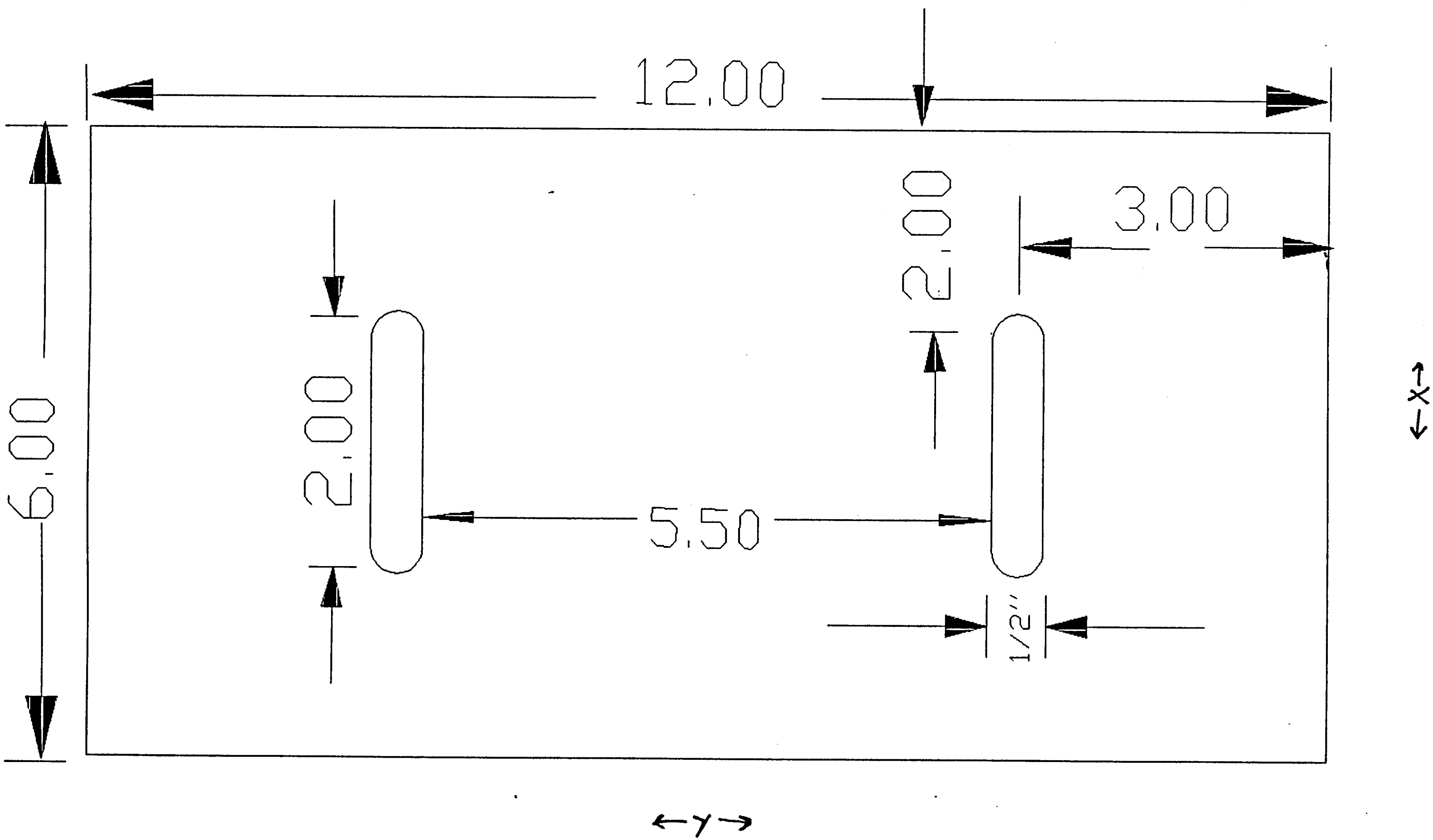
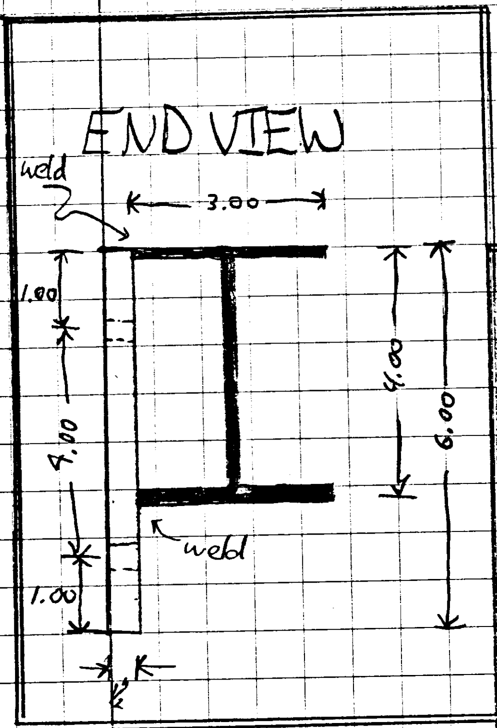


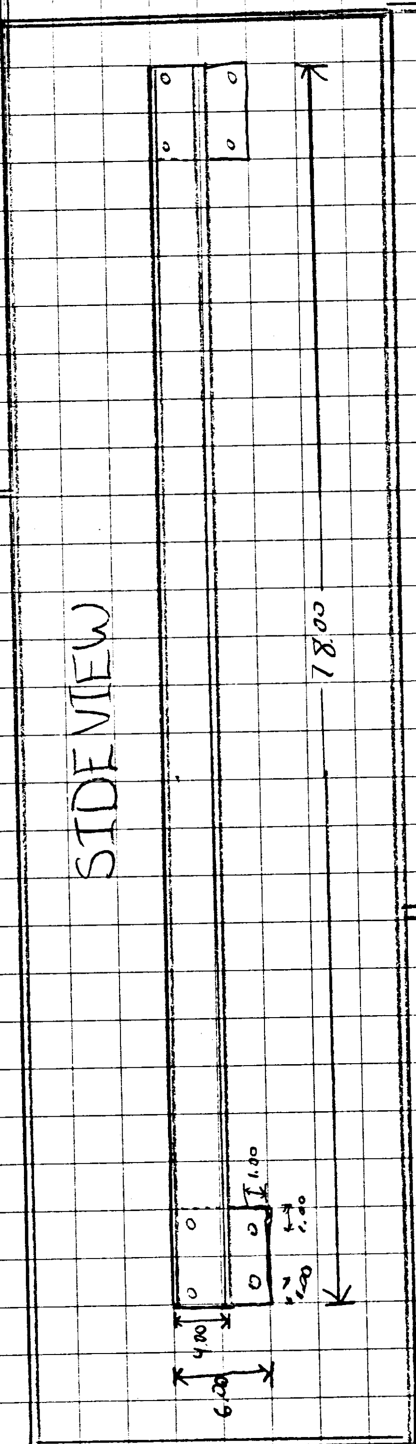
TABLE BEAMS

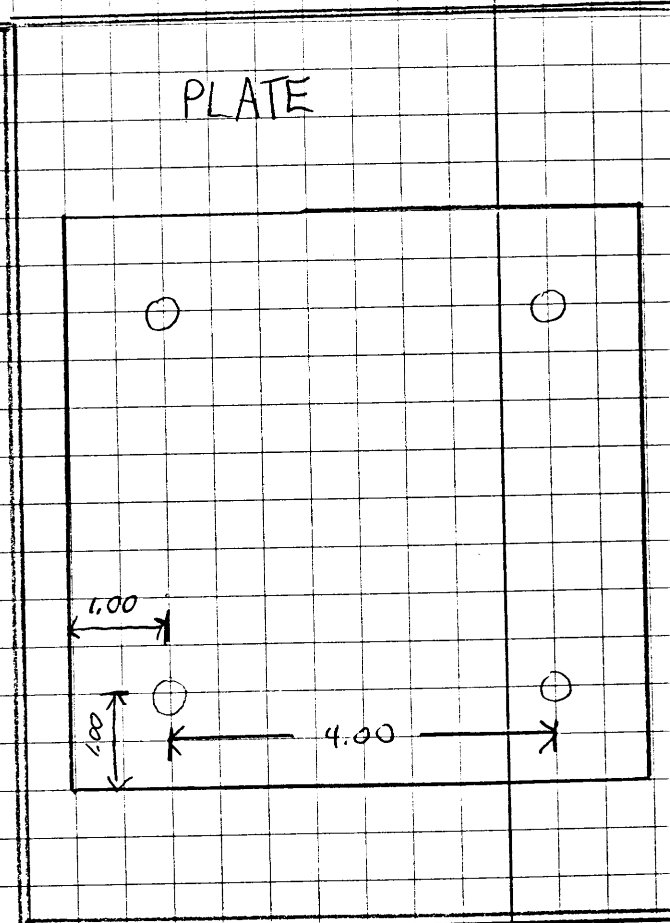
24 JUL 89

units in inches

quantity: 4







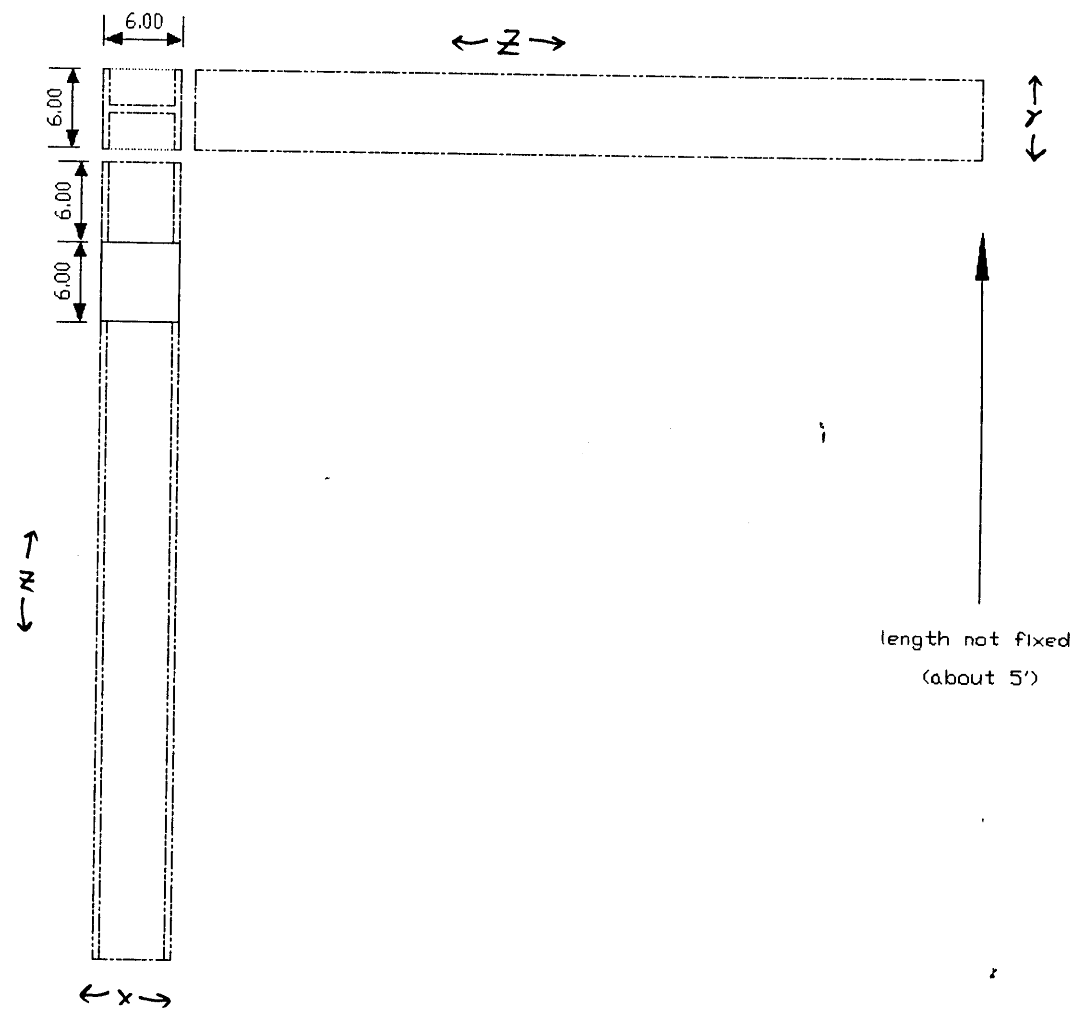
POST1.dwg -- 28JUN89

material:1/2'' Al plate on 6'' H-beam

units: inches

tolerance: 0.01

quantity: 2

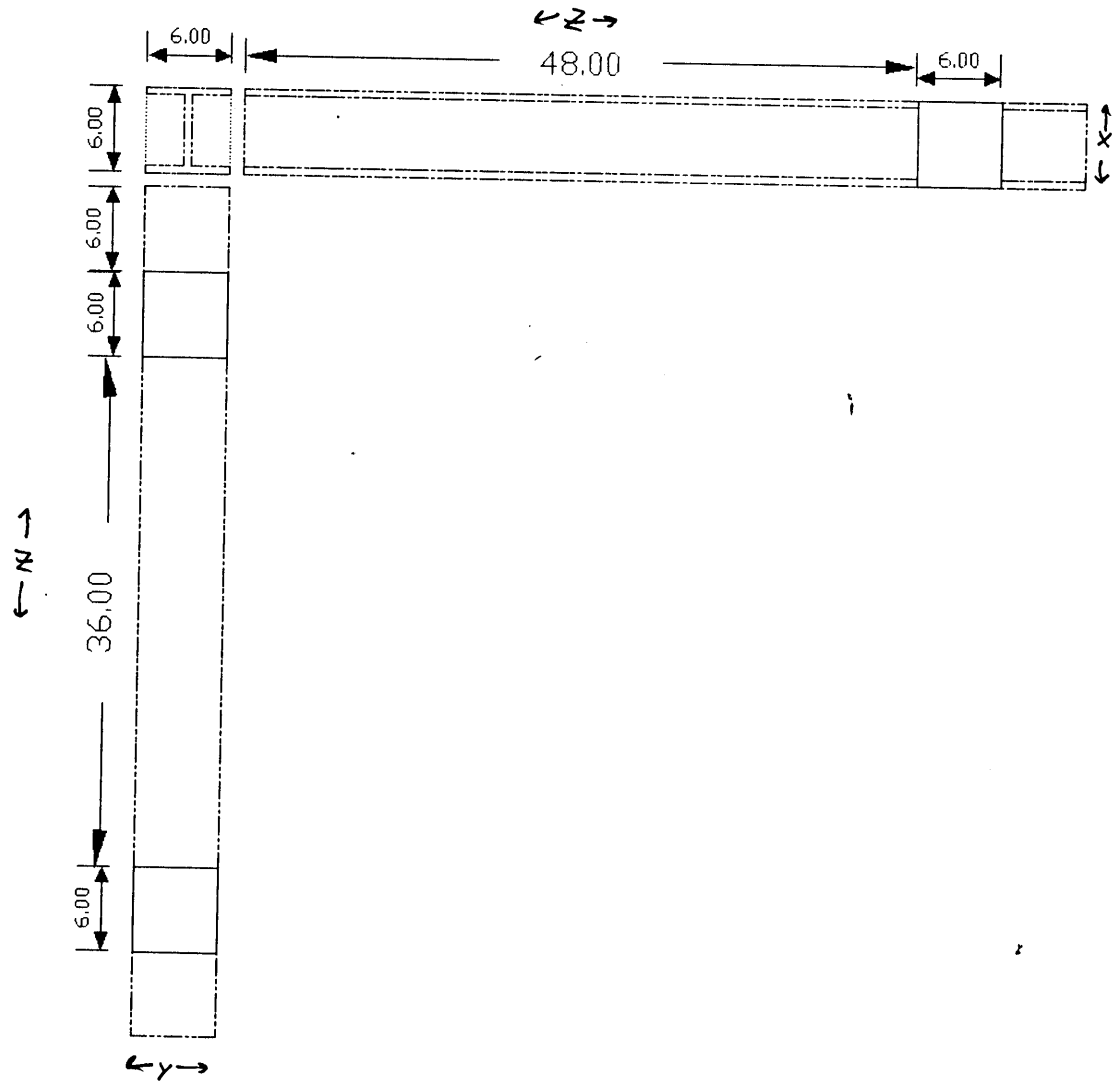


POST2.dwg -- 28JUN89

material: 1/2″ Al plate on 6″ H-beam

units: inches

tolerance: 0.01

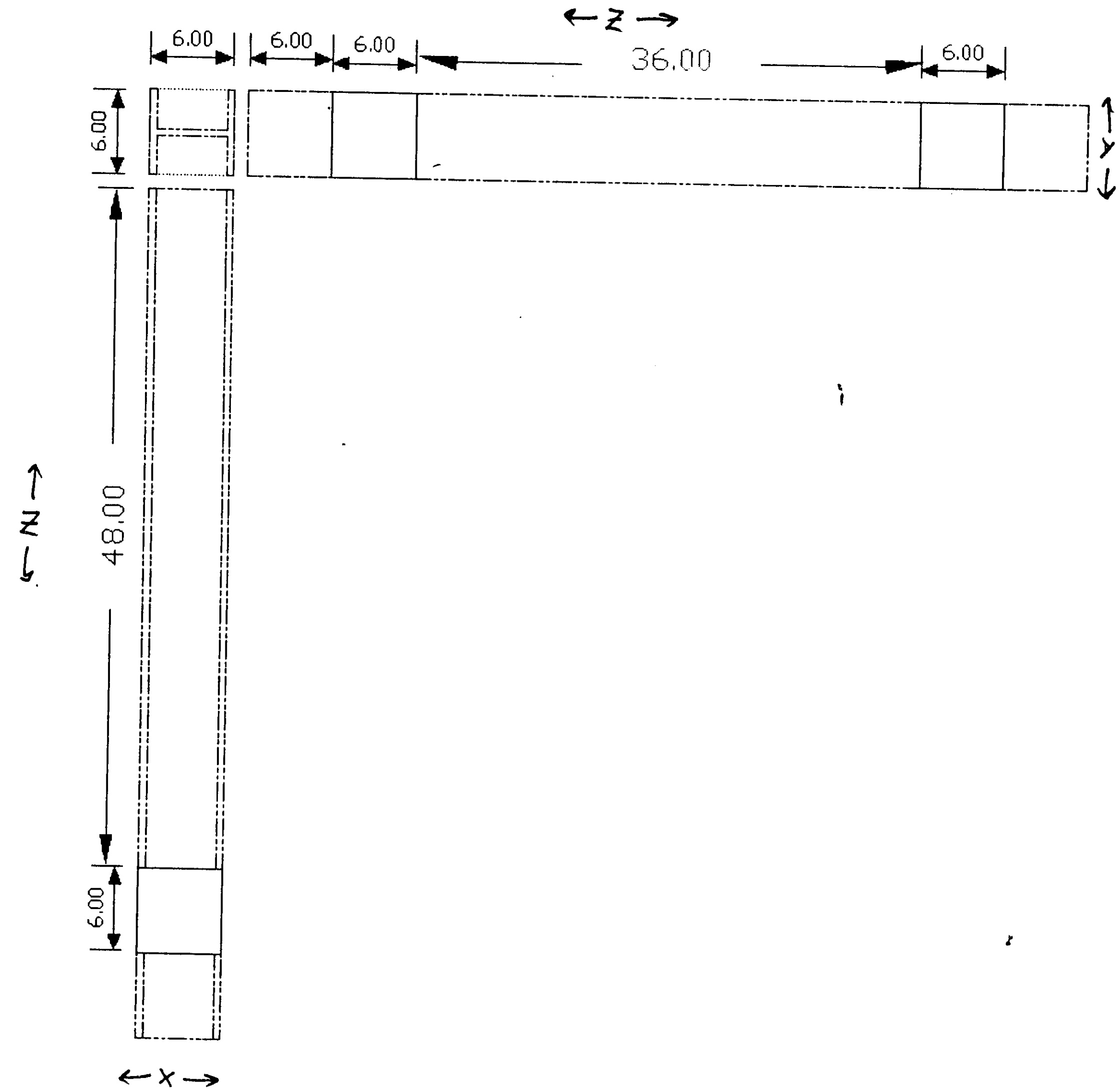


POST3.dwg -- 28JUN89

material:1/2'' Al plate on 6'' H-beam

units: inches

tolerance: 0.01



ROD2.dwg -- 25JUN89

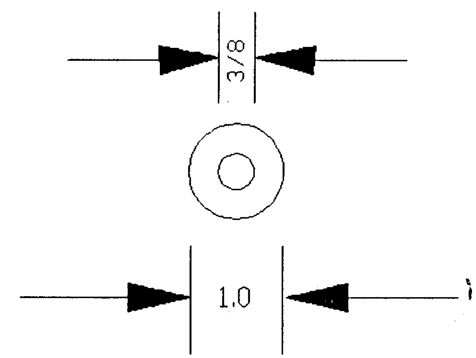
quantity: 28

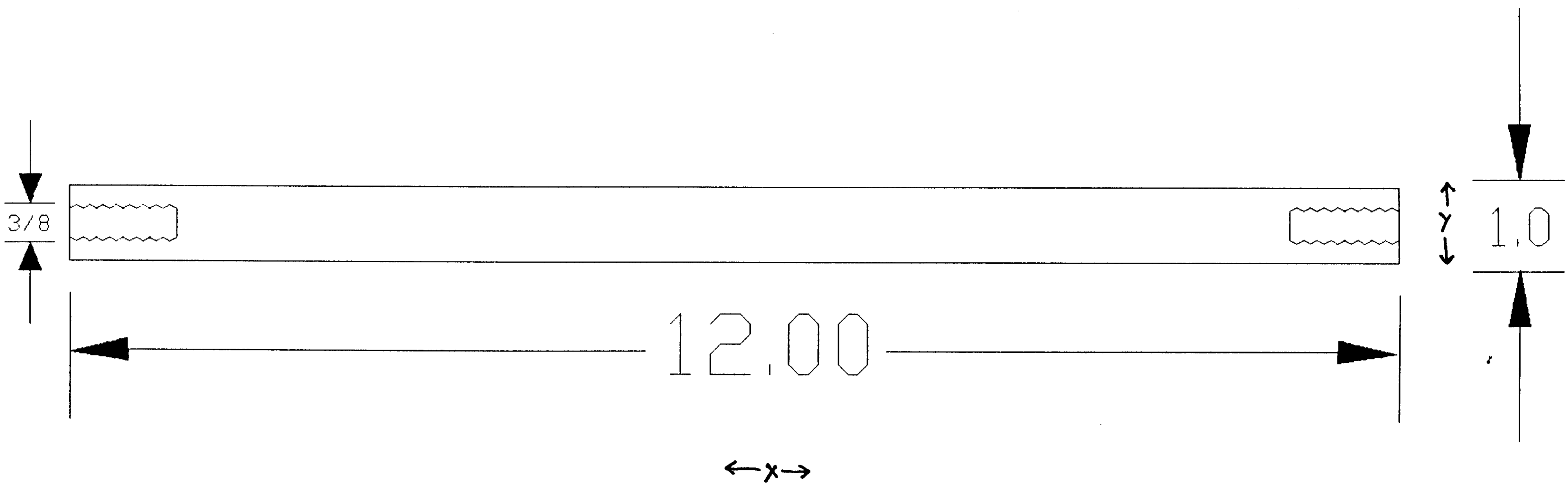
material: 1'' Aluminum rod

units: inches

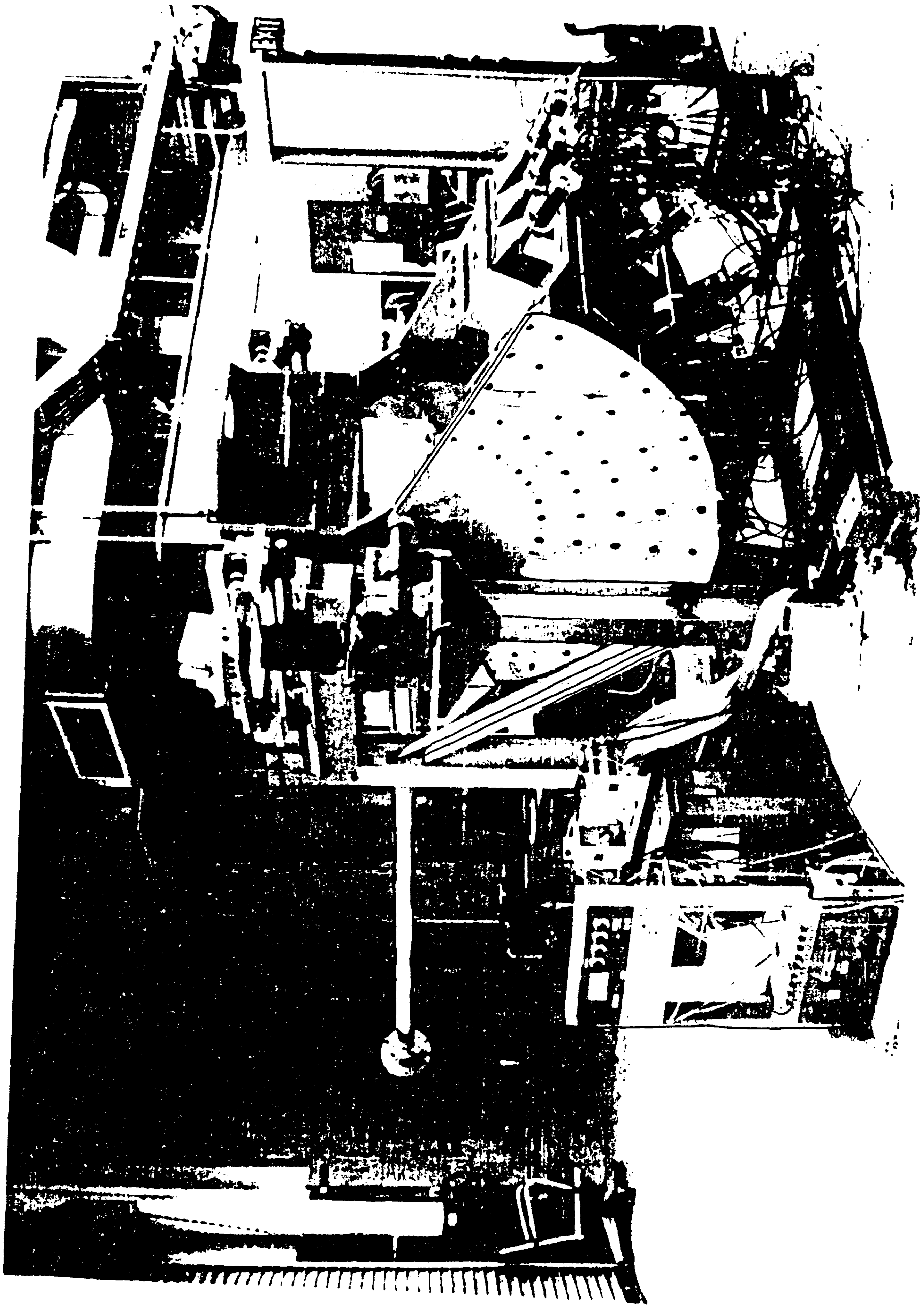
tolerance: 0.01''

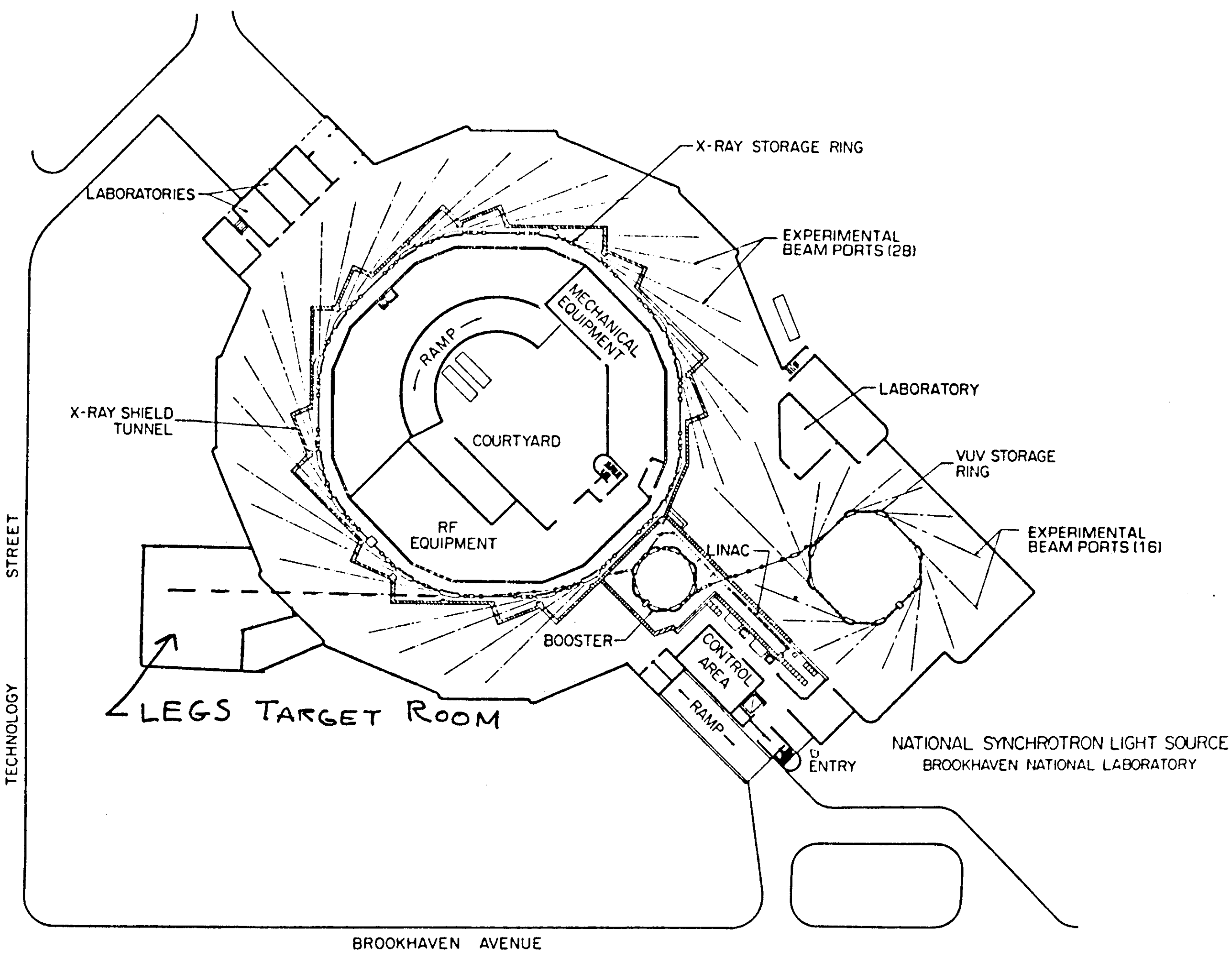
thread: 3/8-16



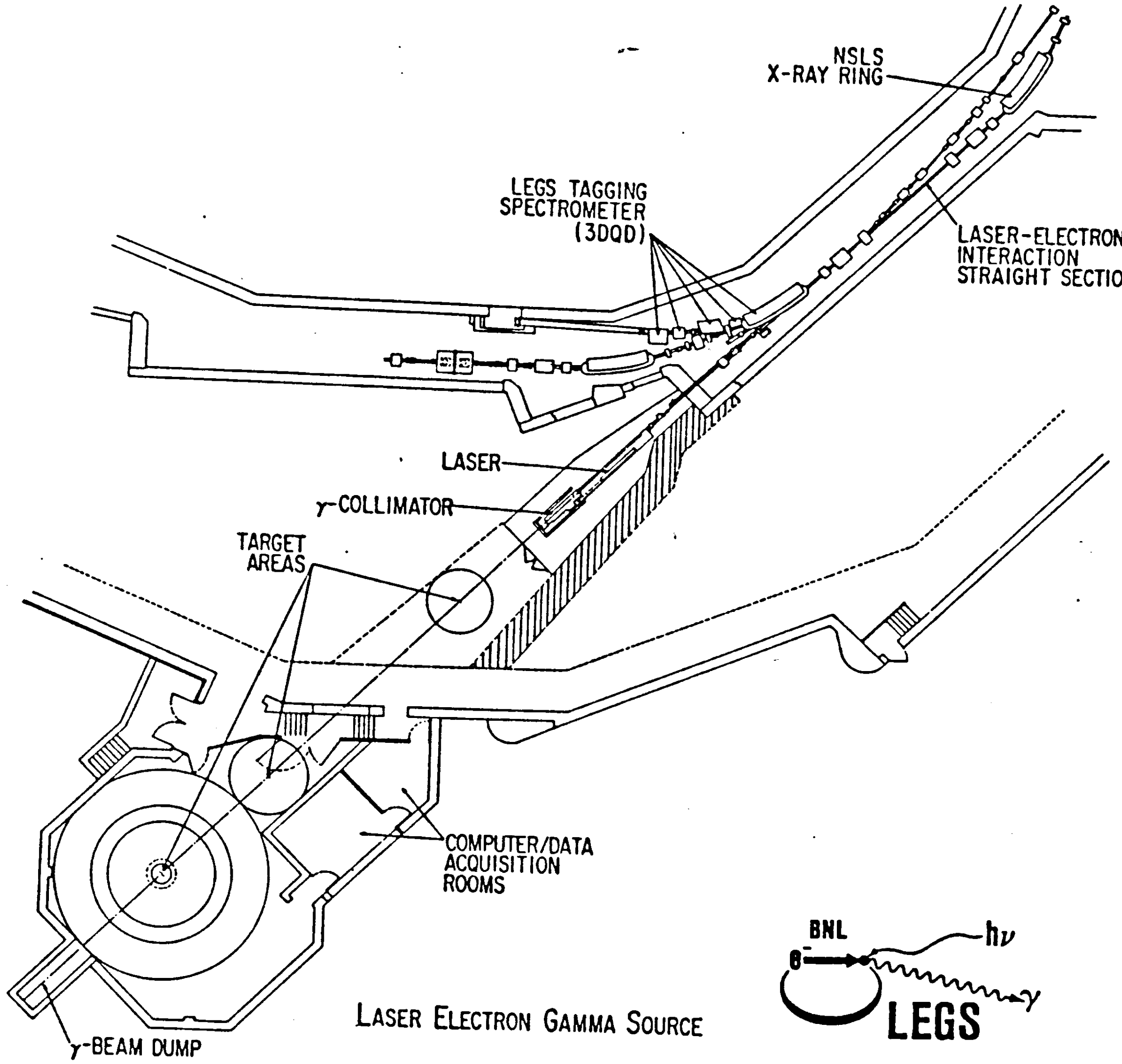


Appendix A





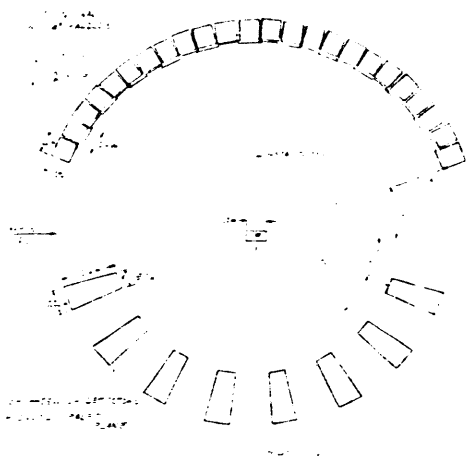
2. Plan view of the NSLS facility from the NSLS 1986 annual report. The new LEGS target room has been added.



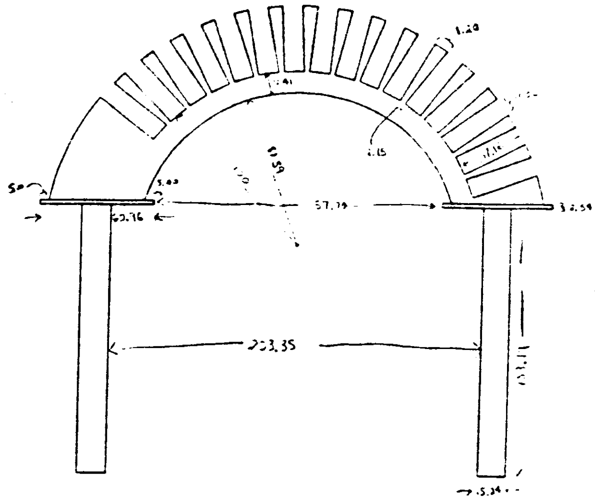
3. Layout of the LEGS facility showing the three target areas and the computer/data acquisition rooms. (From Ref. 3)

Appendix B

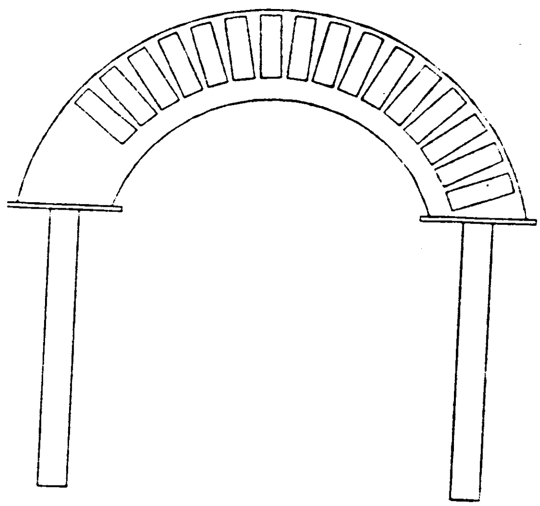
Evolution of the Inner Arcs



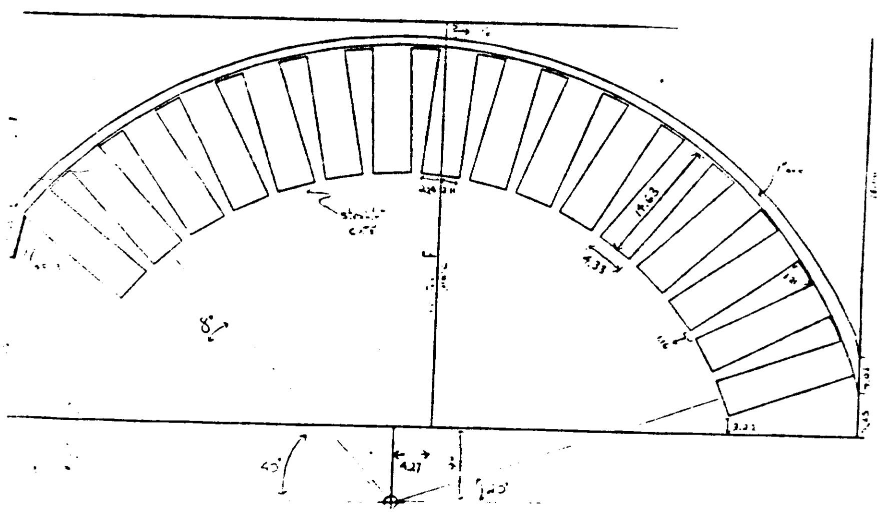
1. Pre-June



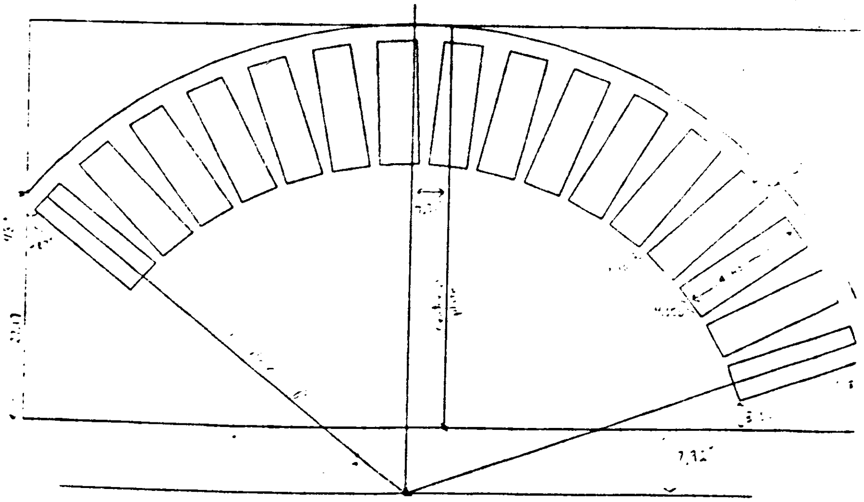
2. June 7th



3. June 11th

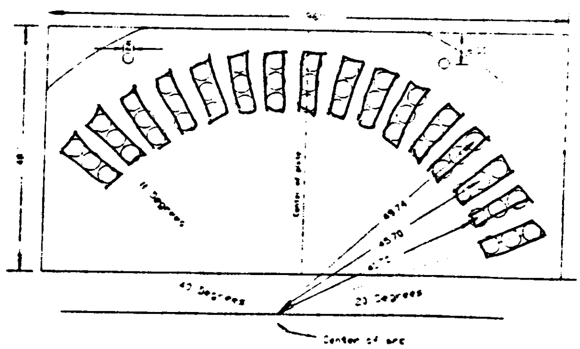


4. June 19th



5. June 20th

NEWout.dwg -



6. July 7th