September 19, 1989

To: R. Drever, R. E. Vogt, Senior Scientists of the MIT LIGO Science Group [Sent to S. Merullo for Distribution]

Subject: The Initial Report of the Caltech 40 m prototype design team.

From: Yekta Gürsel

Design Team: A. Abramovici, Y. Gürsel, F. J. Raab, R. Spero, M. Zucker

The following is a collection of the initial concepts proposed for the upgrade of the Caltech 40 m prototype.

I included all copies circulated among the design group to give an idea about the evolution of the concepts.

This may also inspire new concepts branching from the earlier versions which may lead to better solutions of the problems encountered in the design.

Each document is presented in its original form and it is preceded by a page of text describing the role of the subsystem in the total design.

The documents are presented in the following order:

(a) Introduction:
A description of three different ways of upgrading the Caltech 40 m prototype.
By: Yekta Gürsel

(b) 40 m Prototype Design Decisions
By: F. J. Raab

(c) Aperture Maps for Beam Tubes
By: F. J. Raab

(d) The Test Mass Chamber Conceptual Design
By: Yekta Gürsel

(e) The Combined Central Test Mass and The Beam Splitter Chamber Conceptual Design
By: Yekta Gürsel

(f) Preliminary Design Sketch for the Advanced 40 m System Input/Output Vacuum Enclosure
By: Alex Abramovici.

(g) The Seperated Beam Splitter Chamber Conceptual Design.
[This is to be completed by Mike Zucker]

Introduction

Yekta Gürsel
Sept. 19, 1989

In our design effort we considered <u>three</u> different ways of upgrading the present 40 m prototype facility at Caltech. These are:

(i) Keep the 18" diameter tanks and the 8" diameter pipe. Simply add more tanks and more sections of pipe as needed. This concept is illustrated in Figure 1 which is based on a drawing made by R. Drever.

(ii) Enlarge the beam tube diameter and introduce large chambers for the test masses and the beam splitter optics. Use the 8" diameter pipe and 18" diameter tanks for the Input and the Output Optical Chains. This concept is illustrated in Figure 2.

(iii) Enlarge the pipe diameter and introduce large chambers for the test masses at the end of the arms. Combine the central test mass and the beam splitter chambers as well as a part of the Input/output chain into a very large chamber. This concept is illustrated in Figure 3.

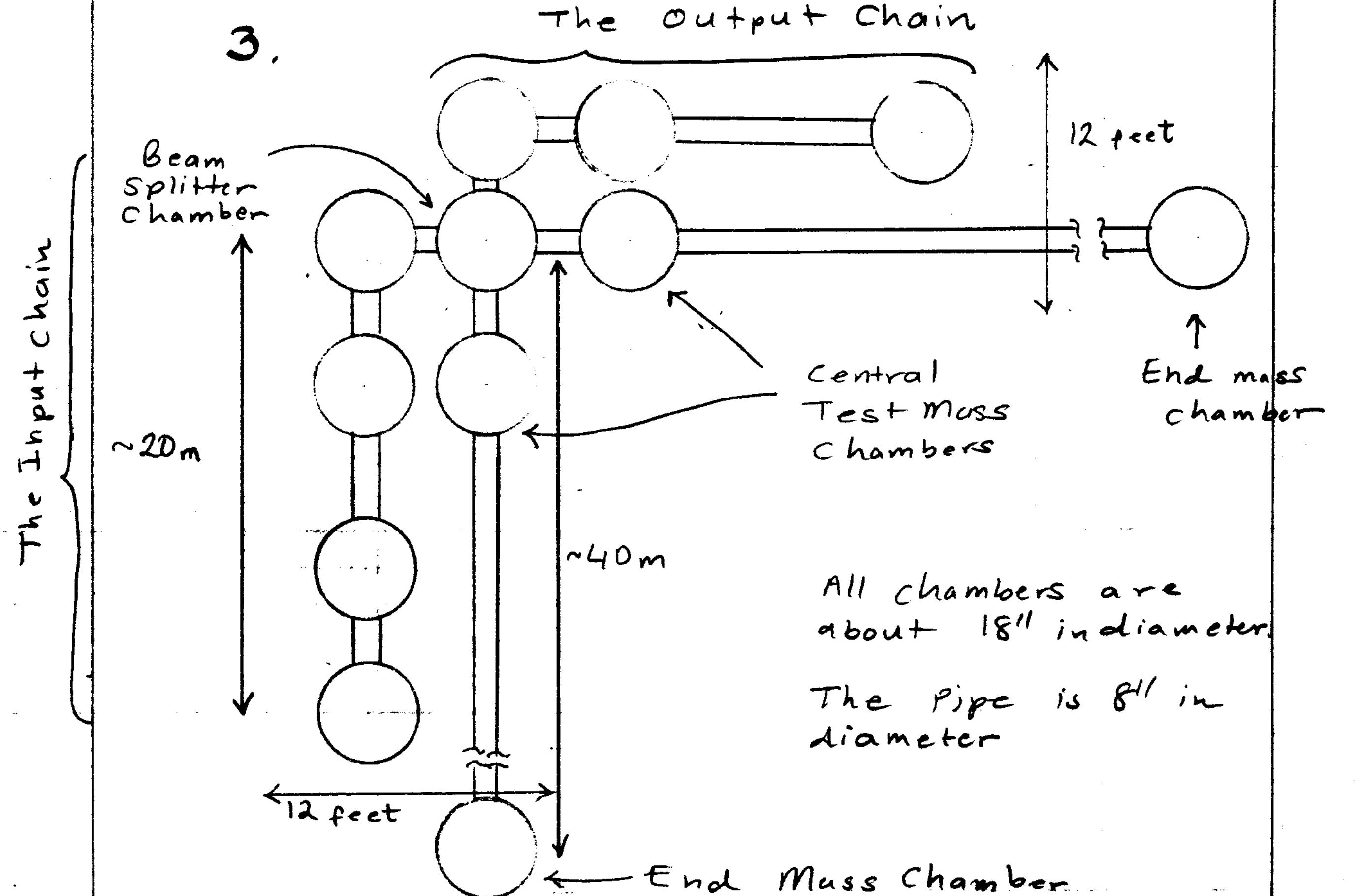


Fig 1. Small Diameter Tanks Concept

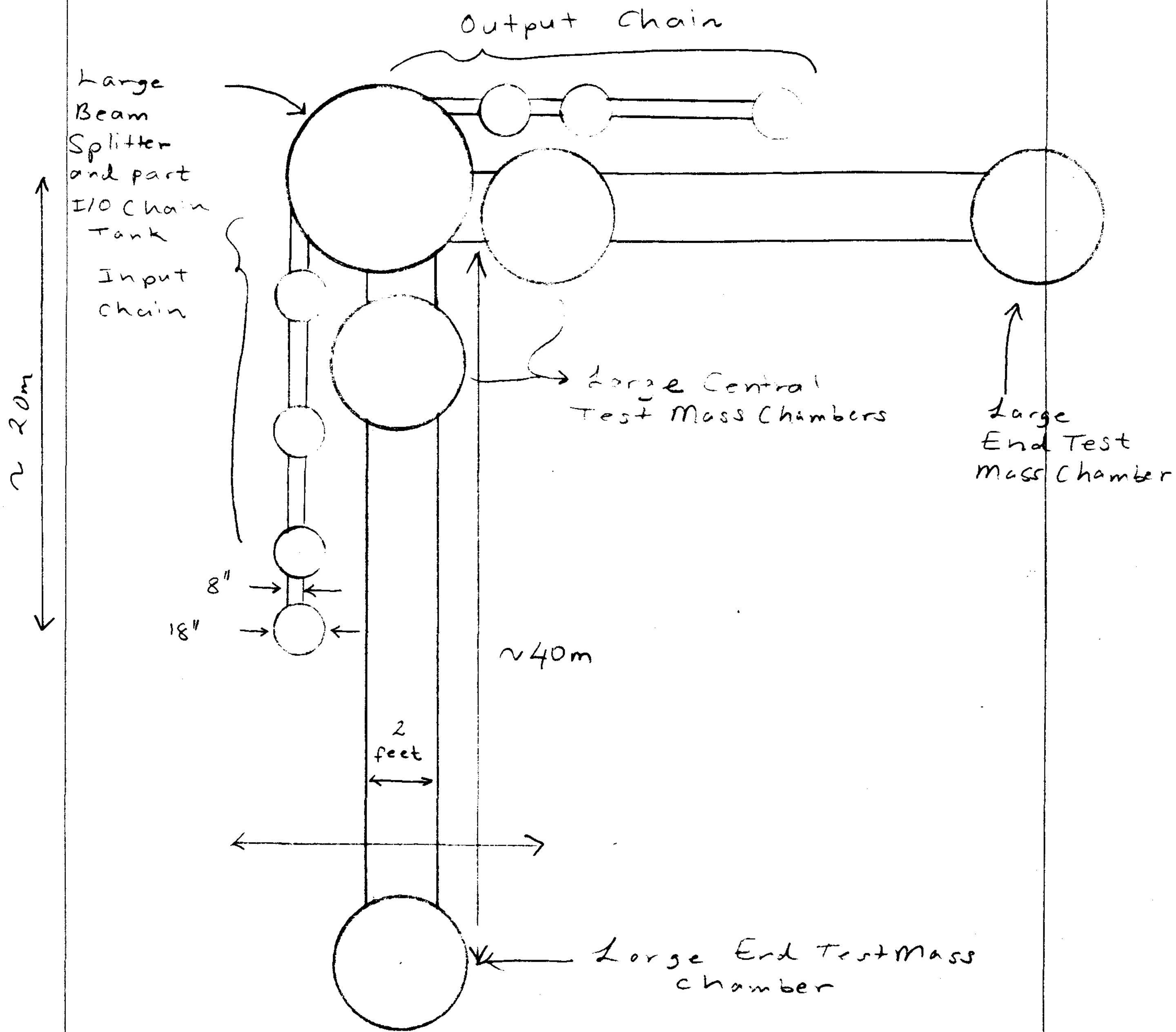


Fig 2. Large Seperate Test Mass and the Beam Splitter tanks Concept

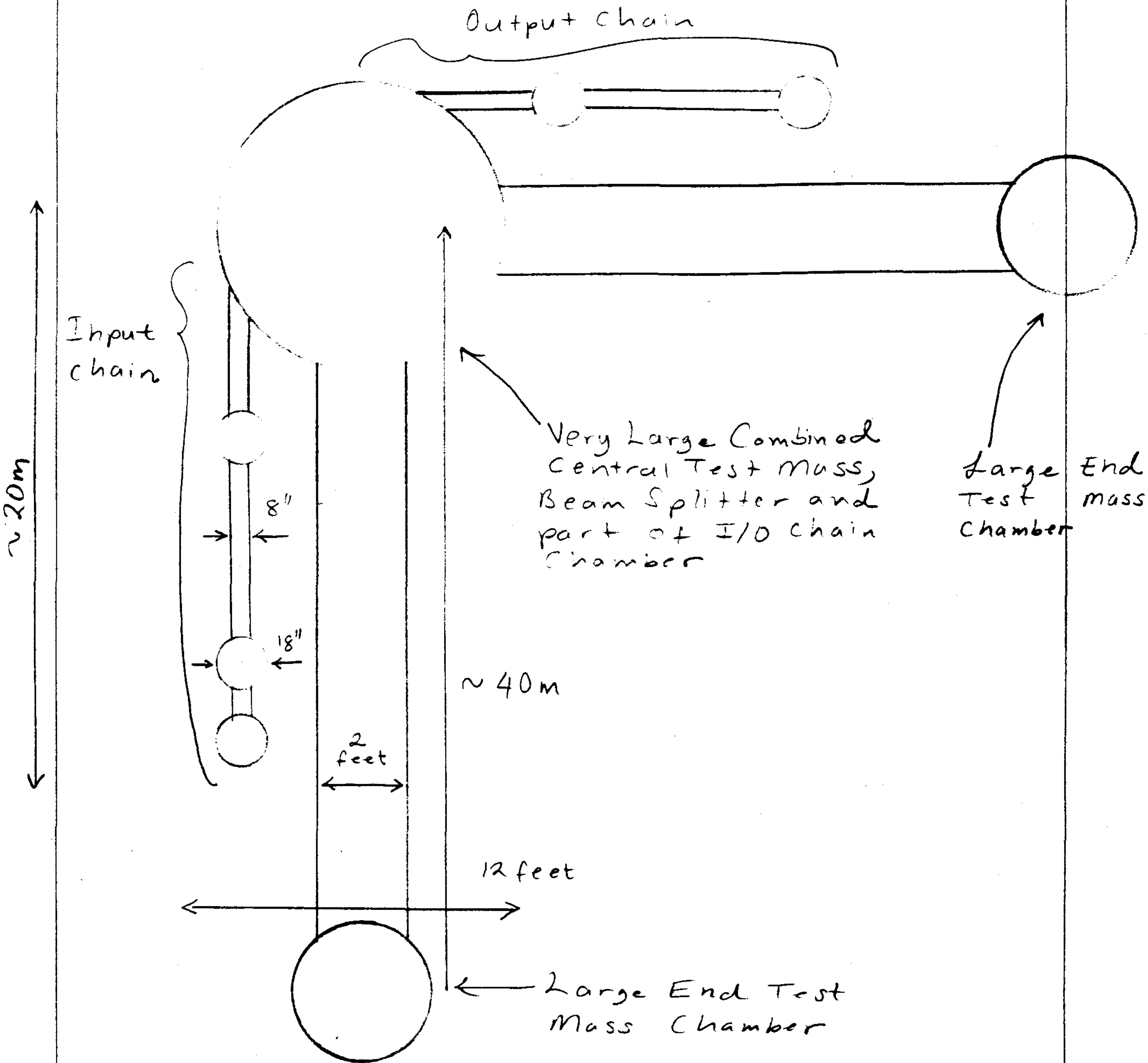


Fig 3. Very Large Combined Beam Splitter and central test Mass Chamber and Large End Test mass chambers Concept.

The following is the document titled "40 m Prototype Design Decisions" by F. J. Raab.

These decisions evolved as we produced the initial drawings for the 40 m prototype upgrade.

A Note about item 3 in the section General Vacuum Decisions:

Although we specified no slings for tube support and recommended floor jacks for anchoring the tube to the floor; the slings supply one important (in California) safety feature: They supply adequate earthquake protection by letting the tube swing. We forgot to discuss this in our meetings; we will discuss it in our future meetings.

40 m Prototype design decisions

FJR 18 Sept 89

Beam tube

- adopt 10" ø x 7" L test mass to be accomodated
  (2 x mass of initial LIGO test masses)

- require global pointing beam zones (input/output) in clear aperture to be on a test mass diameter

- require 2" ø beam zone for suspension pt interferometer

- require 3" ø beam zone for main interferometer beam

- require 1" annular free zone to allow for tube sag
  " 1/2" " " " " " " " baffles

⇒ Tube ø = 20" minimum
24" desired

Test Mass Chambers

- design for 24" tube ø
- design for 4 post tower on square pattern for stability

- require tower posts not to restrict tube aperture

⇒ 42" ø minimum
48" ø desired for thicker tower posts

Pressure spec's

- Required pumping speed to achieve 10^{-2} T in 1-2 hrs after pumping initiation

- Achievable ultimate pressure

Gas	Minimum	Desirable
N_2	3×10^{-6} T	6.5×10^{-10} T
H_2	4×10^{-5} T	10^{-8} T
H_2O	4×10^{-6} T	10^{-9}

Min — To demonstrate same noise equivalent displacement as required in initial LIGO

Desired – To reach quantum limit for 10 kg mass (eliminate residual gas noise entirely).

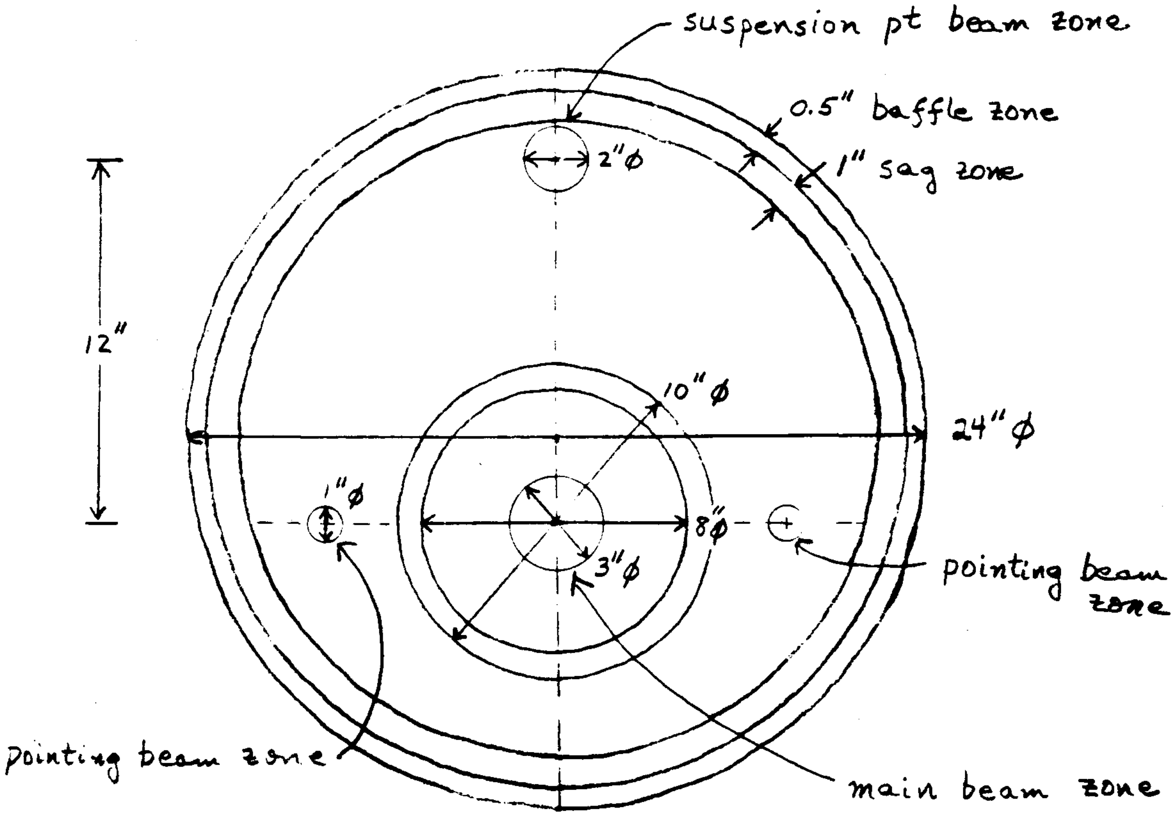
General vacuum decisions

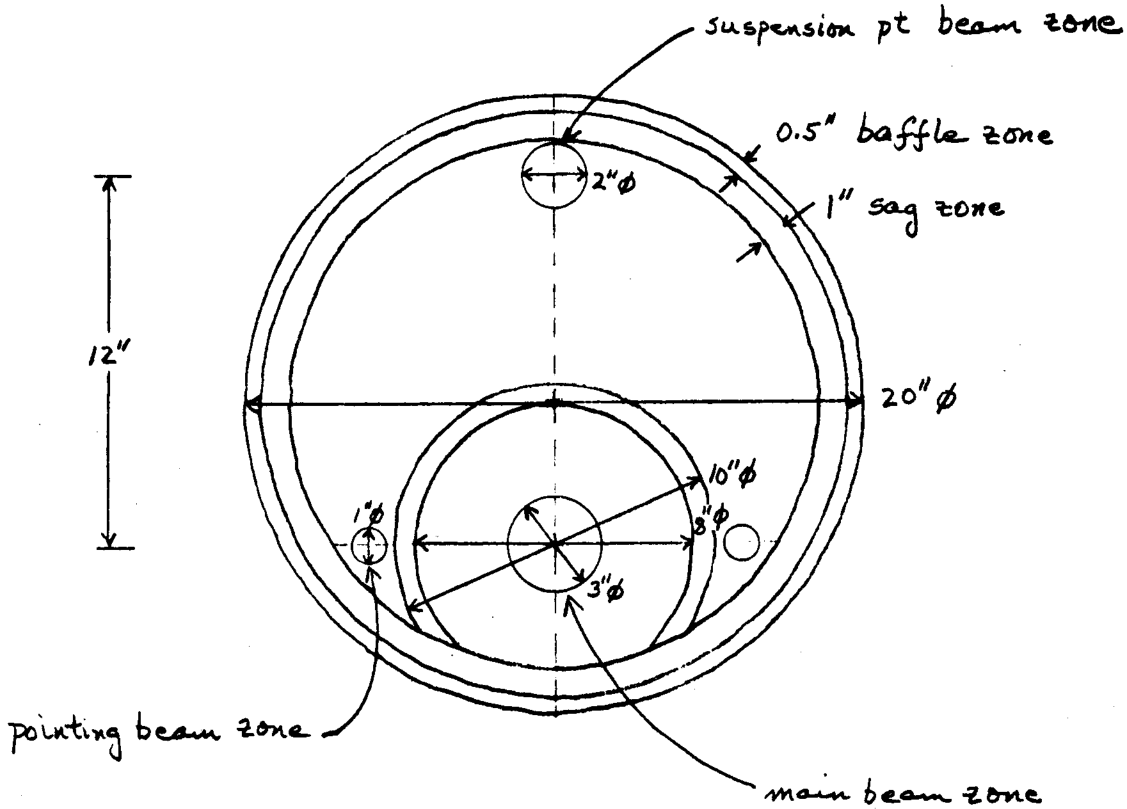
- No gate valves on main tubes; use nipples next to test mass chambers as gate valve placeholders
- No compensated bellows
- No slings for tube support; use floor jacks

The following is the Document titled "Aperture Maps for Beam Tubes" by F. J. Raab.

We considered 3 different large tube apertures: 24", 20" and 18".

If we use the 8" tube we have, a seperate suspension point interferometer tube has to be maintained. We have this system (vacuum) already installed. However such a system will be somewhat short of tube aperture. This is a problem we currently are dealing with. The only reasonable solution seems to be to replace the main beam tube with a larger diameter tube.


suspension pt beam zone
0.5" baffle zone
1" sag zone
2"ϕ
12"
10"ϕ
24"ϕ
1"ϕ
8"ϕ
3"ϕ
pointing beam zone
pointing beam zone
main beam zone


suspension pt beam zone
0.5" baffle zone
1" sag zone
2"ϕ
12"
20"ϕ
10"ϕ
8"ϕ
1"ϕ
3"ϕ
pointing beam zone
main beam zone

Aperture map for 18" beam tube ; Scale : 1" = 0' 6"

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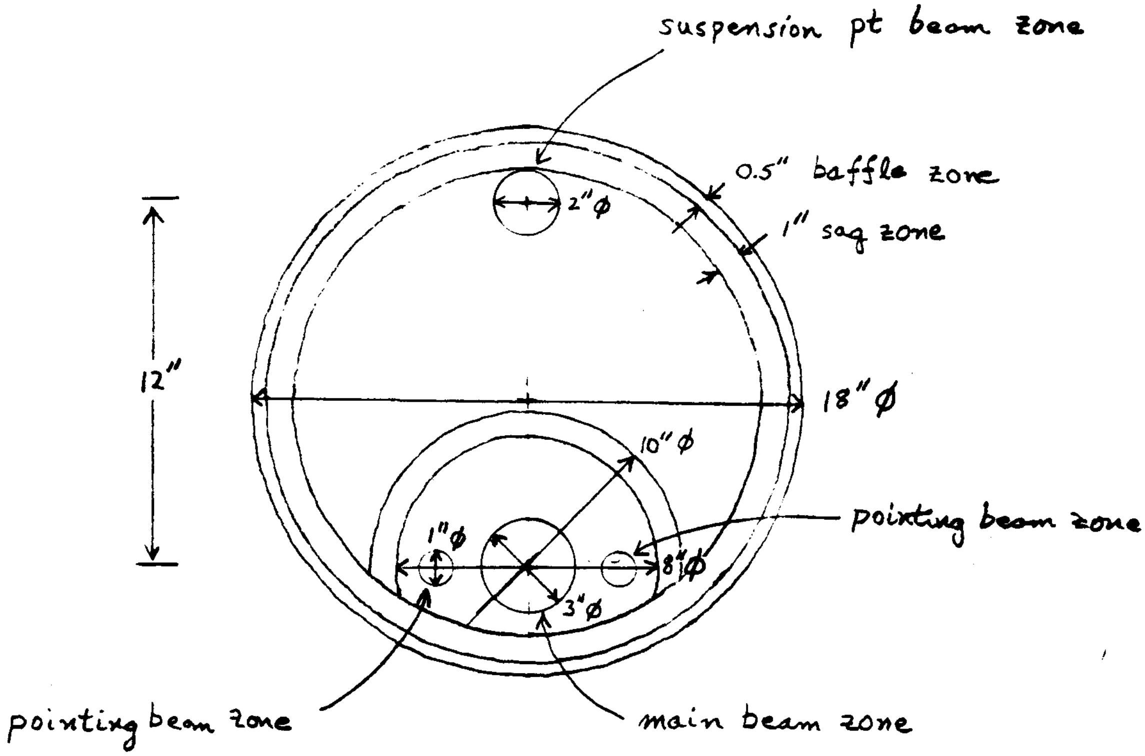


The following is the document titled " Test Mass Chamber Conceptual Design" by Yekta Gürsel.

The chambers are drawn for central test mass chambers; however the design can be adapted to end test mass chambers by eliminating one of the large ports. For each given diameter of pipe, the <u>minimal</u> tank which can accomodate the pipe and the required auxiliary structures. For sturdier support structures (the tower) a slightly larger tank diameter can be used. The design rules which are followed are:

(a) For a given pipe size, <u>no</u> auxiliary structure in the tank should obstruct the clear pipe aperture.

(b) The test masses should be removable through all major ports.

(c) The stack support poles (the tower) should be of sufficient thickness and should be equally spaced in the tank.

(d) The <u>prime</u> area in the tank (the area between the support posts) should be a square whose side is equal in length to the pipe diameter.

(e) The test masses are taken to be 10″ diameter cylinders with a height of 7″. A Guard Mass whose size is equal to the test mass is included. (for electrostatic drives, etc...)

(f) There is only one test mass per chamber.

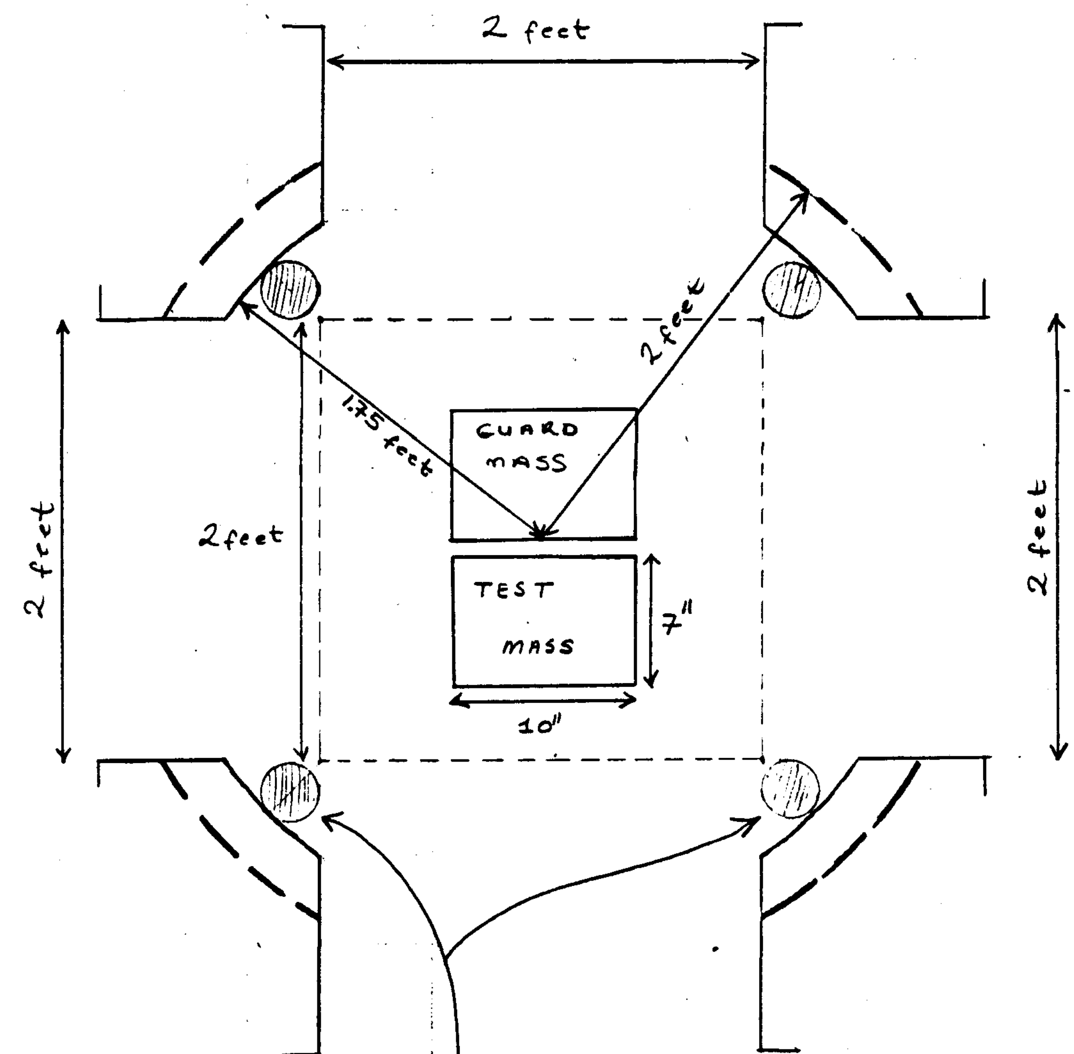
After considering these designs we decided that a 24″ pipe diameter and the corresponding tank concept with a 3.5 feet diameter chamber is desirable. Note that these are initial designs; the details of the internal structure may be different. (the tower, the stacks).

(1) YB

Test Mass Chamber Concept

2 feet diameter pipe

↓ Laser Beam Line



3" diameter Posts to support the upper suspension stack

Proposed tank diameter = 3.5 feet

Scale:

10" actual = 1" on the drawing

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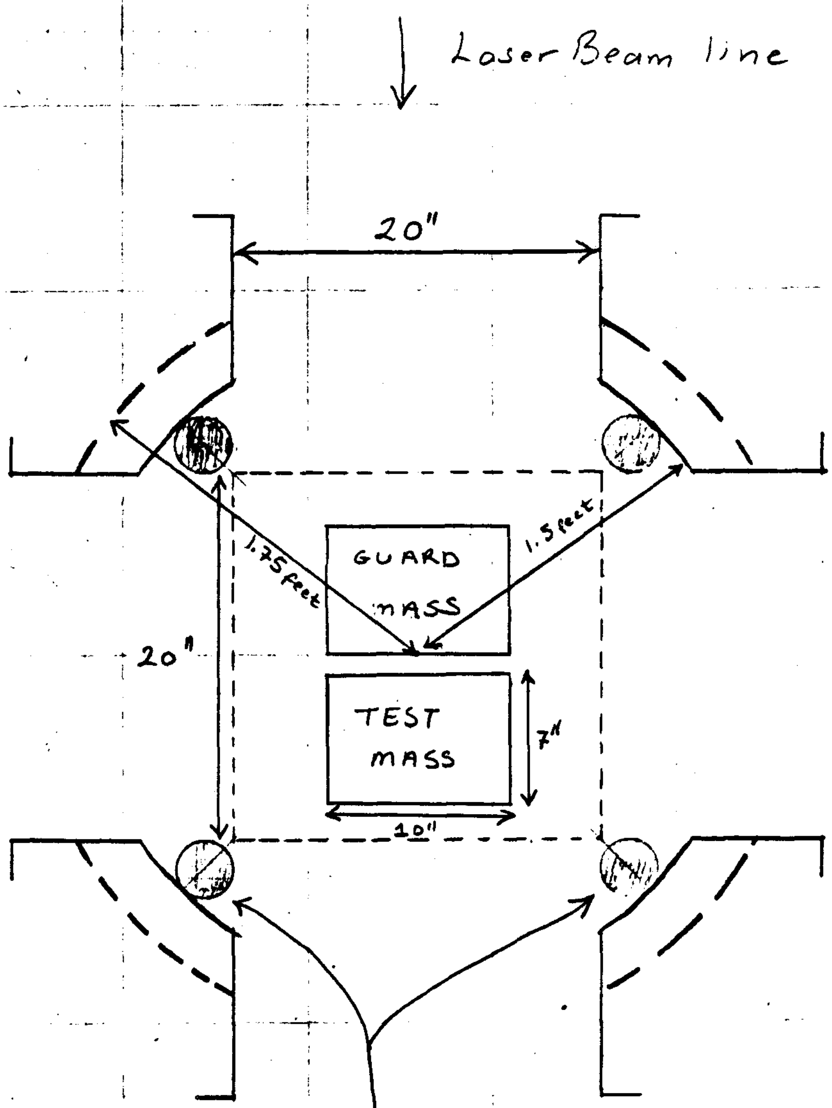
YG

Test Mass Chamber Concept

20" diameter Pipe



3" diameter posts to support the upper suspension stack

Proposed tank diameter = 3 feet

Scale:

10" actual = 1" on the drawing

(3)

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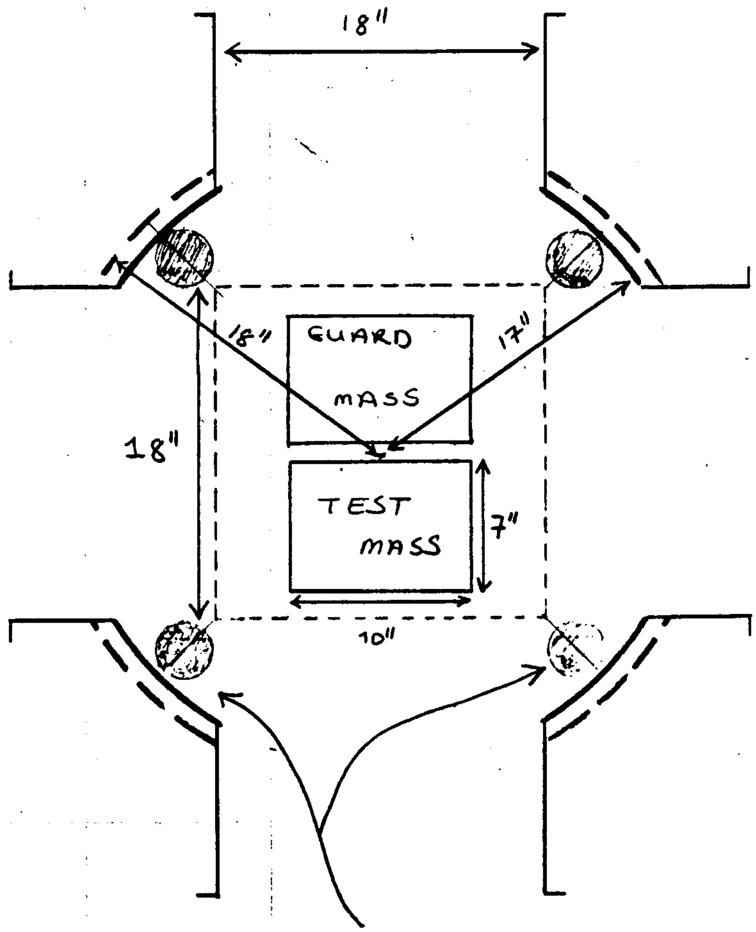
JC

Test Mass Chamber Concept

18" diameter Pipe

↓ Laser Beam Line



3" diameter Posts
to support the upper
suspension stack

Proposed tank
diameter = 34"

Scale:

10" actual =
1" on the drawing

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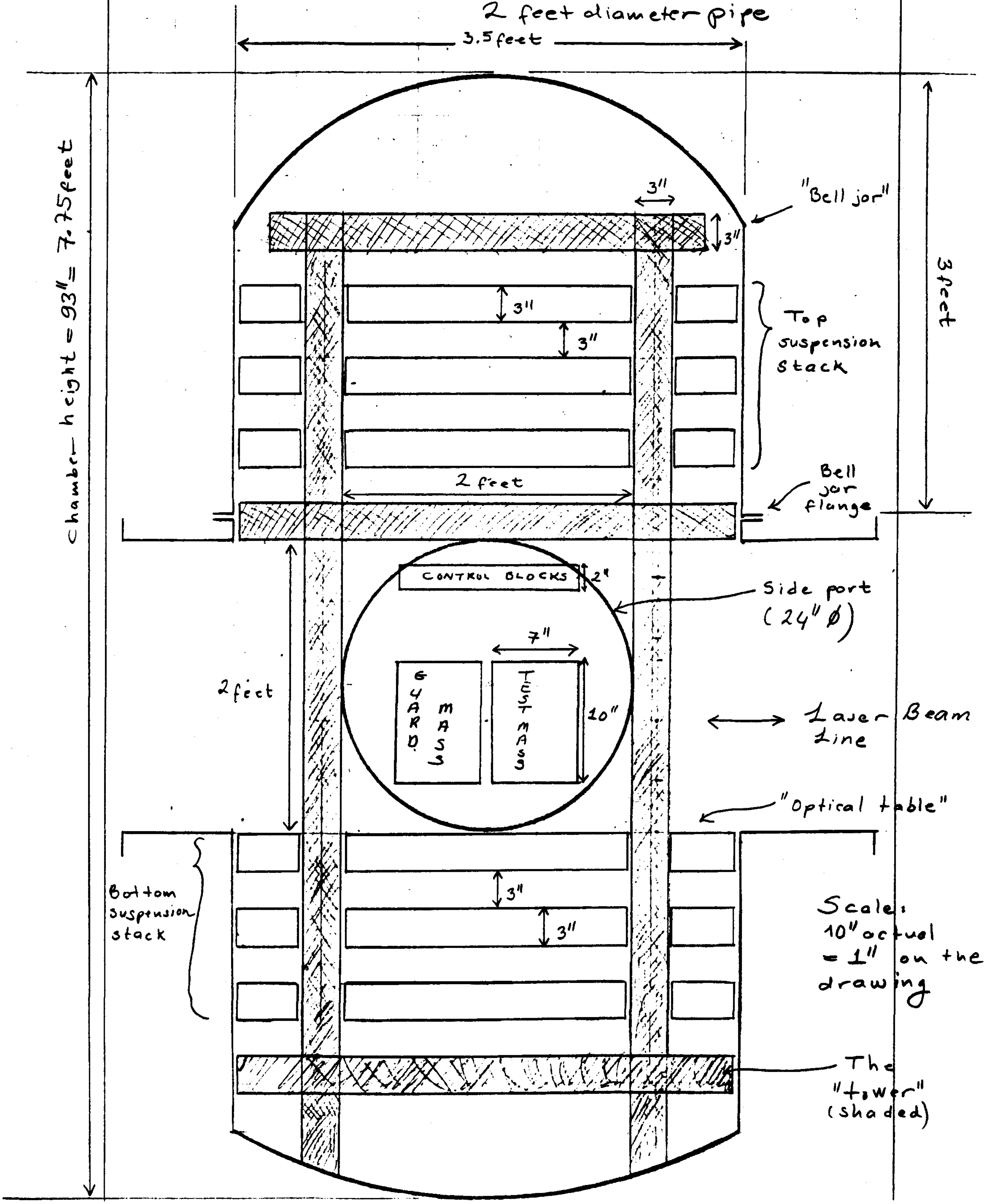
YG

(4)

Test Mass Chamber Concept
Vertical Cross section
2 feet diameter pipe



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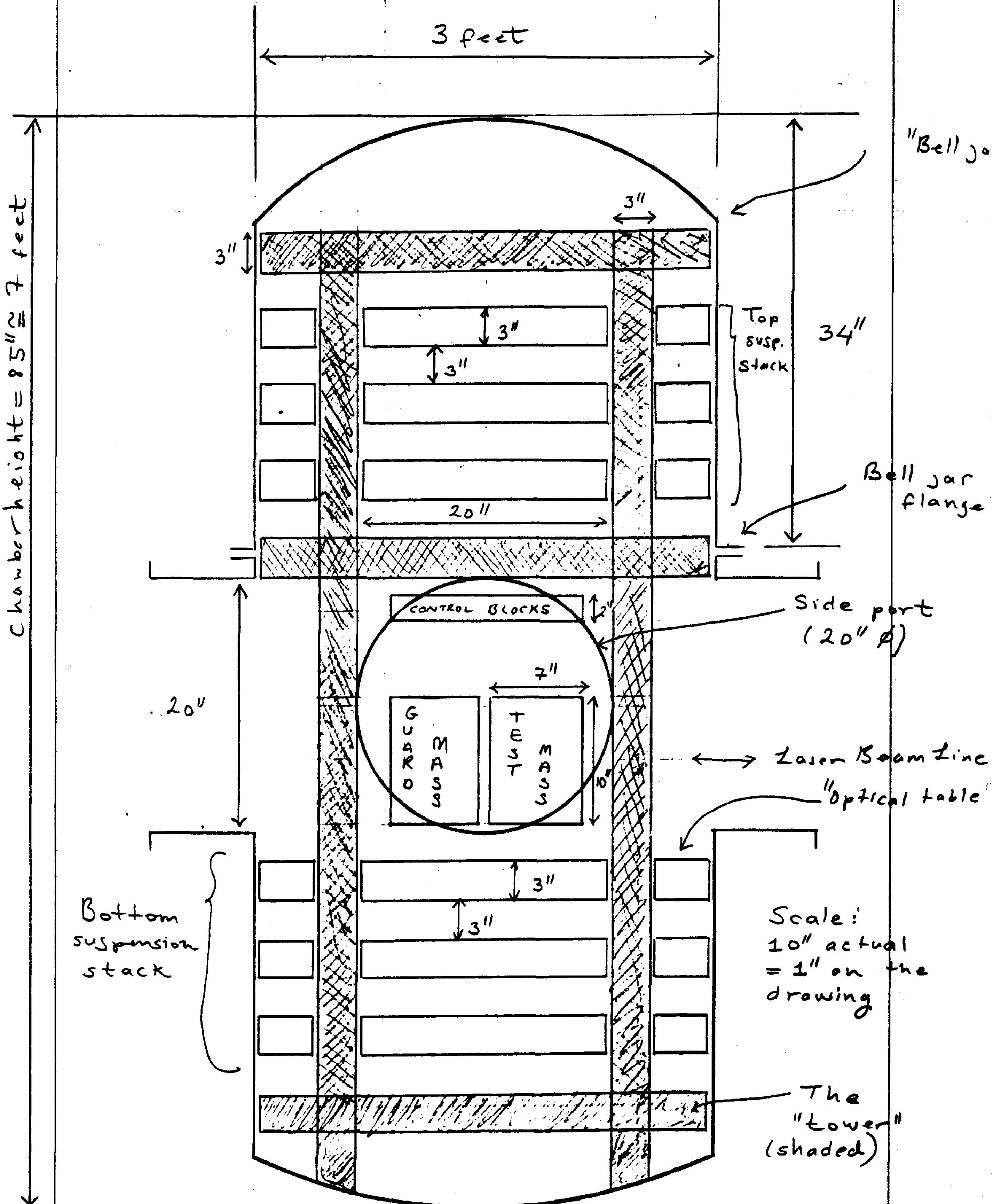
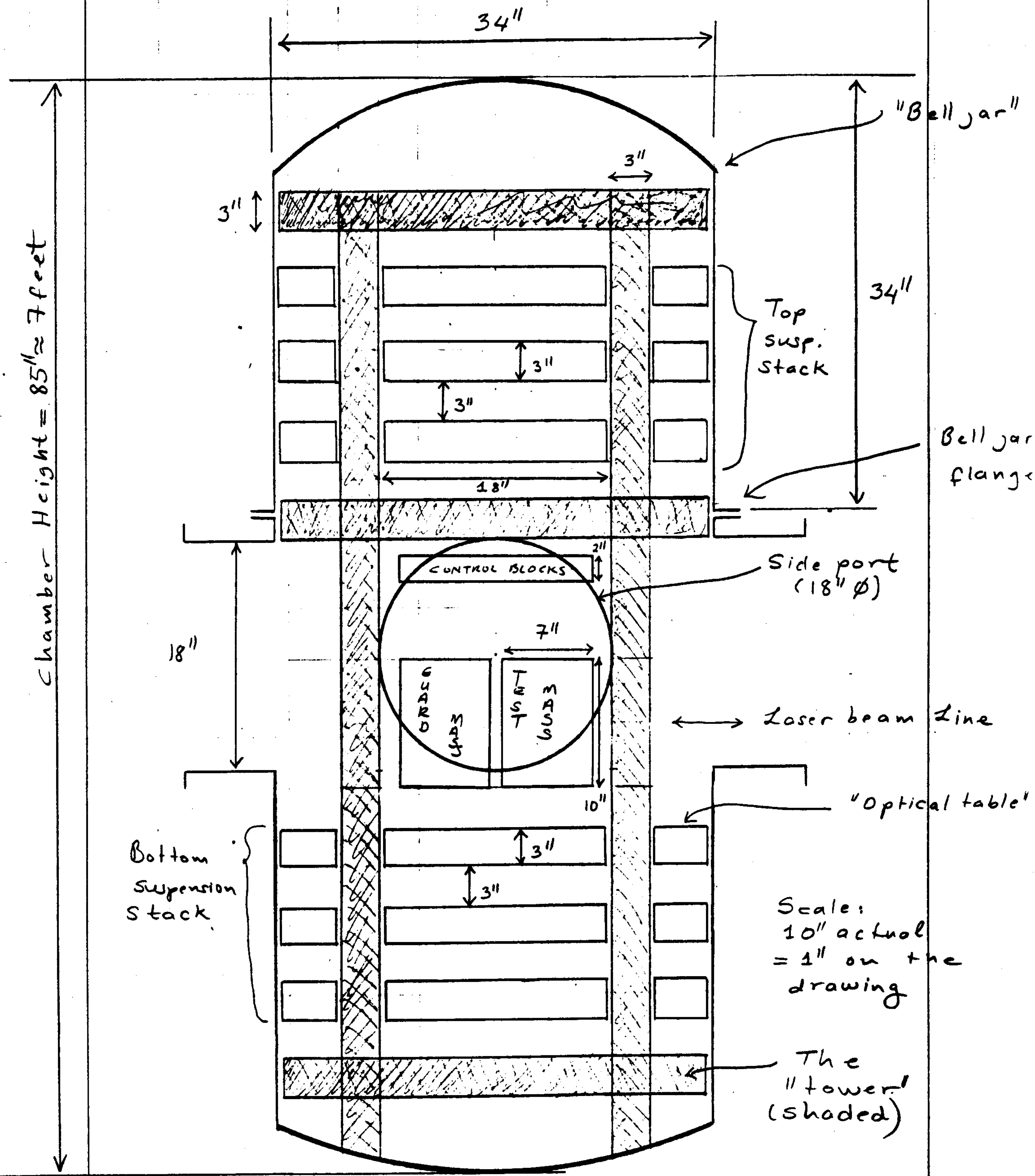
YB

Test Mass Chamber Concept
Vertical Cross-section
20" diameter pipe



September 15, 1989

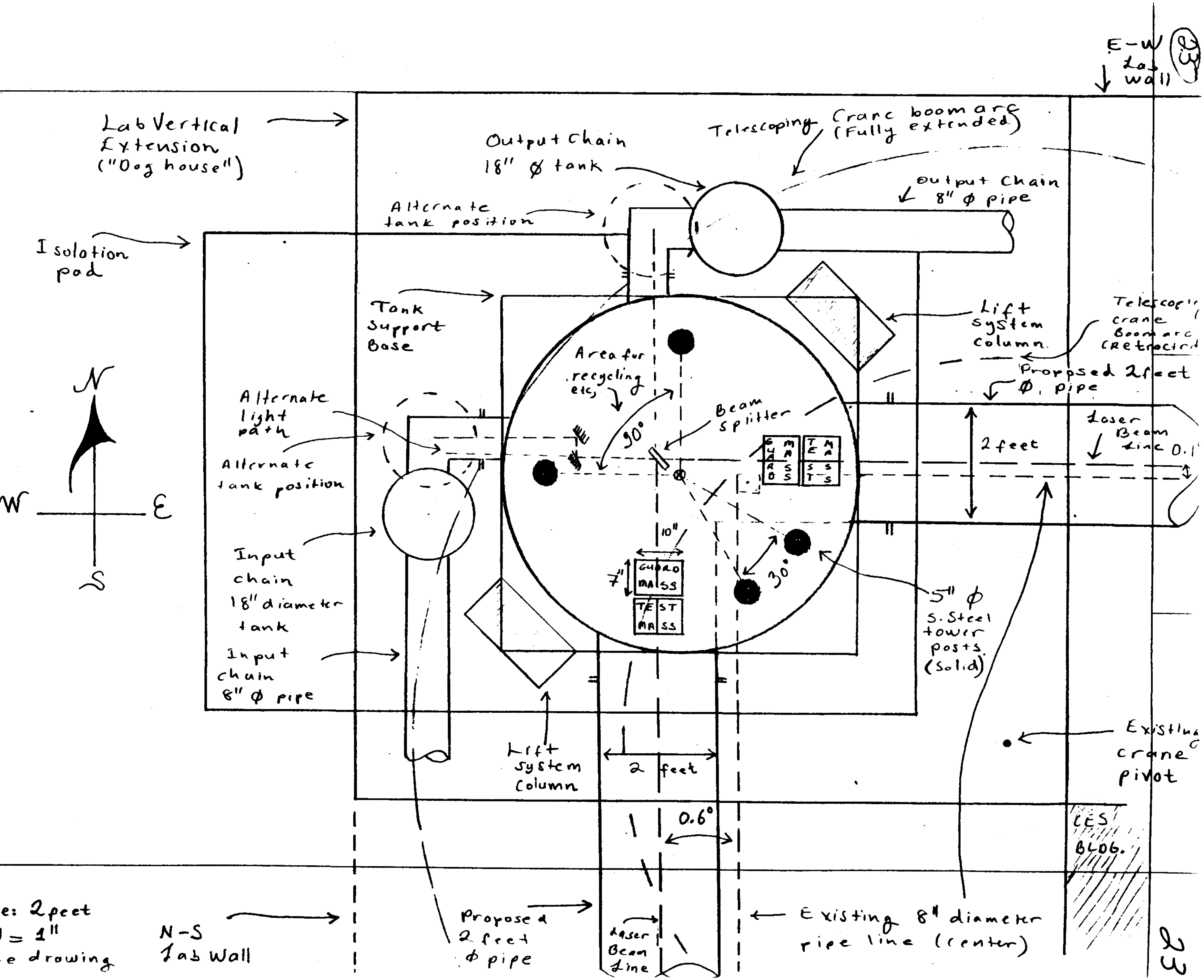
Test Mass Chamber Concept
Vertical Cross-section
18" diameter pipe



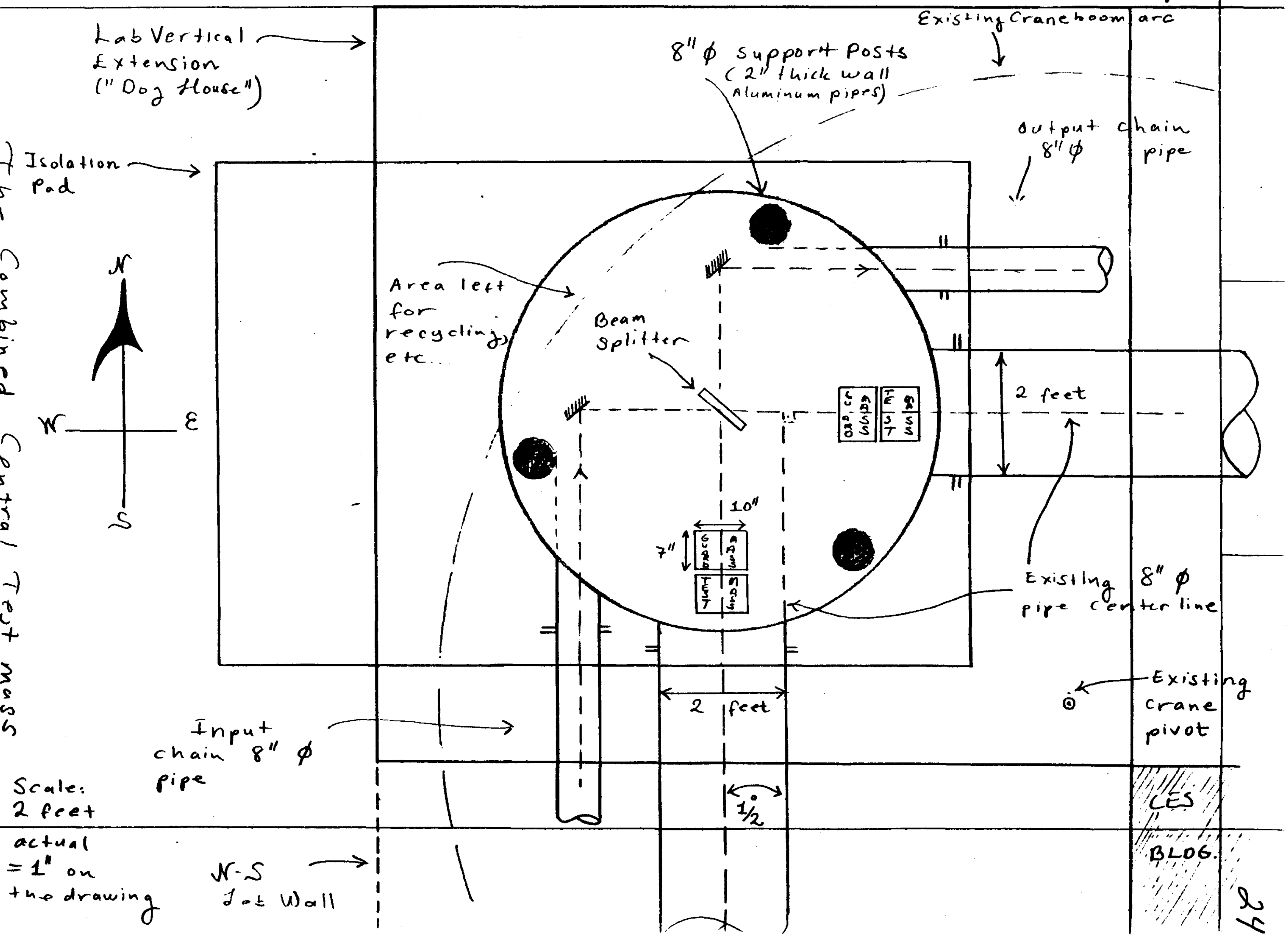
The following is the document titled " The Combined Central Test Mass and The Beam Splitter Chamber Conceptual Design" by Yekta Gürsel.

These drawings show the configuration of the central area of the interferometer for the upgrade concept described in Fig. 3. In one case, the old 6 ft Space Simulator tank was used as the central combined chamber. We have this tank in our possession; but it needs further machining work to be done on it. In the other case; a MIT compatible, 7 feet in diameter tank is used as the central combined tank.

The Combined Central Test mass and the Beam Splitter tank Concept using the old 6 ft Space Simulator Tank Sept 18, 1989



The Combined Central Test Mass and the Beam Splitter tank Concept Using a 7-ft MIT centrl chamber compatible Tank September 18, 1989



The following is the document titled "Preliminary Design Sketch for the Advanced 40m System Input/output Vacuum Enclosure" by Alex Abramovici.

This document shows the details of the design for the input/output optical chains shown in Figures 1, 2 and 3.

Some of the chambers in this design may be "absorbed" into the larger chambers described in Figures 2 and 3.

Note that the enlarged drawings are spread over multiple pages. [Ⓐ, Ⓑ, Ⓒ and Ⓓ]

13-Sep-87

Alex
pg. 26

Preliminary Design Sketch for the
Advanced 40m System
Input/Output Vacuum Enclosure

Assumptions

- Input power: 5 W

- Component clear apertures: 5 mm

- Components: not suspended – if suspensions will be found necessary, we will add tanks.

If one found that the components have to be suspended, one can place all components within one tank on a single, rigid, rail. which would then be suspended. This would allow to accomodate a suspended version of the optical chain within the same tanks (and same number of tanks), provided one would replace the flat lids with bell jarr like tops.

- Results: • Small tank count: 21

  • Length: ▸ ~ 20 m for input optics
  ▸ ~ 16 m for output optics

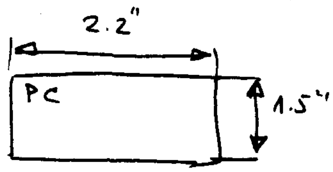
1. Vacuum tank diameter : 18"

2. Mounting platform diameter : 16"

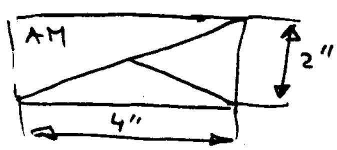
3. Component spacing: 1"

4. Component sizes:

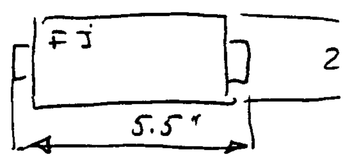
PC • Pockels cell



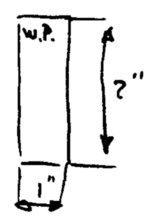
AM • Amplitude modulator:



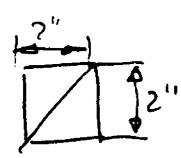
FI • Faraday Isolator:
(complete w. polarizers)



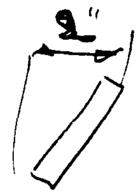
WP • Wave plates (mounted)



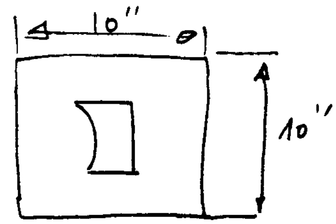
P • Polarizers
(mounted)



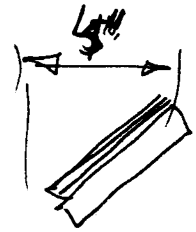
P.O. • Pick-offs (mounted)



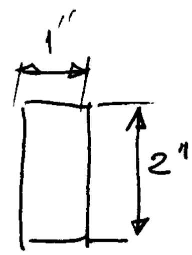
M • Mode cleaner mirrors (suspended)



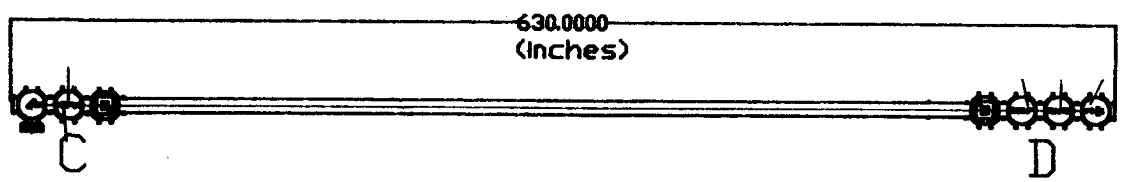
SM • Beam steering mirrors (mounted)



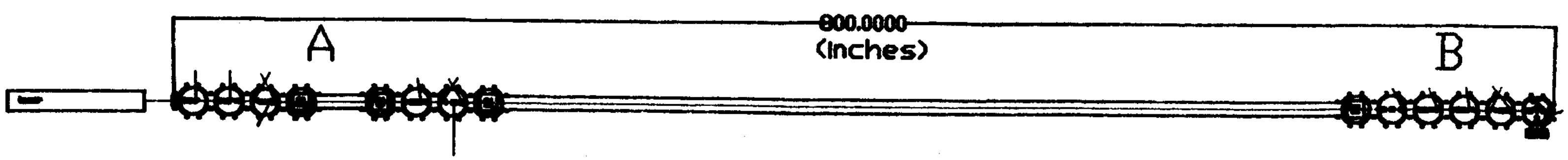
L • Lenses (mounted)

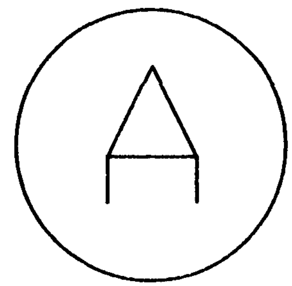


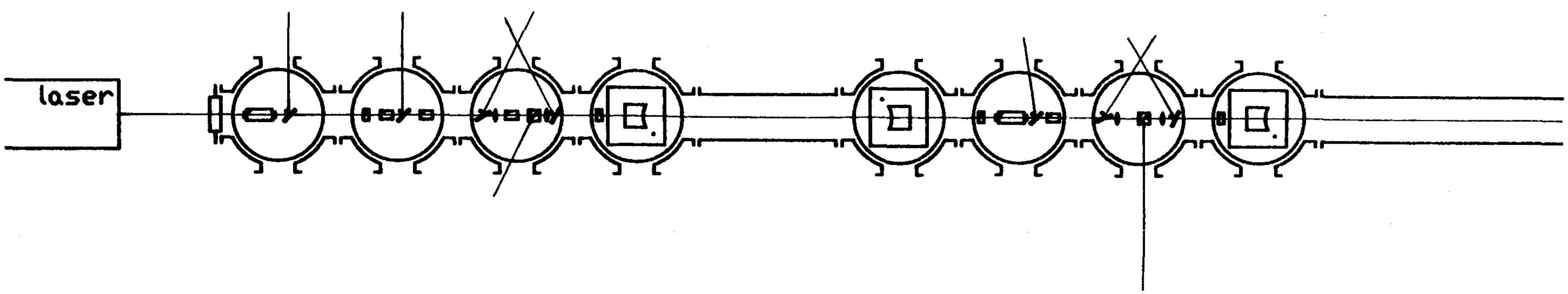
Vacuum enclosure for output optics



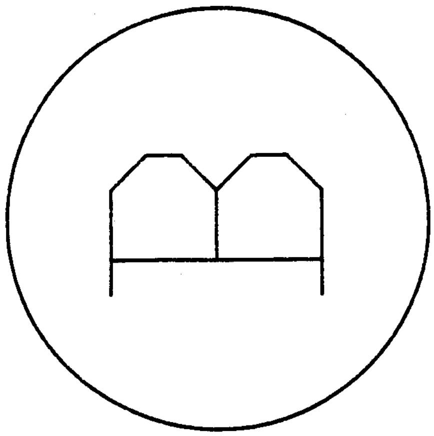
Vacuum enclosure for input optics

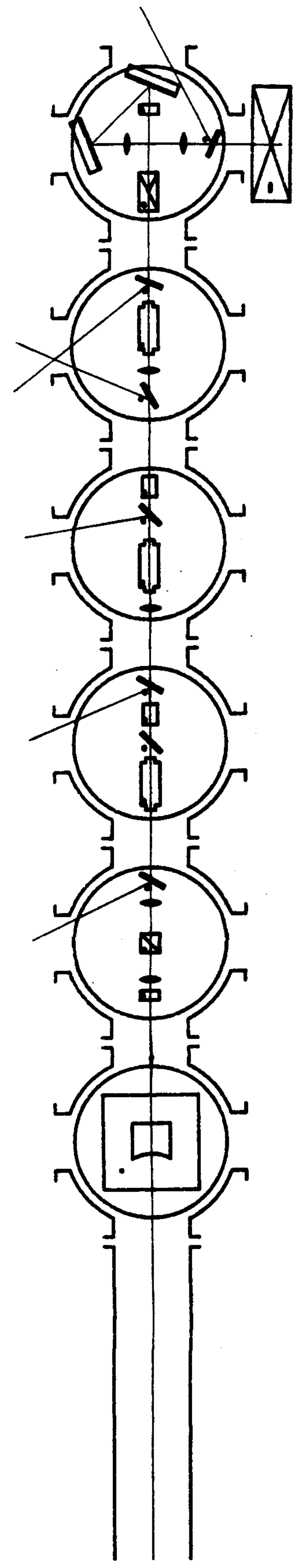


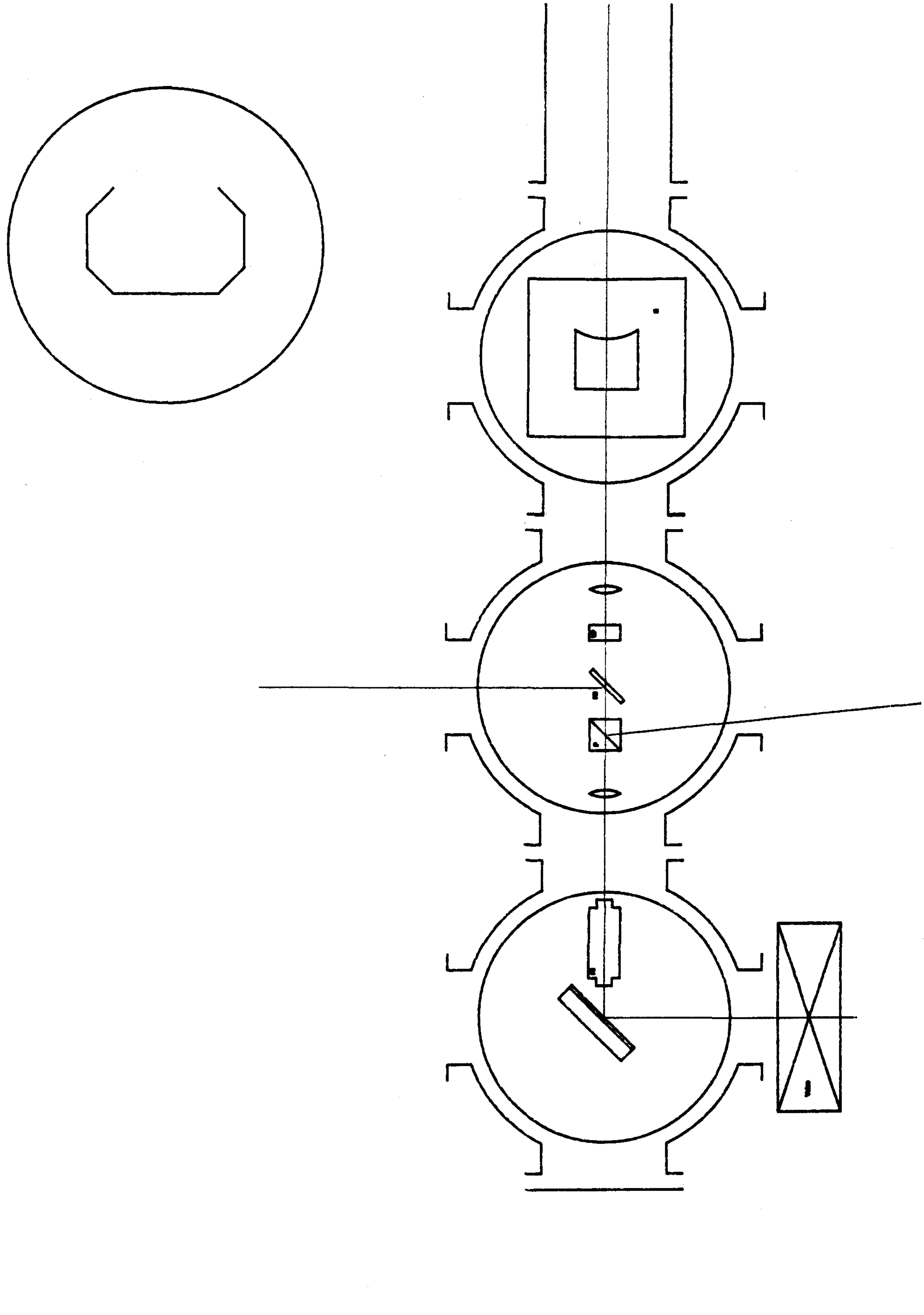



laser

32.







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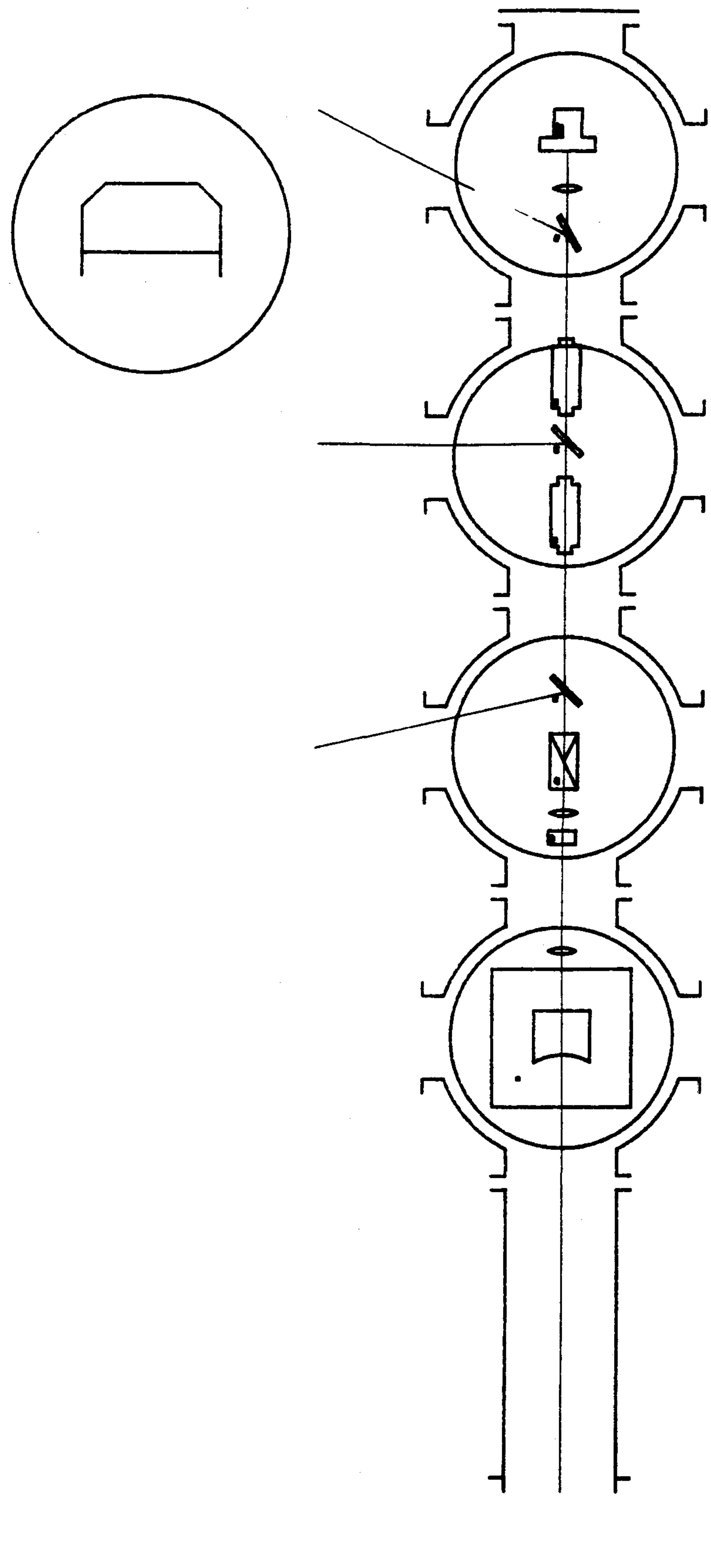
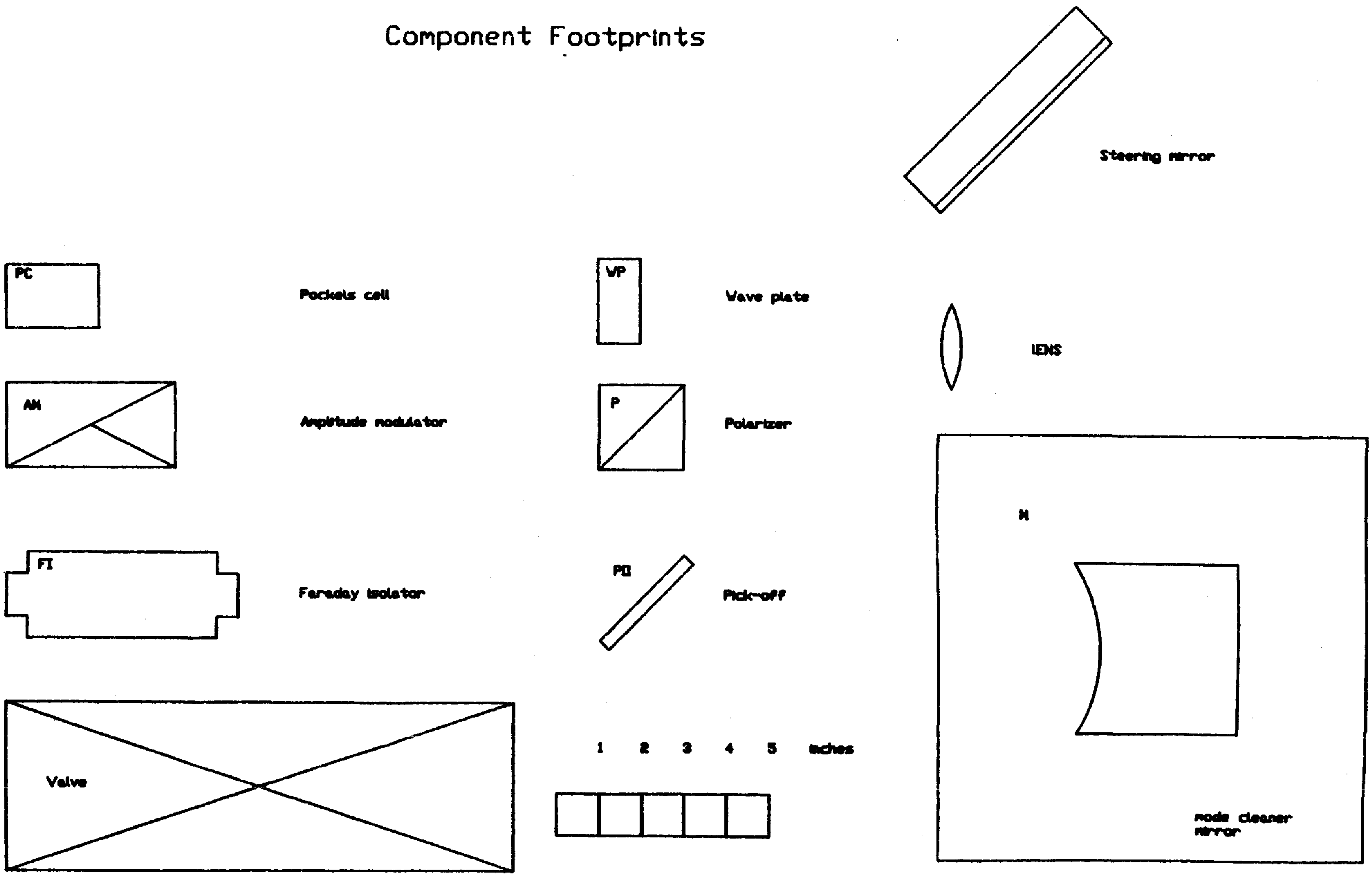


Component Footprints



Component tank outline