NEUTRINO FACILITY PLANS AT NAL

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1. INTRODUCTION

Plans for neutrino experiments at the National Accelerator Laboratory with the U.S.A. 200 GeV accelerator took shape at the 1968 Aspen Summer Study which considered the experimental program for the new machine. The general consensus of this study group was that a vigorous neutrino program be pursued and that it should have a high priority in the experimental physics program of the new accelerator. The detector for productive studies of high energy neutrino interactions should be a large hydrogen-deuterium bubble chamber of about 100 m^3 volume.

2. MASTER PLAN OF THE EXPERIMENTAL AREAS

The present tentative plan for the layout of experimental areas at NAL is shown schematically in Figure 1. In this layout, a single proton beam is extracted from the 200 GeV accelerator. The protons are then directed to a number of target areas for experiments by using beam-splitting and beam-switching magnetic systems.

The first of the four branches of the external proton beam is directed to the neutrino target station for production of an intense secondary beam of π's and k's. After being focussed, the π's and k's enter a long decay region. Following the decay region, the neutrino beam passes through a shield design to filter out by ionization all muons and hadrons. The neutrino beam then enters a large hydrogen-deuterium bubble chamber in which the interactions of the high energy neutrinos are to be studied.

A joint NAL-BNL project is now underway to design and build a 100 m^3 cryogenic bubble chamber. This chamber is expected to be ready for operation at NAL late in 1973 at the same time that an intense proton beam, and hence neutrino beam is available at NAL. A charged particle beam originating from target station No. 1 will also be available at the bubble chamber for studying strong interactions at high energies.

The experimental areas following target stations Nos. 1, 2 and 3 are intended primarily for counter and spark chamber use. For design of the neutrino focussing system, it is necessary to know the differential production cross sections for pions and kayons from a thick target for 200 GeV incident protons. It is planned to make those measurements in one of the earliest experiments in experimental area No. 1 which will be the first to come into operation so that the focussing element can be constructed and operable by the end of 1973.

The developing plans for the neutrino beam, detectors, and analysis facilities, will be frequently discussed and reviewed with the high energy physics community -- largely by means of summer study programs. It is intended to freeze the design of the neutrino facility by the end of 1970 so that the facility can be constructed, exclusive of the focussing system, by mid 1972. The facility could come into limited operation e.g., for spark chamber experiments soon thereafter. By the end of 1973, when the accelerator is expected to reach its full design intensity of 5×10^{13} protons per pulse, and the large bubble chamber is planned to become available, the major neutrino physics program should come into operation.

3. NEUTRINO BEAM DESIGN CONCEPTS

A wide variety of possible neutrino beam designs for NAL was discussed at the 1968 Aspen Study.[1] The design concept which is presently favored is a wide-band neutrino beam (WBS) which includes a magnetic focussing system for π's and k's. This beam is favored because it maximizes the neutrino intensity over the entire neutrino energy spectrum. The present plans envisage the use of an earthen shield to filter out by ionization the muons and hadrons. The earthen shield is proposed largely for economical reasons; a higher density shield would be several million dollars more expensive. However, for neutrino energies below about 10 GeV, there is a substantial loss in neutrino flux when using an earthen shield in comparison to an iron shield. Because of these reasons, the subject of shield material is still under study.

Other possible neutrino beams are being investigated. In particular, possible methods of modifying an initially installed WBS are being considered. The possibilities include:

i) Longitudinal movement of the neutrino beam target station to modify the overall length of the neutrino beam.

ii) At the same time that the neutrino target is moved, the earthen shield could be replaced by a more dense shield. This could allow enhancing the low energy part of the neutrino spectrum, or allow the facility to operate with 400 GeV incident protons.

iii) Reroute the external proton beam at a lower energy e.g., 100 GeV, to a second neutrino beam target station which would be optimized for the lower energy end of the neutrino spectrum.

Conceptual design of the neutrino beam is now in progress using a variation of the computer program NUFLUX.[2)] This program is modified to also calculate the muon flux incident on the tunnel walls and entrance face of the shield.

The present plans call for the entire neutrino facility (target station, decay tunnel, etc.) to be located at the same altitude as the accelerator main ring i.e., below ground. The neutrino detectors would then be located in a man-made hollow, downstream of the muon shield. A major reason for the underground location of the neutrino beam is that the radiation levels anticipated are on the order of several thousand R in the neighborhood of the target, and several R along the length of the decay tunnel. The induced radioactivity in the various components of the neutrino beam represents a major problem in the design of the components, the method of replacement of faulty components and methods of making modifications to the initial beam arrangement.

4. NEUTRINO DETECTOR CONCEPTS

Detectors envisaged in the neutrino experimental area will include spark chamber-type arrays and a large cryogenic bubble chamber. Since the lead time necessary for design and construction of the bubble chamber is considerably greater than for the other detectors, we are now considering in detail only the design of the bubble chamber.

The general consensus of the participants of the 1968 Aspen Summer Study was that a large cryogenic bubble chamber of about 100 m^3 volume be available for the experimental neutrino program at NAL. Toward this goal, in May 1968, the National Accelerator Laboratory and Brookhaven National Laboratory agreed to colloborate in the construction of a 25-foot hydrogen-deuterium bubble chamber. BNL will be responsible for the detailed design and construction of the chamber, while the parameters which affect its research capabilities are to be agreed upon by both laboratories. The site plan, the design, construction and assembly of beams, buildings and on-site utilities necessary for operation of the chamber will be the responsibility of NAL.

A first design study[3)] of the 25-foot chamber was completed by BNL during August 1968, and a brief description follows. The chamber body shown in Figure 2 is an 18-foot diameter sphere capped on each end by 14-foot diameter hemispheres. The chamber has a total expandable volume of 105, 000 liters, and a volume of 72, 000 liters which can be seen by all three cameras. The chamber is expanded by a 90-inch diameter fiber glass reinforced plastic piston in contact with the liquid on the bottom of the chamber as shown in Figure 3. The piston stroke for a 1% expansion is 10 inches. The piston is hydraulically driven to give an expansion cycle of about 0.08 sec with a repetition rate of 150 msec.

Six cameras using 140° lenses would be used to view the chamber liquid. The lenses, which are telecentric, are mounted with their axes in planes normal to the axis of symmetry of the chamber body. Parallel beam tracks, therefore, give parallel images on the photographs. Bubbles at the bottom of the chamber of 1 mm diameter will produce images of 7 μ diameter on the film. A nine-foot optical system will transport the images to the outside of the vacuum shell. An artists view of the proposed bubble chamber is shown in Figure 4.

It is proposed to use a hollow conductor helium-cooled superconducting magnet which will produce an average magnetic field of 40 kilogauss. It is proposed that the vacuum chamber also serve as an outdoor housing for the bubble chamber. This double use of the vacuum chamber realizes a considerable cost savings for the conventional facilities.

Money for further conceptual design of the chamber is presently being requested. If funds for construction are obtained in July 1970, detailed design could start with a view to completing construction by the end of 1973. A tentative cost estimate for the chamber is $17M, including about $4M for deuterium to fill the chamber.

A film analysis facility is being evolved at NAL which by late 1973 should be able to handle a reasonable fraction of the film produced by the large chamber. The type of measuring system which has the best chance to handle the film from the 25-foot chamber can be decided upon within the next year because of the coming into operation of the BNL 7-foot and ANL 12-foot bubble chambers.

5. SUMMARY

Physics experiments will begin at NAL in July 1972 when a 200 GeV proton beam will be available at experimental area No. 1. Soon thereafter, neutrino physics could also begin in the neutrino area with counter-spark chamber experiments but with an unfocussed neutrino beam. After a particle survey in experimental area No. 1, the focussing elements can be constructed. Experiments using a focussed neutrino beam with the 25-foot bubble chamber could begin at the end of 1973.

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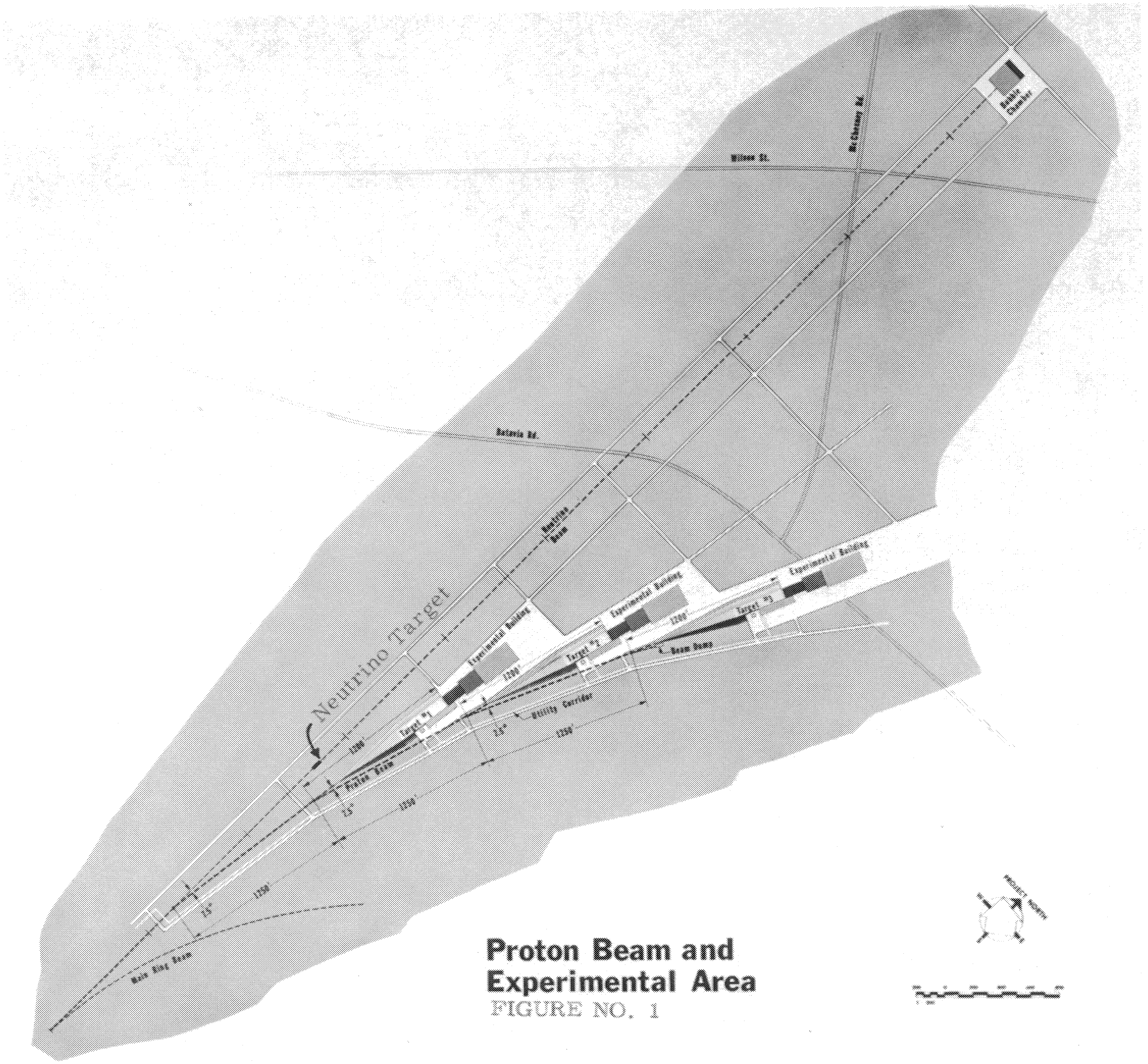
REFERENCES

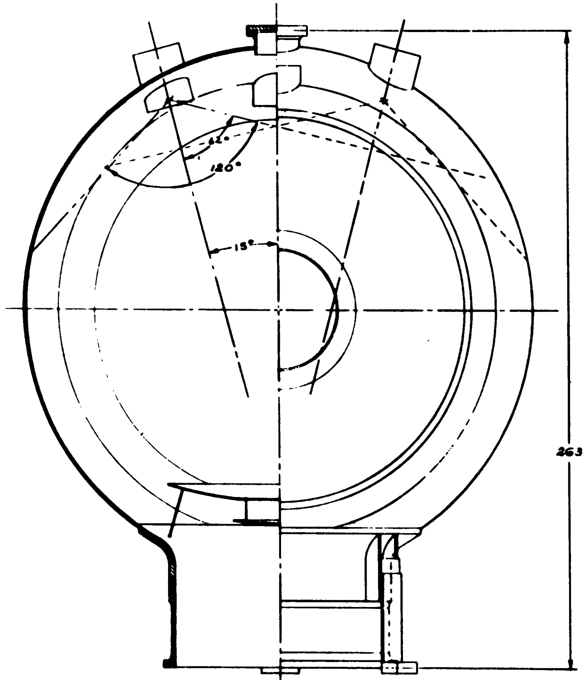
1) NAL Summer Study Report B. 1-68-104, M. L. Stevenson, "The Neutrino Facility at NAL."

2) NUFLUX Program, Private Communication of W. Venus, CERN.

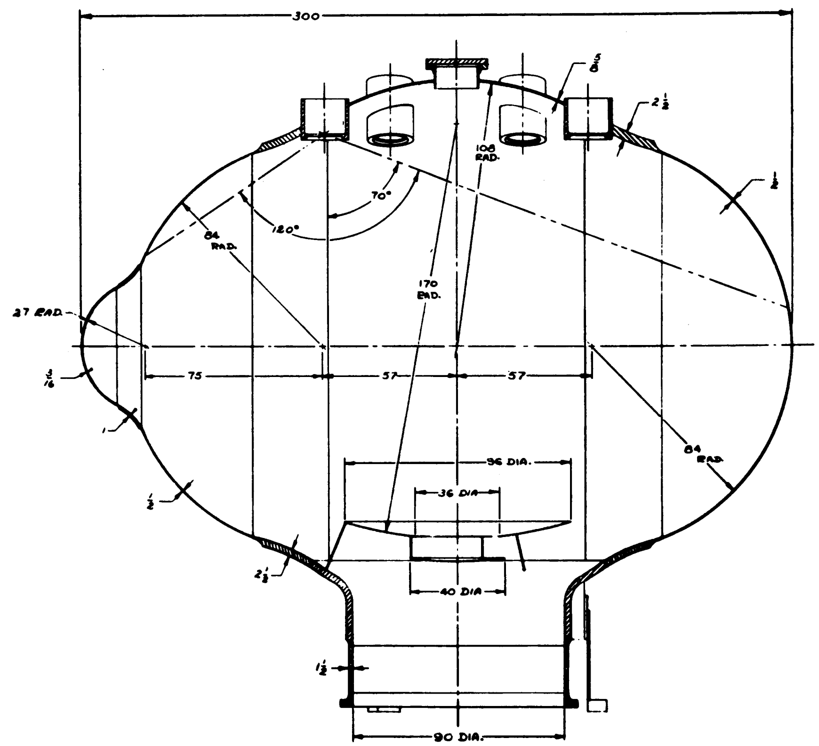
3) 25-Foot Cryogenic Bubble Chamber Proposal, August 1968, BNL 12400.



Proton Beam and Experimental Area
FIGURE NO. 1

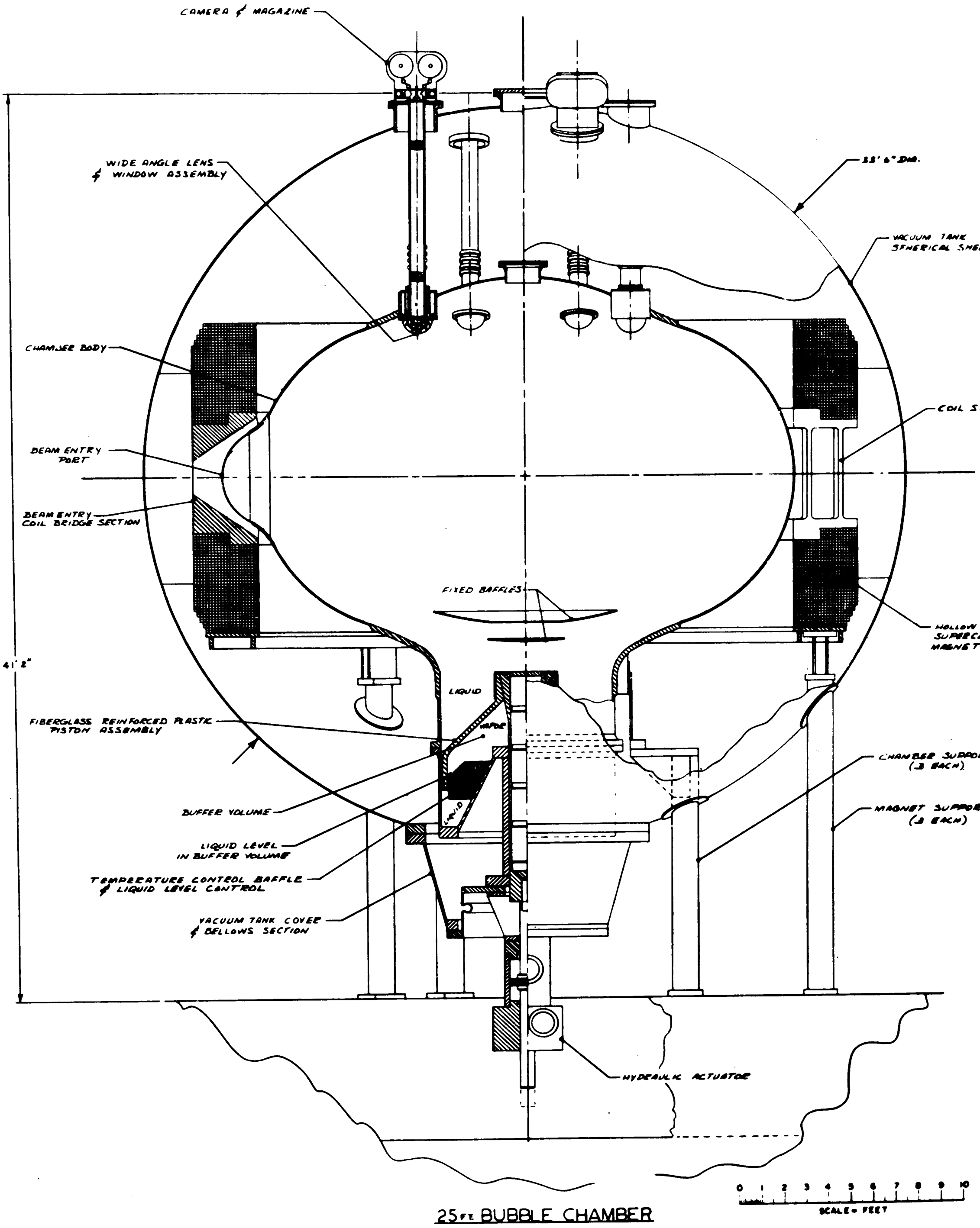


25 FT. BUBBLE CHAMBER
CHAMBER ASSEMBLY
FRONT ELEVATION



25 FT. BUBBLE CHAMBER
CHAMBER ASSEMBLY
SIDE ELEVATION

FIGURE NO. 2



25 FT BUBBLE CHAMBER
MAIN ASSEMBLY

SIDE ELEVATION
SECTIONED VIEW

FIGURE NO. 3

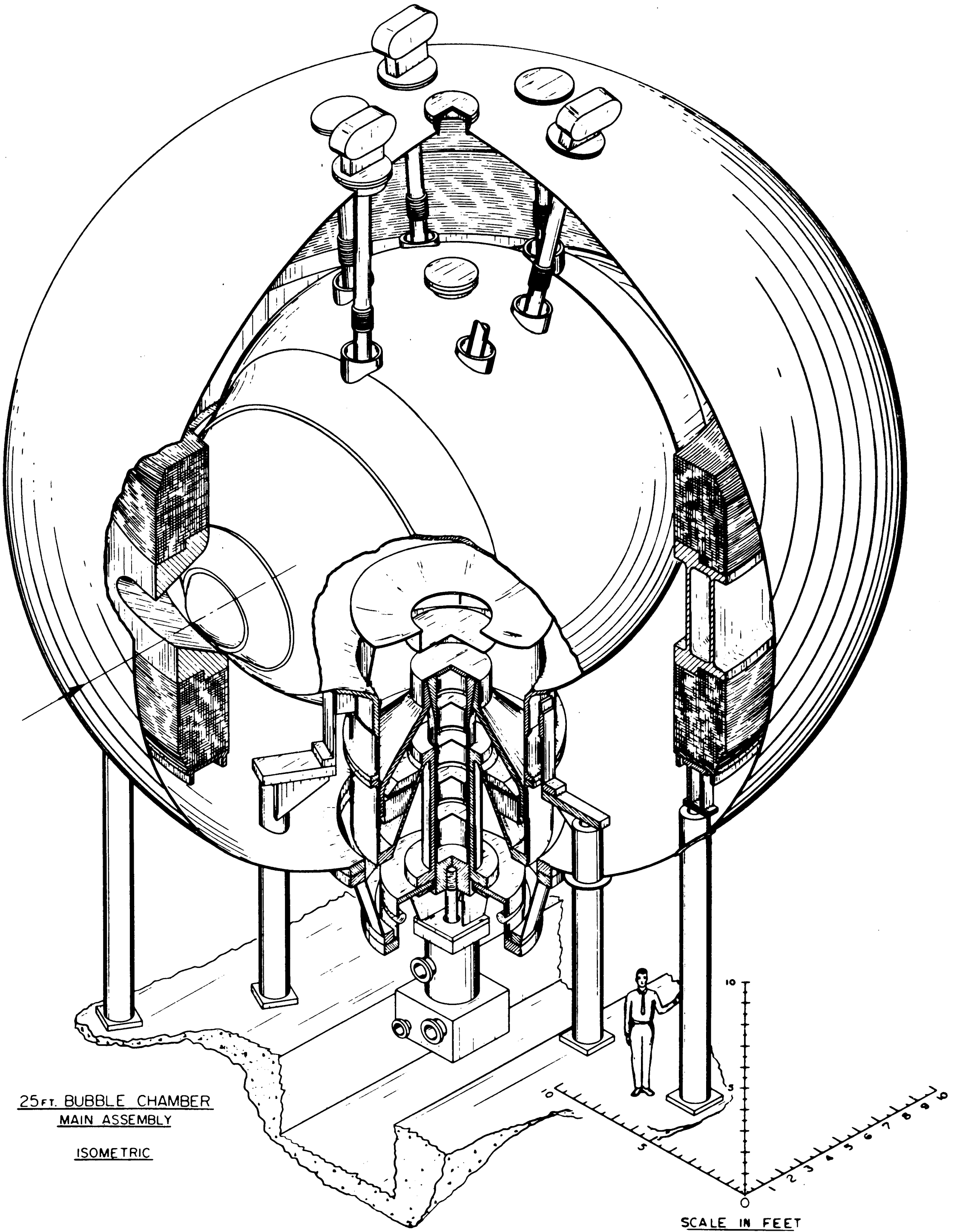


FIGURE NO. 4