THE SUPERCONDUCTING MAGNET FOR THE PROPOSED 25-FOOT CRYOGENIC BUBBLE CHAMBER*

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A preliminary proposal has been made for the construction of a 25-ft cryogenic bubble chamber for use at the 200 GeV accelerator at the National Accelerator Laboratory. This chamber, which is to be designed by Brookhaven National Laboratory, is to have an air-core superconducting split-pair magnet capable of generating an average magnetic field intensity of 40 kG over the bubble chamber volume. The superconducting air-core design makes more accessible the component parts of the bubble chamber assembly and gives large savings in magnet costs and power for operation.

To eliminate the need for a magnet helium Dewar and to achieve a magnet coil configuration that is compact and mechanically strong, it is proposed that the 25-ft chamber magnet conductor be a hollow stabilized superconducting conductor cooled by an internal flow of helium.

Hollow stabilized superconducting conductors have recently been fabricated which consist of a number of superconducting filaments embedded in the wall of a tube of copper of square, or rectangular cross section. These conductors may be cooled by an internal flow of helium which is maintained at a temperature of 4.5°K and at pressures above its critical pressure of 2.23 atm. By maintaining the pressure of the helium fluid above 2.23 atm, the formation of two phases within the conductor is prevented. The one-phase positive fluid flow through the conductor insures that cooling is continually brought to all parts of the magnet conductor. The total volume of helium in contact with the conductor is less than that required to cool the magnet by pool boiling. Thus liquid and gas storage requirements are minimized with the hollow superconducting design.

The normal conductor material in which the superconducting filaments are bonded not only stabilizes the superconductors but also aids in supporting the electromagnetic forces to which the magnet is subjected. The amount of normal conductor to be bonded to the superconductor for stabilization for a given magnet current depends on the rate of heat transfer from the conductor to the helium coolant and on the resistivity of the normal conductor. The resistivity of the normal conductor is a function of its purity, of the stress in the conductor, and of the magnetic field intensity at the conductor.

The 25-ft bubble chamber magnet is designed for 3×10^7 ampere-turns to generate a central field of 38 kG with an average magnetic field intensity of 40 kG over the chamber volume. At this value of average field, the maximum field at the magnet windings will be 65 kG and the magnet coil will be subjected to total radial pressures of the order of 2800 psi. To aid in supporting the stresses in the magnet windings, to limit deformation of the conductor material, and to reduce the amount of normal conductor required, a reinforcing or stiffener strip of a high strength material such as stainless steel is wound in the magnet coil windings with the hollow conductor. A thin strip of fiberglass epoxy or Mylar tape is also wound in the magnet coil between the

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surfaces of the hollow conductor strip and the stiffener strip to provide turn-to-turn electrical insulation. A schematic of the proposed magnet coil configuration is shown in Fig. 1. A hollow copper-multifilament superconductor composite of the type shown in the schematic, 0.75 in. square with an 0.375 in. diameter hole, may be designed to carry 8500 A in a magnetic field of 65 kG. Sufficient reinforcement is also wound in with the conductor to limit the stress in the copper to 15 000 psi.

The 25-ft bubble chamber magnet is a split-pair of coils, each coil-half consisting of a number of single layer pancakes as shown in Fig. 2. The pancakes are insulated from each other by thin sheets of fiberglass epoxy. Each pancake is made self-supporting against radial forces by clamping the external free end of the conductor at the periphery of the coil. The pancakes are connected electrically in series with stabilized superconducting connectors soldered and clamped at the inner and outer diameters of the magnet coils. The pancakes are connected in parallel to the helium supply manifold at the inner diameter of the magnet and to the helium return manifold at the outer diameter of the magnet coil.

The single layer pancakes are stacked vertically for each of the two magnet-half coils. Each magnet-half coil is 4 ft 6 in. high and has an inner diameter of 23 ft 6 in. and an outer diameter of 29 ft 2 in. The two half-coil assemblies are separated by 5 ft to allow for particle beam entry to the bubble chamber. This large coil separation permits the winding of magnet coils of a smaller diameter, reduces the axial forces on the coils, and improves the uniformity of the magnetic field over the bubble chamber volume. It also permits the large curved beam window section of the bubble chamber to extend 2 ft into the gap between the coils, as shown in Fig. 3, for easy entry of particle beams with a large range of momentum. The magnetic field intensity transverse to the beam axis has an average value of about 22 kG in the volume in the beam window between the coils. An elevation view of the magnetic field intensity plot is shown in Figs. 4 and 5. With a total of 3×10^7 ampere-turns in the magnet and an average field over the chamber volume of 40 kG, the two coil-half assemblies are attracted to one another with a force of the order of 30 000 tons. This force between the coils is supported by a coil spacer which is reinforced around the chamber beam window so that a large aperture is available in the spacer for beam entry.

The pancakes of each magnet-half coil assembly are tied together by vertical rods at the inside and outside diameters of the magnet which are threaded into or bolted to stainless-steel washers at the top and bottom of each coil-half. These rods serve to align the coils. The bottom washer of the top coil and the top washer of the bottom coil are bolted to the coil spacer, while the bottom washer of the bottom coil is bolted to the three support legs. These legs support the magnet and bridge assembly in the bubble chamber vacuum tank and are designed to carry the total weight of approximately 400 tons. Thermal insulating pads are placed between the coil-halves and the coil bridge, and between the bottom coil and the support legs to minimize the heat leak from these structures to the coil. The magnet is thermally insulated from the bubble chamber and the vacuum tank by multilayer insulation.

The final figure, Fig. 6, shows an isometric view of the main assembly of the bubble chamber.

This brief description represents a summary of some of the preliminary general design concepts being developed by the Bubble Chamber Group at Brookhaven National Laboratory for the superconducting magnet for the 25-ft cryogenic bubble chamber.

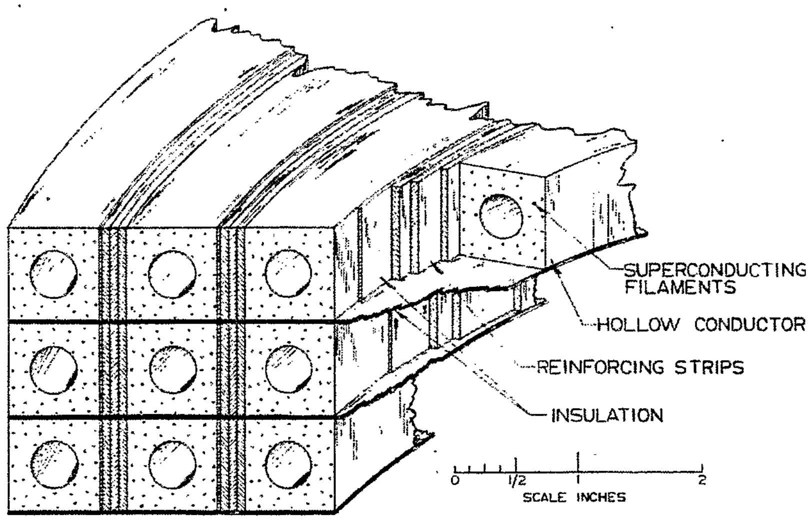

Fig. 1. Magnet coil components.

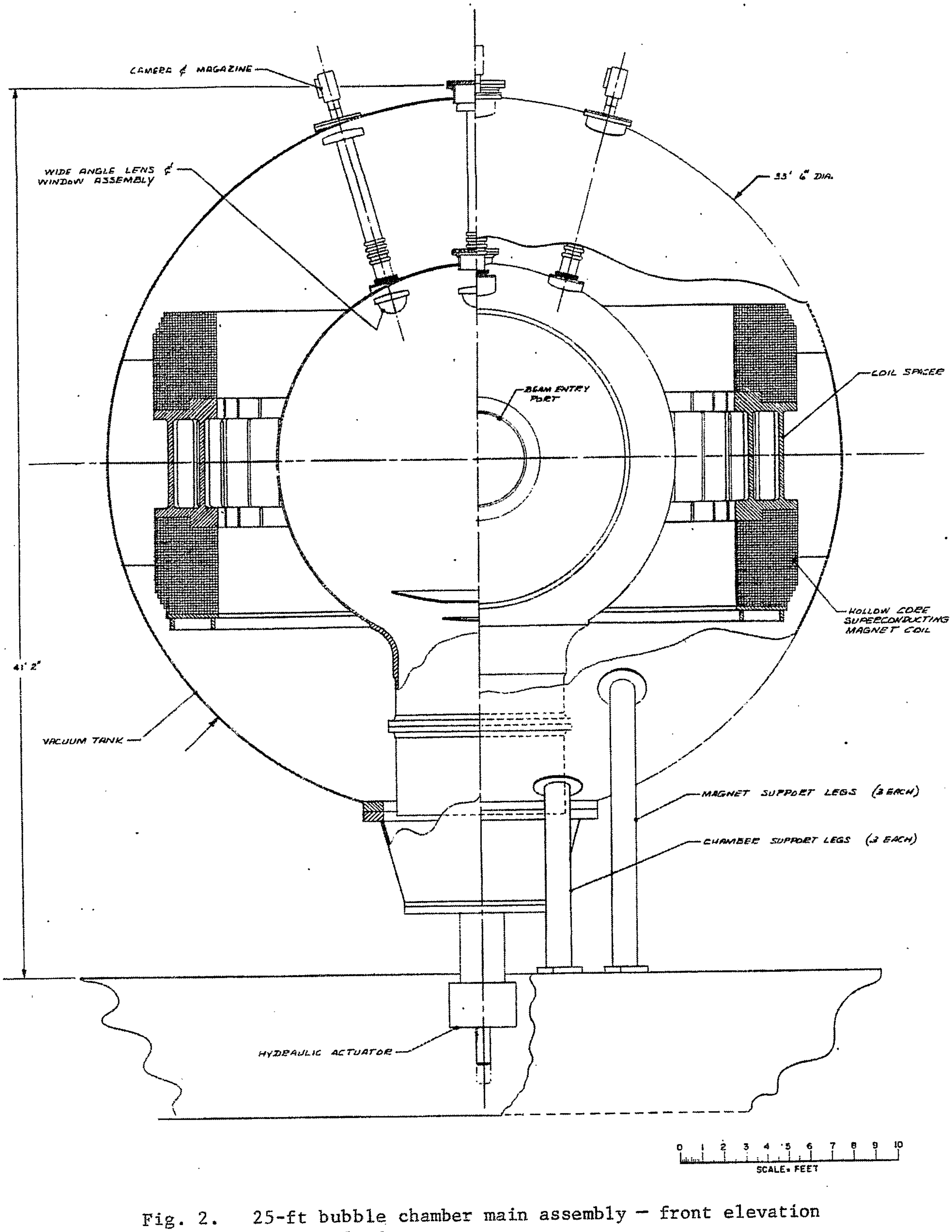

Fig. 2. 25-ft bubble chamber main assembly — front elevation sectioned view.

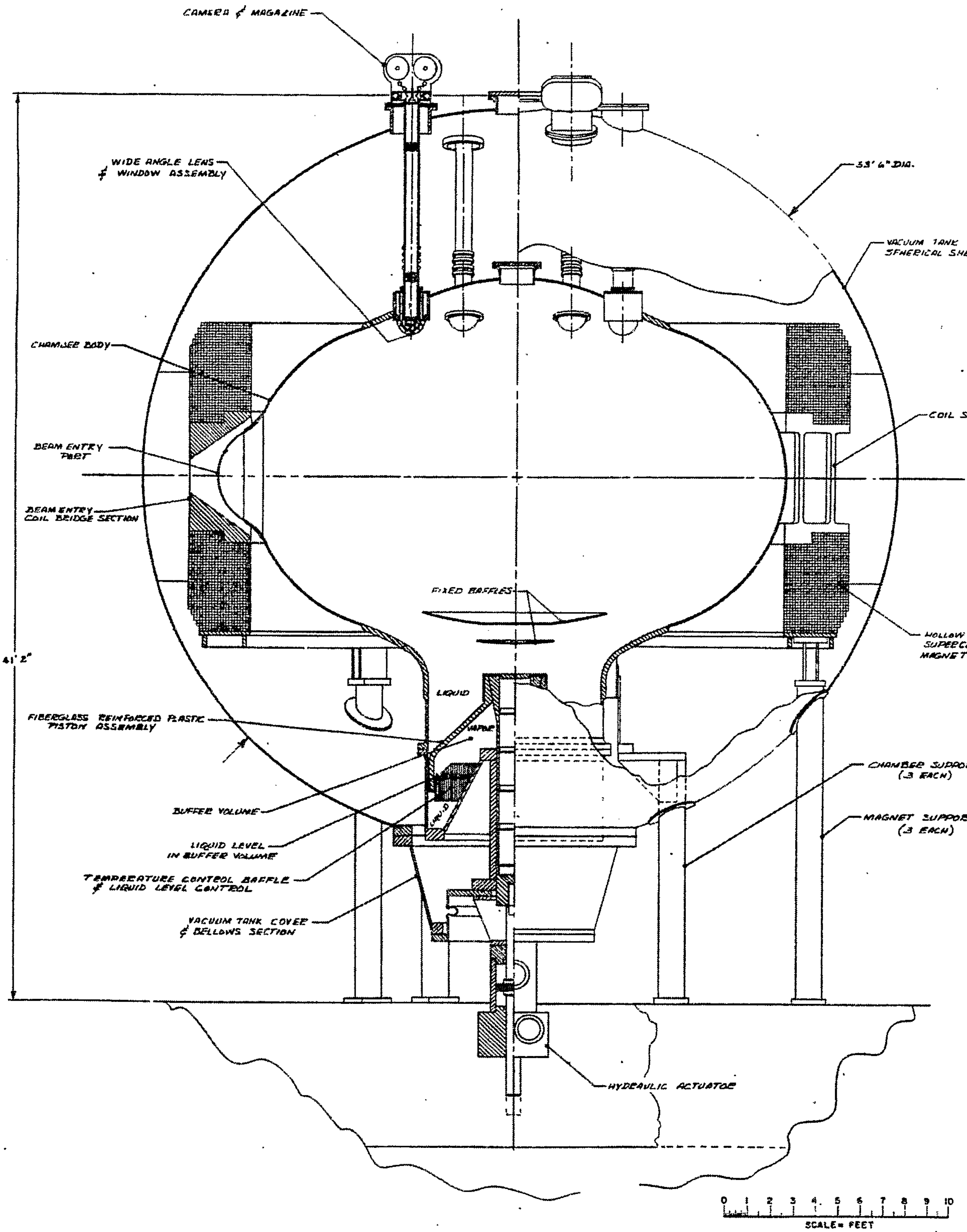

Fig. 3. 25-ft bubble chamber main assembly — side elevation sectioned view.

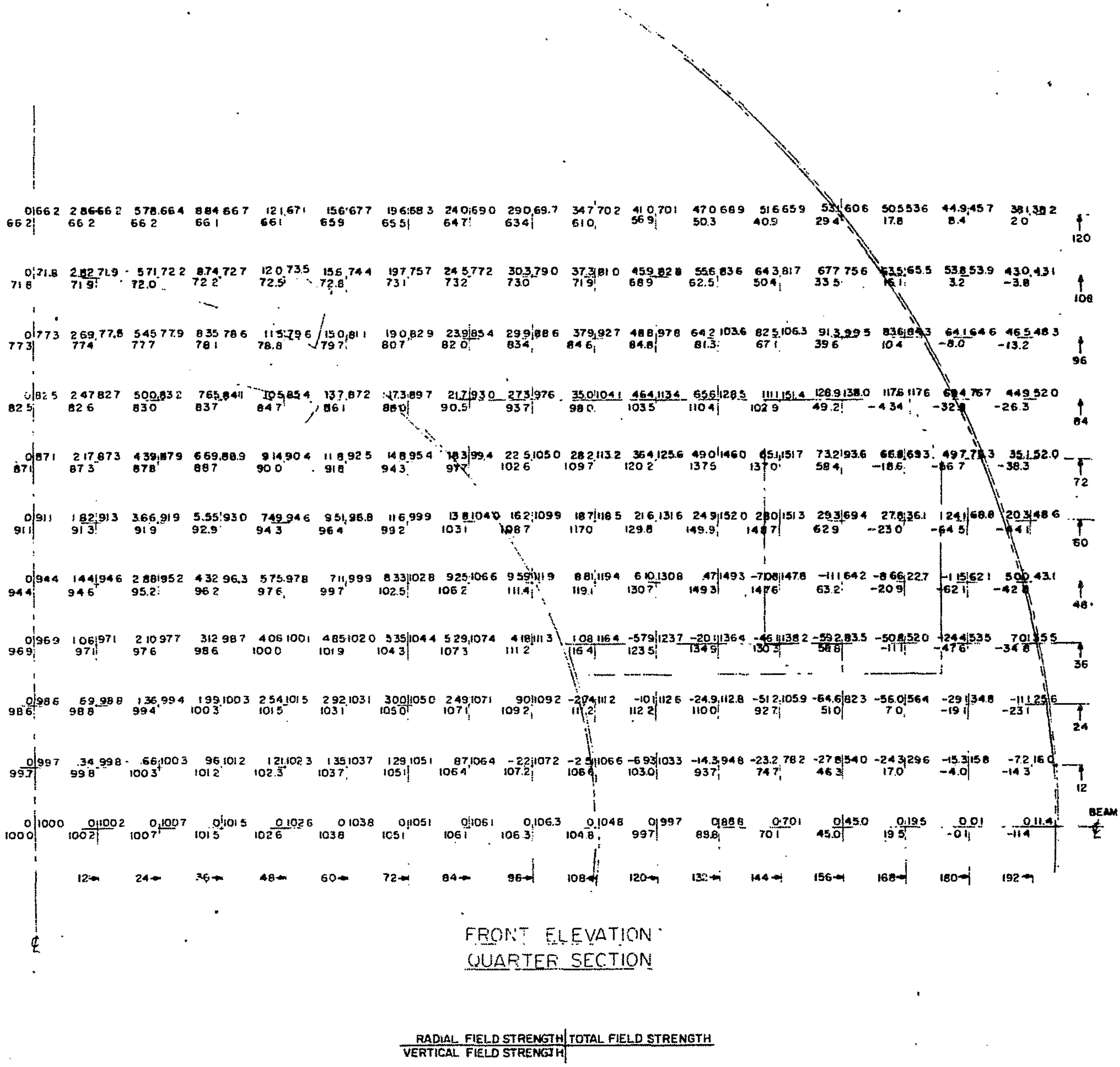

Fig. 4. Field strengths expressed in percent of field strength at intersection of vertical center line and beam center line.

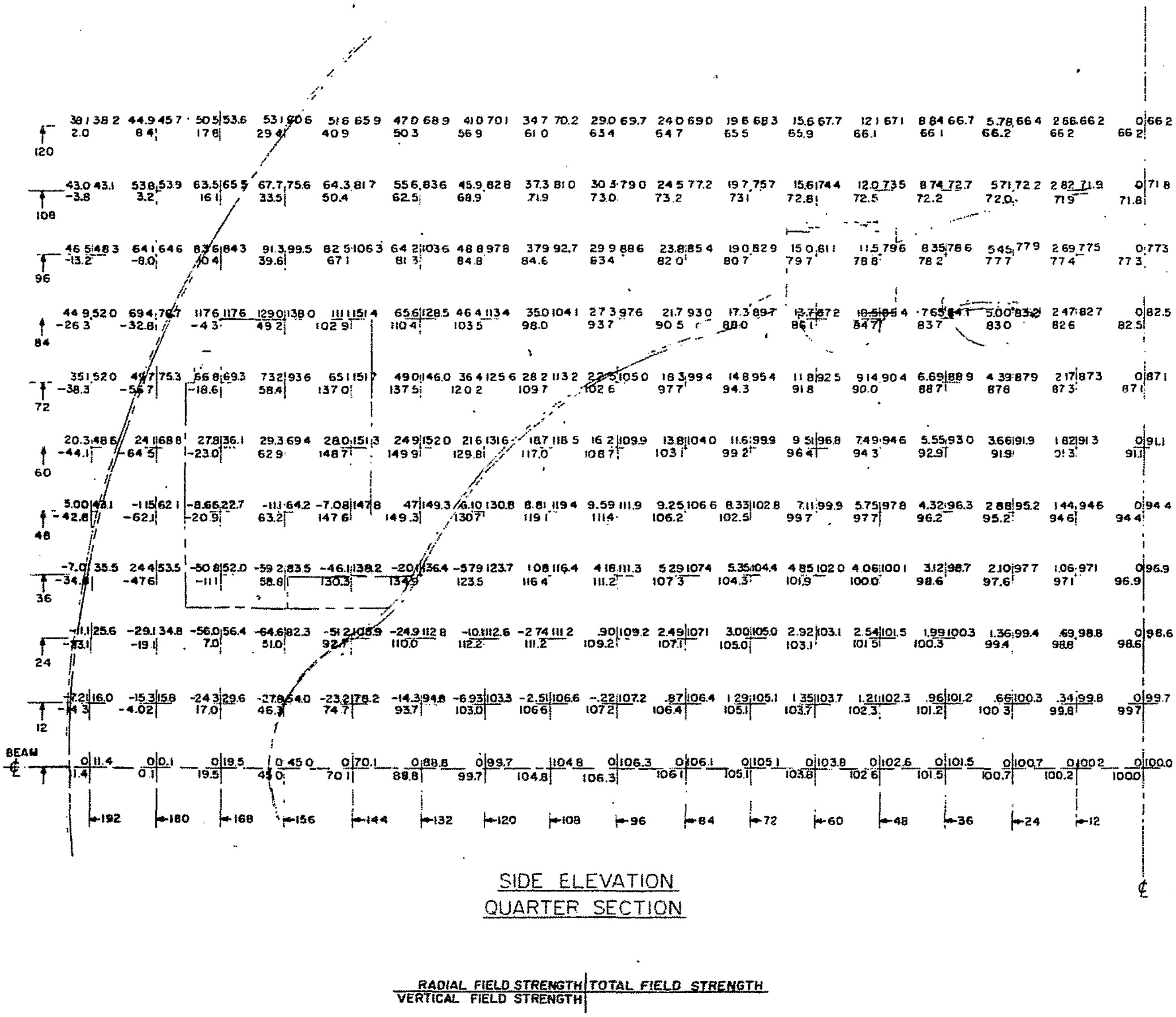

Fig. 5. Field strengths expressed in percent of field strength at intersection of vertical center line and beam center line.

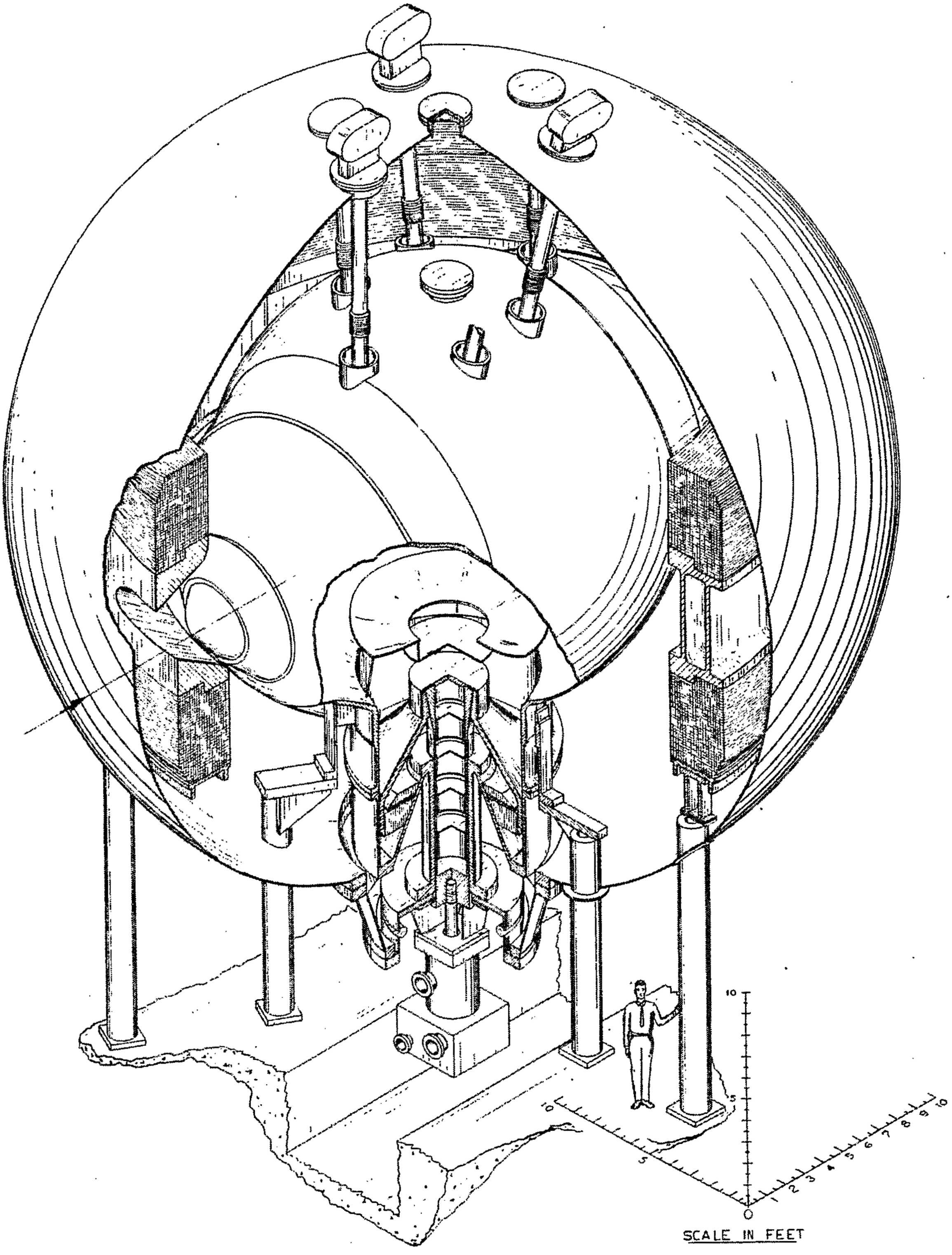

Fig. 6. 25-ft bubble chamber main assembly — isometric view.