5.1 THE SUPERCONDUCTING MAGNET ASSOCIATED WITH THE ANL 12-FT HYDROGEN BUBBLE CHAMBER *

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When this project was begun two years ago, it was not possible to make a firm decision to use a superconducting coil in the 12-ft chamber system. Although we had constructed a superconducting magnet for the 25-cm ANL-CIT helium chamber, there remained numerous engineering problems. In order to consider using a superconducting coil and still meet the four-year construction schedule, parallel designs of superconducting and conventional coils were undertaken which would be compatible with the hydrogen chamber and with the magnet iron. In addition to dimensional constraints, this fixed the operating field strength at 20 kG and fixed the requirement that the superconducting magnet have its own vacuum container.

In June 1966 the design of the superconducting coil had progressed to a point that a decision was made to construct the magnet with superconducting coils. The design clearly demonstrated that the problems were mechanical and cryogenic in nature and not those of "superconductivity." Detailed cost estimates showed that the capital costs of conventional versus superconducting coils were essentially equal. The decision was based mainly on an expected large saving in operating cost by eliminating the required 10 MW of power which would be required for operating the conventional coils.

Figure 1 is a perspective of the chamber assembly. The magnet container is of all-welded construction with a stainless steel inner vessel and an aluminum vacuum container. The all-welded construction of the inner vessel was chosen instead of demountable cold seals because of space limitations, reliability, and cost. The schedule permits at least one disassembly of the cryostat; however, it is expected that by proper modeling of the problems, this will not be necessary.

The coil support structure (which in reality is the helium vessel) is suspended by eight tension support tubes from the magnet iron. The windings are clamped to 10-cm thick stainless steel girder rings which provide radial stiffness. Radial stability is provided by eight rods attached from the girder ring to the magnet iron, as shown in Fig. 1.

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Because of the holes in the top of the iron, the net force on the coil assembly centered between the pole faces is expected to be approximately 20,000 Kg downward. The weight of the cryostat will impose an additional load of 100,000 Kg. Vertical adjustment of 1.25 cm in either direction from center is provided to account for mechanical error in coil position, variation in iron permeabilities, and other effects which tend to perturb the downward force. The force on the coil assembly in the vertical direction changes approximately 100,000 Kg per cm of displacement. The eight vertical supports are designed to support 500,000 Kg in tension. The radial instability forces are calculated to be approximately 20,000 Kg per cm of radial displacement from magnetic center. This force will be transmitted to the iron by the radial support members (see Fig. 1) located at 90 degree intervals. The system is designed to support a transverse load of 250,000 Kg.

The schematic for the cooldown of the coils is shown in Fig. 2. Cold helium gas enters a manifold at the top of each coil compartment. This cold gas mixes with warmer gas within the container, setting up large convective flow which cools the coils uniformly. This method of gas circulation in conjunction with vertical aluminum shunting bars connected to the aluminum coil spacers results in very small thermal gradients and, hence, low stresses during cooldown. A 50-cm internal diameter model with the depth of winding of the full size coil and with the full height of one compartment is being constructed to confirm the cooldown calculations and evaluate clamping techniques. Cooldown time is determined by compressor capacity of the 400 W helium refrigerator and is approximately three days.

The details of the coil construction can be seen in Fig. 3. The coils are held in position by an aluminum tie-rod assembly, which clamps the coils to the 10-cm thick girder rings. Aluminum is used for the clamping bolts to maintain clamping force on the coils as the system is cooled down. The coefficients of thermal expansions are such that the clamping force increases somewhat at $4^{o}K$. The details of the coil construction are also shown. Aluminum spacers between coils (not shown in the figure) are located every 6 degrees, and they are faced with a thin electrical insulating material. The coefficient of thermal expansion of aluminum matches the coefficient of the copper-teflon composite of the coil, resulting in very low shear forces on the coil-spacer interface. As mentioned above, the ends of the aluminum spacer blocks are thermally shunted in a vertical direction with large aluminum tie bars to minimize vertical temperature differences within the coil stack during cooldown.

The 2000 amp conductor of the coil is a fully stabilized strip, $5 \times 0.254\ cm^2$ in cross section. To evade the problem of a reinforced conductor, the coils were designed so that the copper stabilizing material will support the total hoop stress on the windings. The resulting low current density permits edge cooling and allows the rigid "wafer" construction. A partial list of the magnet parameters is given in Table I.

Table I

MAGNET PARAMETERS

Design Field	18 kG
Design Current	2000 amps
Stable Current (Calculated)	4200 amps
Resistance Ratio of Copper	170-200
Conductor Dimensions	5-cm x 0.254-cm
Total Conductor Weight	45,000 Kg
Weight of Superconductor (NbTi)	2000 Kg
Hoop Stress on Conductor	420 kG/cm^2

The electrical circuit is shown in Fig. 4. With 10-V power supply, the charging rate of the magnet is 0.25 amp/sec, resulting in a total charge time of two and one-half hours. During normal operations, switch S2 will be closed to provide stabilization of the magnet. With S1 and S2 open, the energy dump resistor will adsorb the energy stored in the magnetic field whenever it is desirable to quickly reduce the field. In the unlikely event of an open circuit (conductor breakage), the aluminum vacuum vessel walls will limit the field decay with an 8-sec time constant, preventing energy deposition in the chamber vessel.

The construction has proceeded according to schedule so far, and the completion of the magnet is expected in 1969.

LIST OF FIGURES

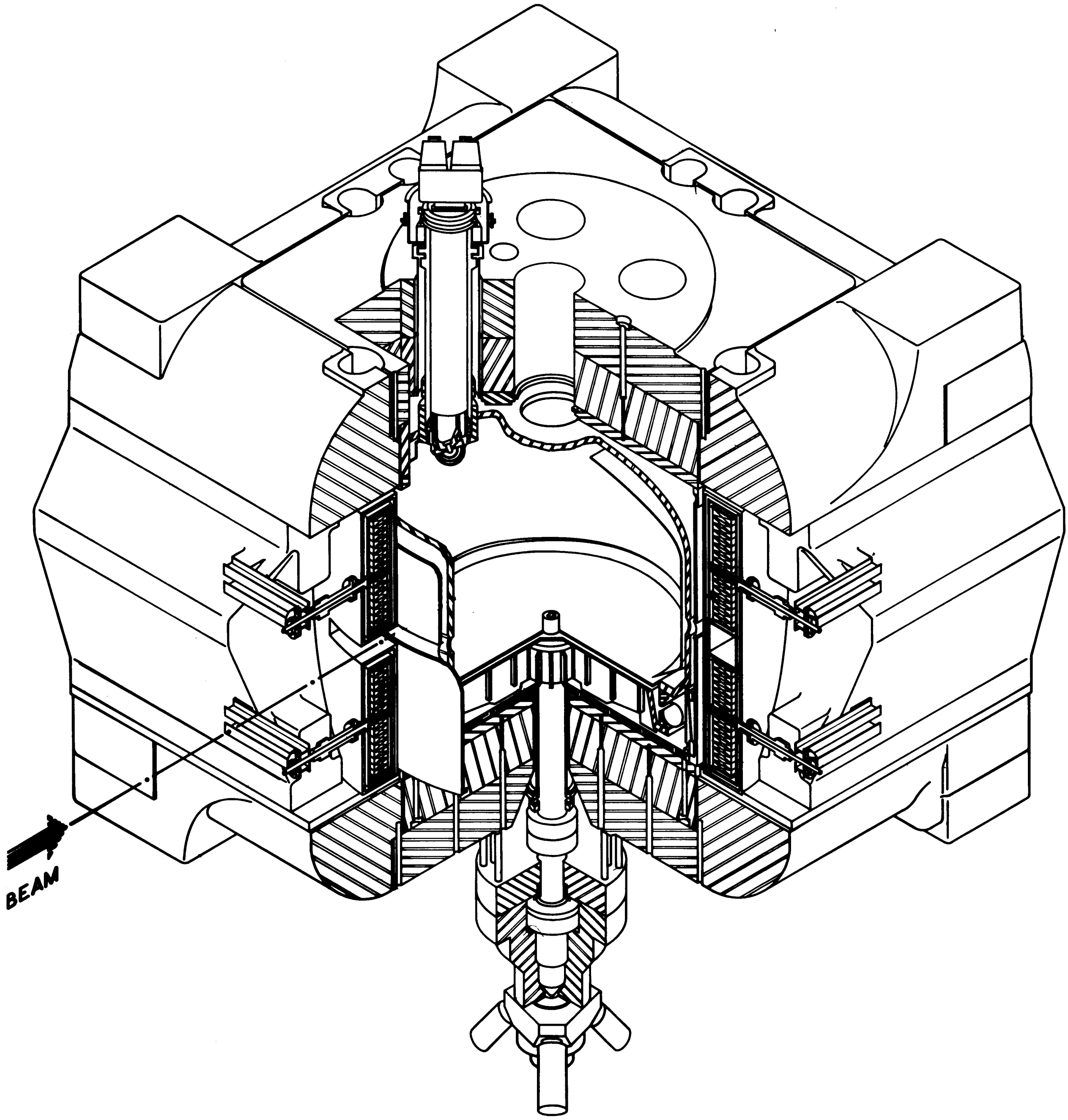

Fig. 1

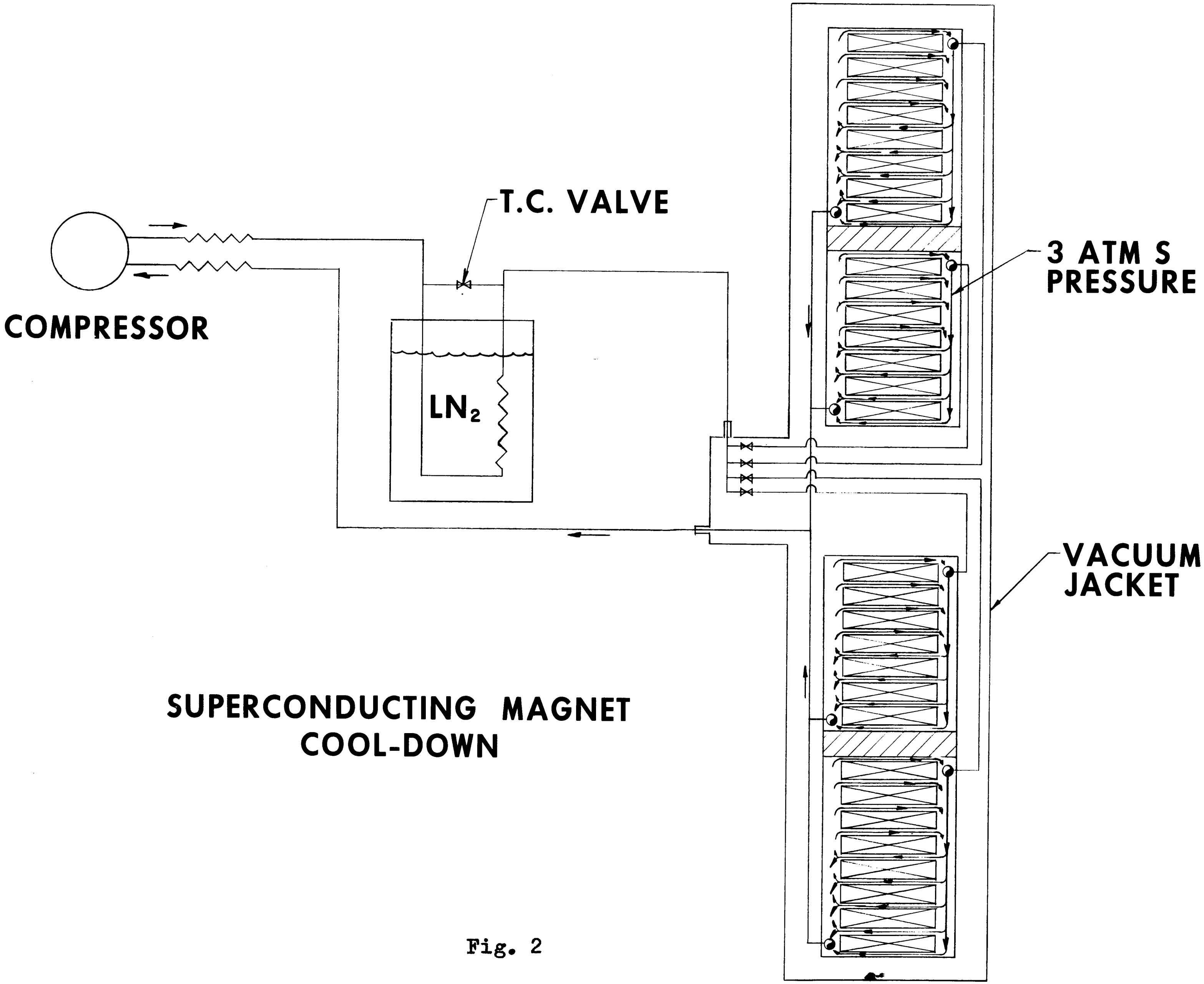
T.C. VALVE
COMPRESSOR
LN$_2$
3 ATM S
PRESSURE
VACUUM
JACKET
SUPERCONDUCTING MAGNET
COOL-DOWN

Fig. 2

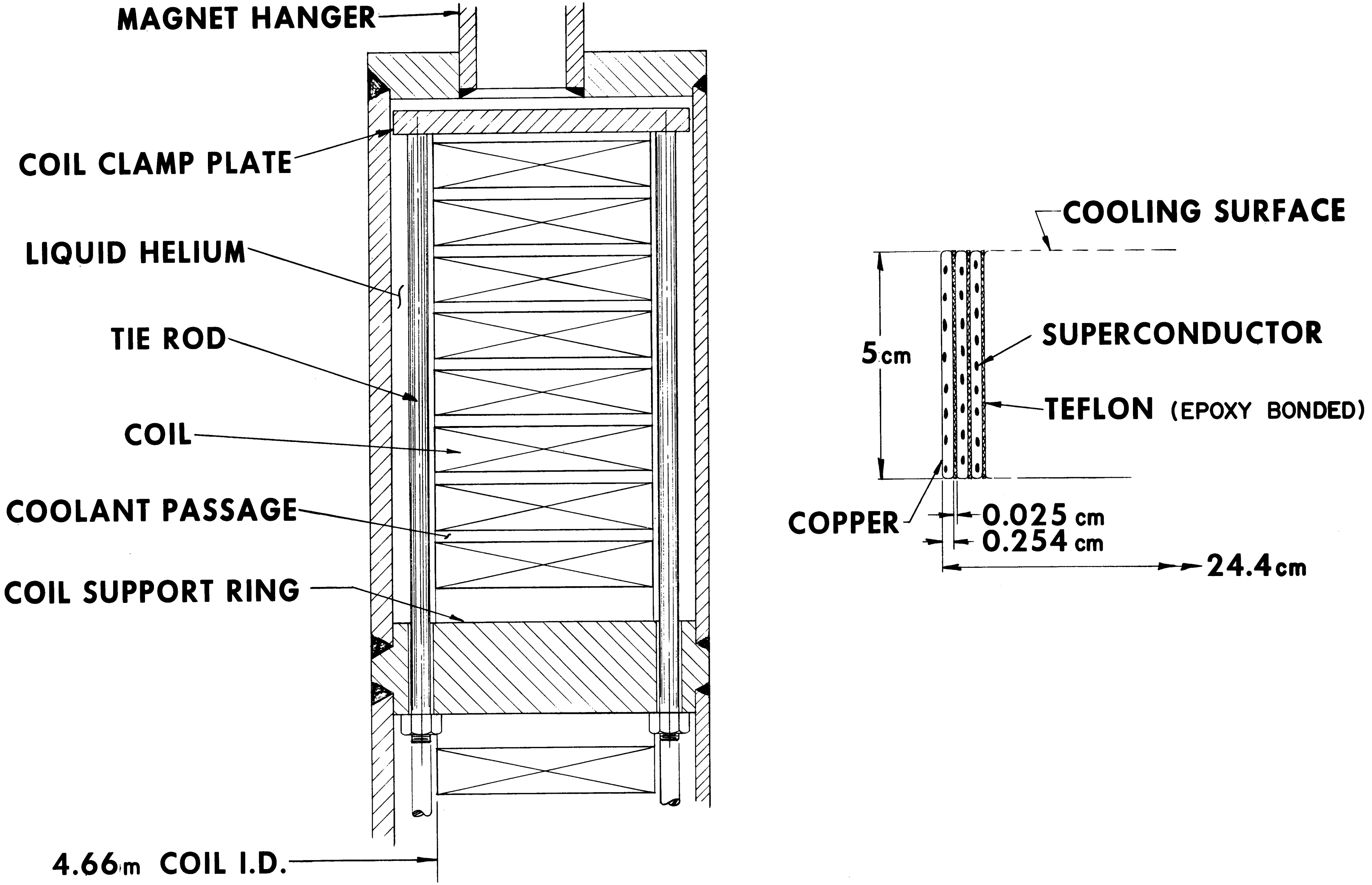
MAGNET HANGER
COIL CLAMP PLATE
LIQUID HELIUM
TIE ROD
COIL
COOLANT PASSAGE
COIL SUPPORT RING
4.66m COIL I.D.
COOLING SURFACE
SUPERCONDUCTOR
TEFLON (EPOXY BONDED)
5cm
COPPER
0.025 cm
0.254 cm
24.4cm

Fig. 3

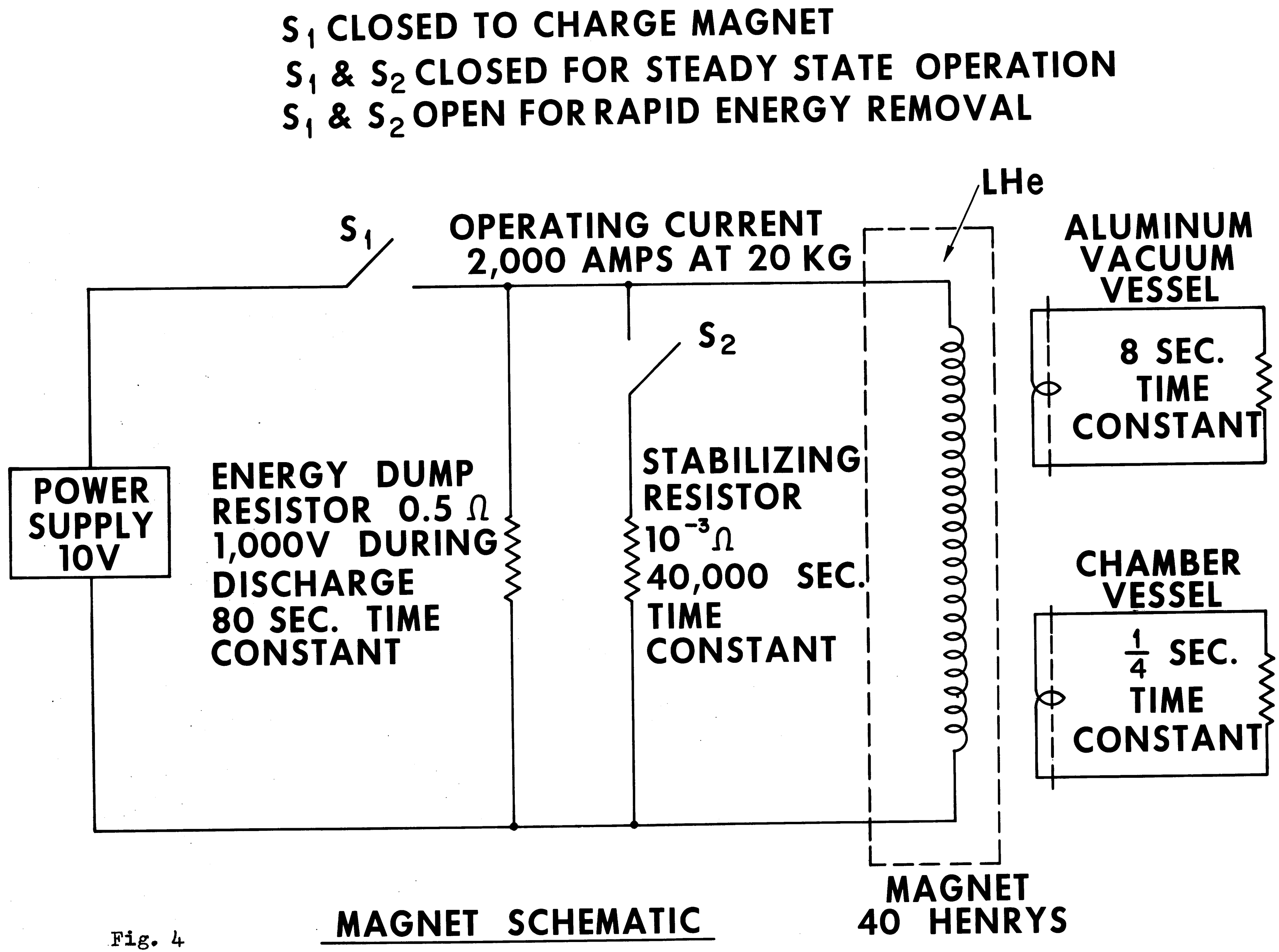

Fig. 4

MAGNET SCHEMATIC