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THE FENIX TEST FACILITY

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INTRODUCTION

The Fusion ENgineering International EXperimental Magnet Facility (FENIX), under construction at Lawrence Livermore National Laboratory (LLNL), is a significant step forward in meeting the testing requirements necessary for the development of superconductor for large-scale, superconducting magnets.

A 14-T, transverse field over a test volume of 150 x 60 x 150 mm in length will be capable of testing conductors the size of the International Thermonuclear Experimental Reactor (ITER).

Proposed conductors for ITER measure ~35 mm on one side and will operate at currents of up to 40 kA at fields of ~14 T. The testing of conductors and associated components, such as joints, will require large-bore, high-field magnet facilities.

FENIX is being constructed using the existing A_{2o} and A_{2i} magnets from the idle MFTF (Mirror Fusion Test Facility). The east and west A_2 pairs will be mounted together to form a split-pair solenoid. The pairs of magnets will be installed in a 4.0-m cryostat vessel located in the HFTF (High-Field Test Facility) building at LLNL. Each magnet is enclosed in its own cryostat, the existing 4.0-m vessel serving only as a vacuum chamber.

With iron cores inserted in the bores of the high-field magnets, the maximum field is 14 T. Forced-flow helium at adjustable temperatures, pressures, and flows will be provided. Samples can be from one to several meters in length, with about 0.15 m being in the uniform, high-field region. Power supplies are available to provide currents up to 40 kA.

The cost of constructing FENIX is minimized by the use of pre-existing equipment. The cryogenic equipment, cryostat, magnet, and sample power supplies are in place. The only major expense is the relocation and integration of the MFTF A_{2o} and A_{2i} magnets. The total cost for setup of FENIX is about $400K. This compares favorably with an estimated cost of $13M for construction of a comparable, all new facility.

Work on FENIX is now underway. The MFTF magnets have been removed. FENIX is expected to be operational in 1990. The facility will be available for use by researchers internationally.

The following design specifications and capabilities regarding services to the test conductors are preliminary and can be modified if there is a need. Consequently, user suggestions and requirements are solicited at this time.

GENERAL DESCRIPTION

Figures 1 through 8 show and describe the FENIX facility.

Figure 1 shows a pictorial cutaway. The 4-m-diameter external vessel already exists at LLNL. The A_2 magnet sets were removed from the MFTF facility in June 1989 and will be installed in about three months. The various components (including magnet supports, helium reservoir, and test well) are presently being fabricated. A Koch, model 2800, helium refrigerator is in place at the FENIX site and will be used to provide refrigeration to the facility's A_2 magnet sets, their vapor-cooled supports, and current leads. An Airco 400-W helium refrigerator also exists at the test site. The Airco refrigerator will be used to provide liquid helium to the test well, thus providing refrigeration for the test conductor leads and the forced flow through the test conductor.

Figure 2 shows a plan and elevation drawing of the system's major components.

Figure 3 shows the size and geometry of the test well. This is the space provided to facility users for testing conductor. The lower test well, which houses the test conductor, can be filled with liquid helium or operated dry for testing forced-flow conductors. In either case, liquid helium will exist in the upper test well during testing.

Figure 4 shows the test-well, magnetic-field plot at the magnet centerline where the field is greatest. The plot is dimensioned so future users can determine field conditions for test conductors.

Figure 5 is a plan view of Building 445 at LLNL and the layout of FENIX within that building. An area field plot is also illustrated, showing a 135-G field near the building walls. Users must consider this field in planning the use of diagnostics and other equipment in the area.

Figure 6 shows the the existing building, crane, and 4-m cryostat. The dotted lines above the 4-m cryostat depict the test conductor and its supporting structure. The cold-sink and heat-exchanger coils used to provide cryogens to the test conductor are within the upper dotted lines. The test conductor can be removed from the test well without warming the facility.

Figure 7 provides some of the FENIX magnet-set specifications.

FORCED-FLOW HELIUM AVAILABLE FOR TEST CONDUCTOR

Figure 8 shows a schematic of the system used to provide cryogens to the test conductor. The heat exchanger is a coiled tube-in-tube unit located in the upper part of the test well. The liquid-helium bath is maintained by the Airco refrigerator and supports both lead cooling and conductor forced-flow cooling. Room-temperature helium flows from high-pressure storage through the heat exchanger, where it is cooled to near liquid-helium temperature. It then passes through a cold-sink coil where it is cooled to the liquid-helium-bath temperature. The flow then branches into four paths which can be separately controlled. Temperature to each path can be controlled by the heaters shown, as well as the bypass valve that bypasses the cold sink. Flow rate to each path can be controlled by the flow meters and valving shown in the upper right on Fig. 8.

The use of four paths provides the user with flexibility. For example, three paths might be paralleled to provide high flow to the main test conductor, and the fourth path used to provide flow to a conductor joint. Another possibility is providing flow to two different test conductors at the same time, with the ability to monitor conditions in each conductor separately.

The heaters can be used to provide pulsed or steady-state heat to the test conductors. Longer term testing with warmer inlets will probably by accomplished by using the bypass valve to avoid the heat load introduced by the heaters.

As shown, inlet and outlet temperatures, pressures, and flows to each path can be monitored. One limitation of the present design is that the same inlet pressure is provided to all paths. Pressure-dropping valves could be used to vary inlet pressures, but these are not planned unless users indicate a need for them.

The extended lip on the smaller test conductor portion of the well permits operating it dry. Here a slight amount of heat will be added at the bottom of test well to boil off any helium spillover from the upper test well. Pool-boiling conductors can also be tested by flooding the entire test well.

Flow Available for Test Conductors

Inlet pressure:	0.5 to 3.0 MPa, adjustable
Inlet temperature.	3.5 K to >10 K — 3.5 K by pumping on test well, 4.3 K by use of atmospheric test well, higher temperatures using heaters and by-pass.
Flow rate:	30 g/s total for all paths with 0.5-MPa pressure at the test coil outlet — maximum flow is proportional to pressure.

Duty cycle: Continuous with 40-kA test conductors for several hours — here an existing 10-kL dewar will supplement the liquid-helium supply to the test conductor and its leads.

TEST CONDUCTOR POWER SUPPLY, CONTROLS, AND DIAGNOSTICS

A NWL 6-V, 40-kA power supply is used as the test conductor current source. The voltage available to the sample at full current, 40 kA, is about 0.5 – 0.75 V. Water-cooled leads are used to deliver the current from the power supply, located outside the building, to the sample in the FENIX test well. The power supply will be controlled by a Hewlett Packard 9000/300 series computer with user-programmable ramping.

The diagnostics will consist of the following systems:

1. HP 9000/300 series computer at the FENIX/HFTF building with an EtherNet link to the LLL VAX 8600 on the NMFECC Network. Data will be archived on the LLL VAX in data files for the IDL data analysis/plotting software. We are planning to make the data available in WKS spreadsheet files, also for use in PC/MAC applications. This data can be available to the client/customer via the NMFECC network.

2. HP 3852 Data Acquisition Units with two multi-channel analog sampling modules. One low-speed (up to 20 samples/second with 20 channels available) Integrating DVM with high resolution and high accuracy. The second is a high-speed (up to 10,000 samples/second with 50 channels available), 13-bit, analog-to-digital converter.

3. Several miscellaneous signal conditioners are available for pressure transducers, strain gages, temperature sensors, hall probes, etc.

SCHEDULE AND CONTACTS

Anticipated completion of the FENIX facility is about April 1990. System testing and shakedown should take another three to six months. The system should then be available for conductor testing.

More information is available by contacting Don Slack (phone, 415-422-1503) or John Miller (phone, 415-422-0679) at LLNL. The mailing address is Lawrence Livermore National Laboratory, P.O. Box 5511, L-643, Livermore, CA 94550.

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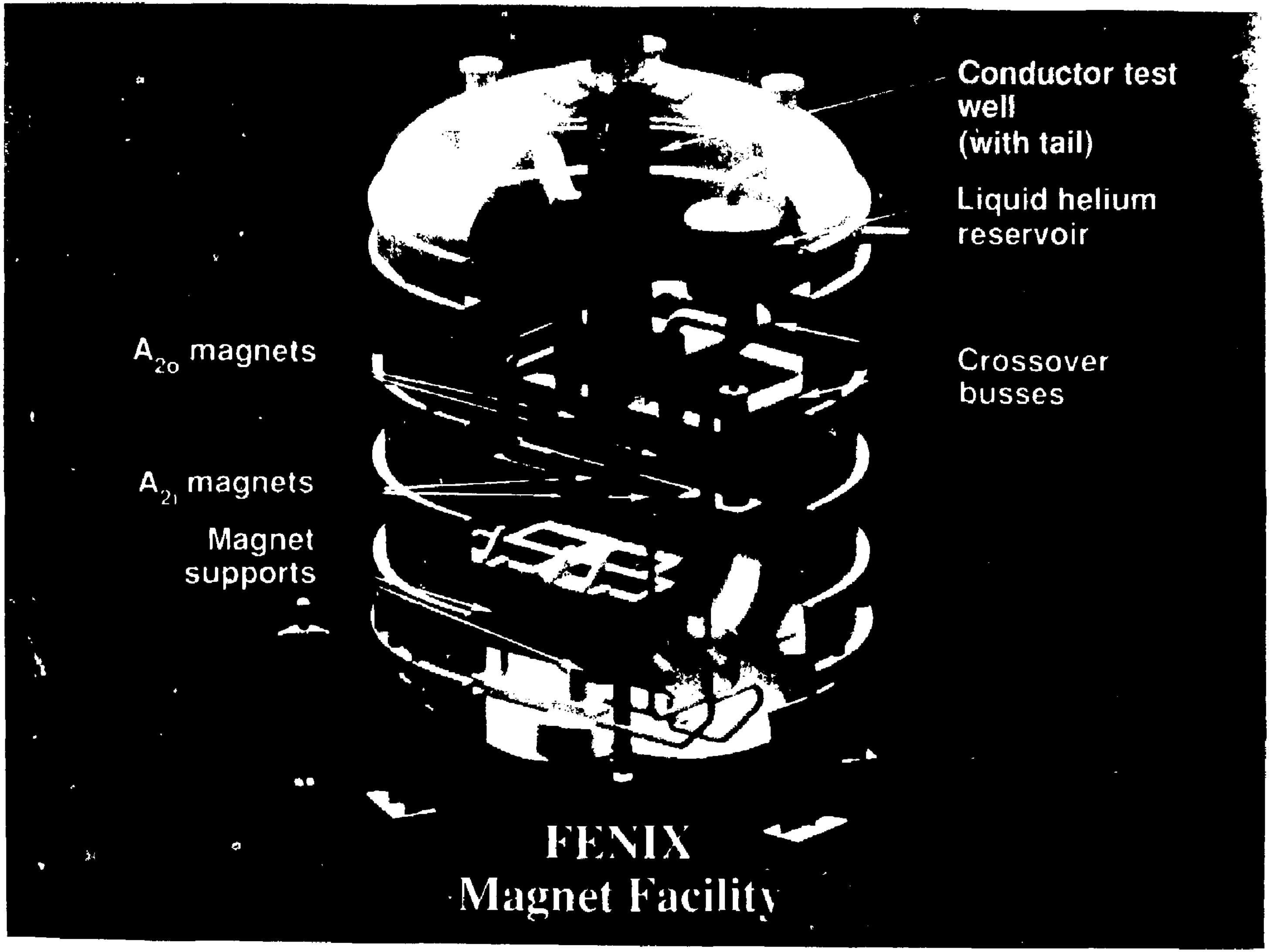
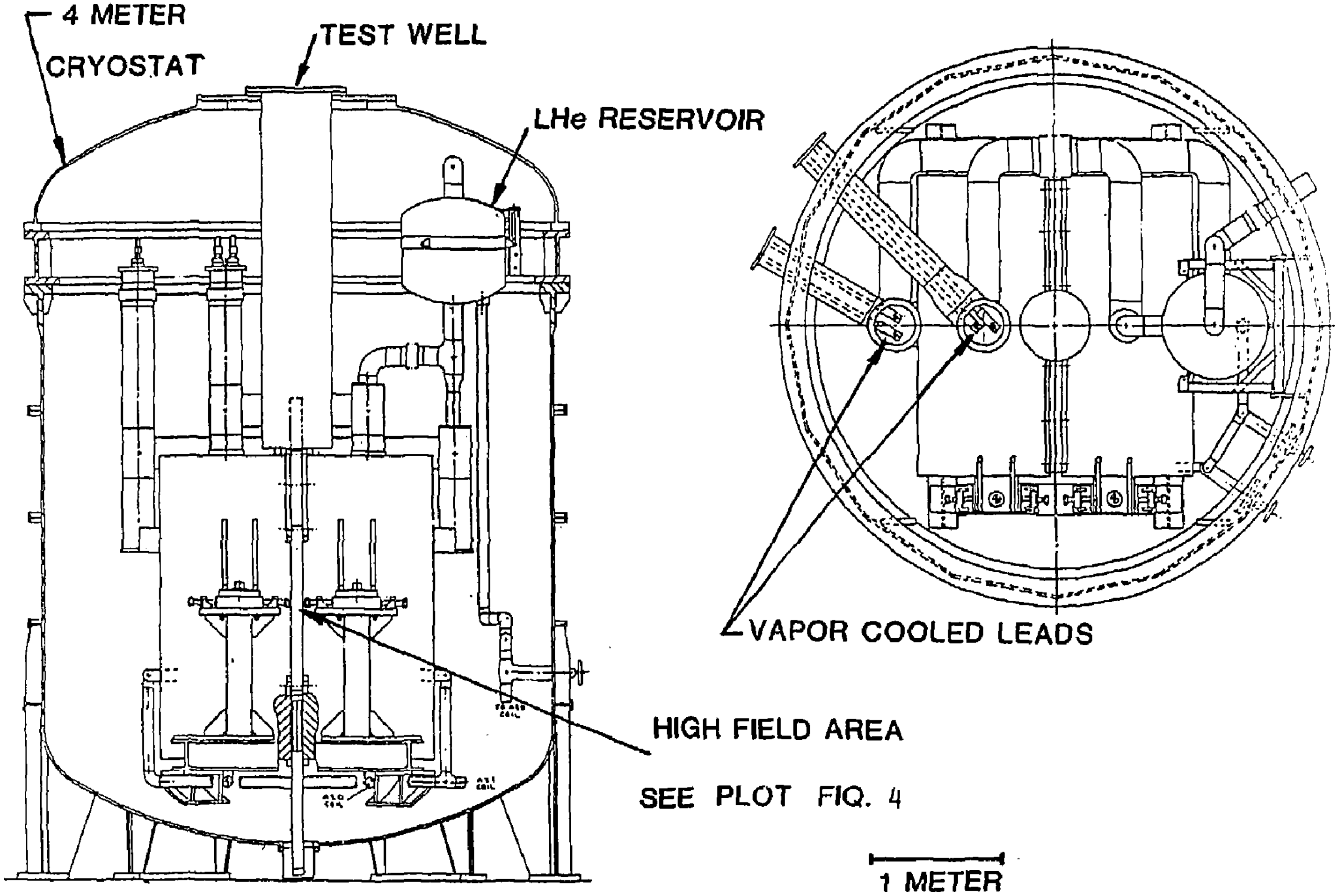
4. J. R. Van Sant and J. P. Zbasnik, *Liquid Helium Cooling of the MFTF Superconducting Magnets,* paper LI-8, IEEE Trans on Magnetics, Vol MAG-23, No. 2, March 1987.

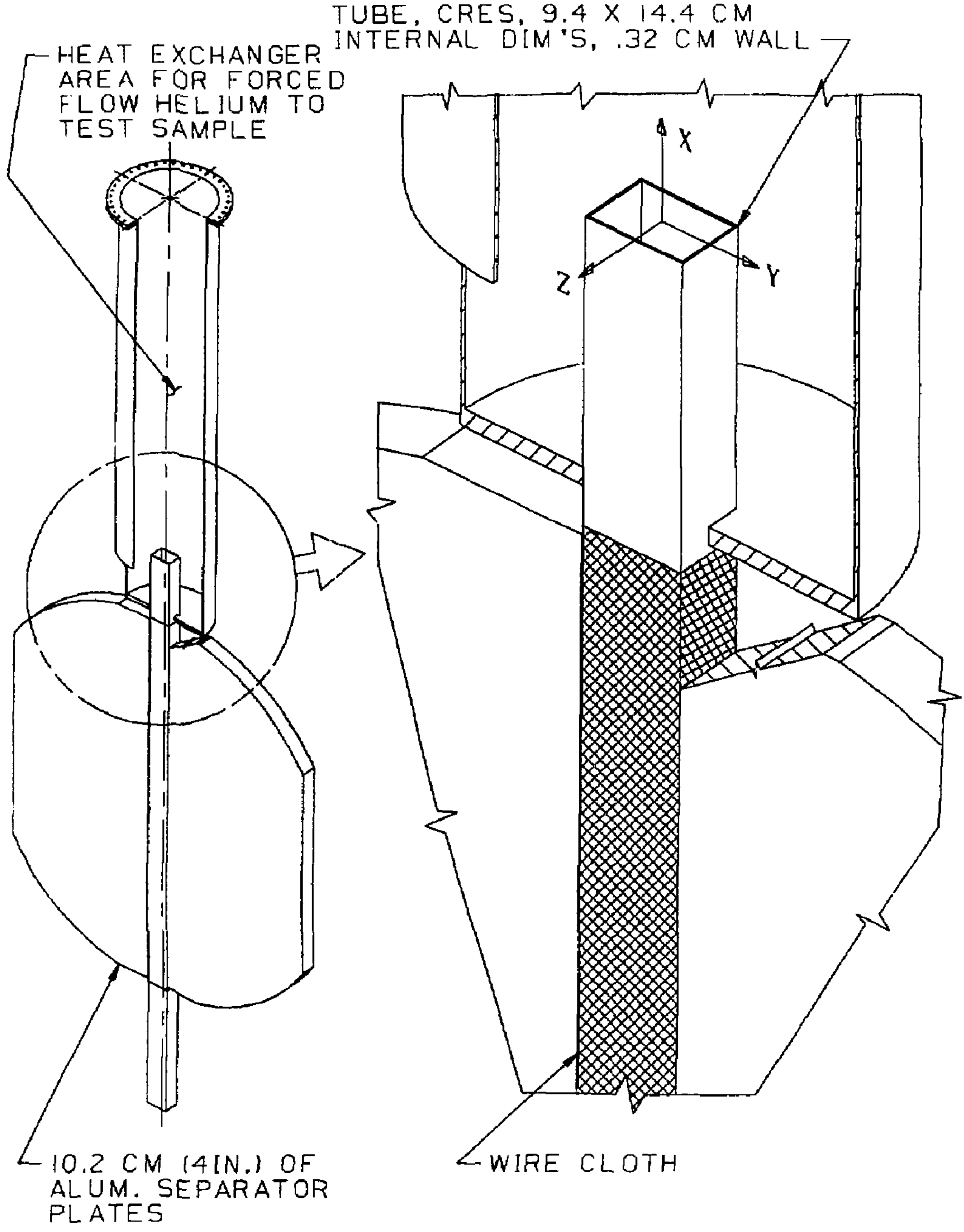

Conductor test well (with tail)
Liquid helium reservoir
Crossover busses
A_{2o} magnets
A_{2i} magnets
Magnet supports
FENIX
Magnet Facility

FIQ. 1



FENIX TEST FACILITY

FIGURE 2



FENIX TEST WELL

FIGURE **3**

LLL.FENIX.SAMPLE-WELL.SKETCH 6/28/89

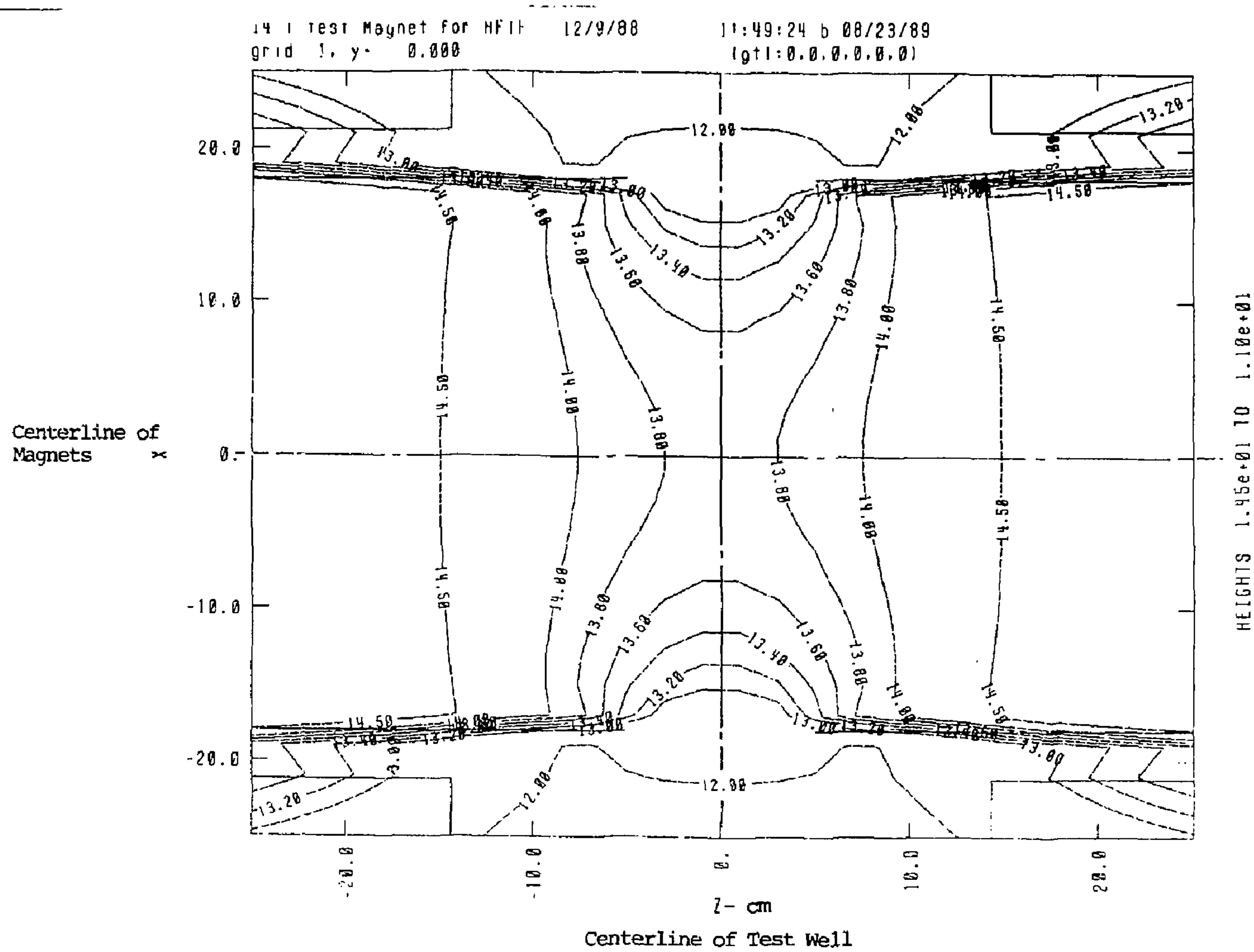
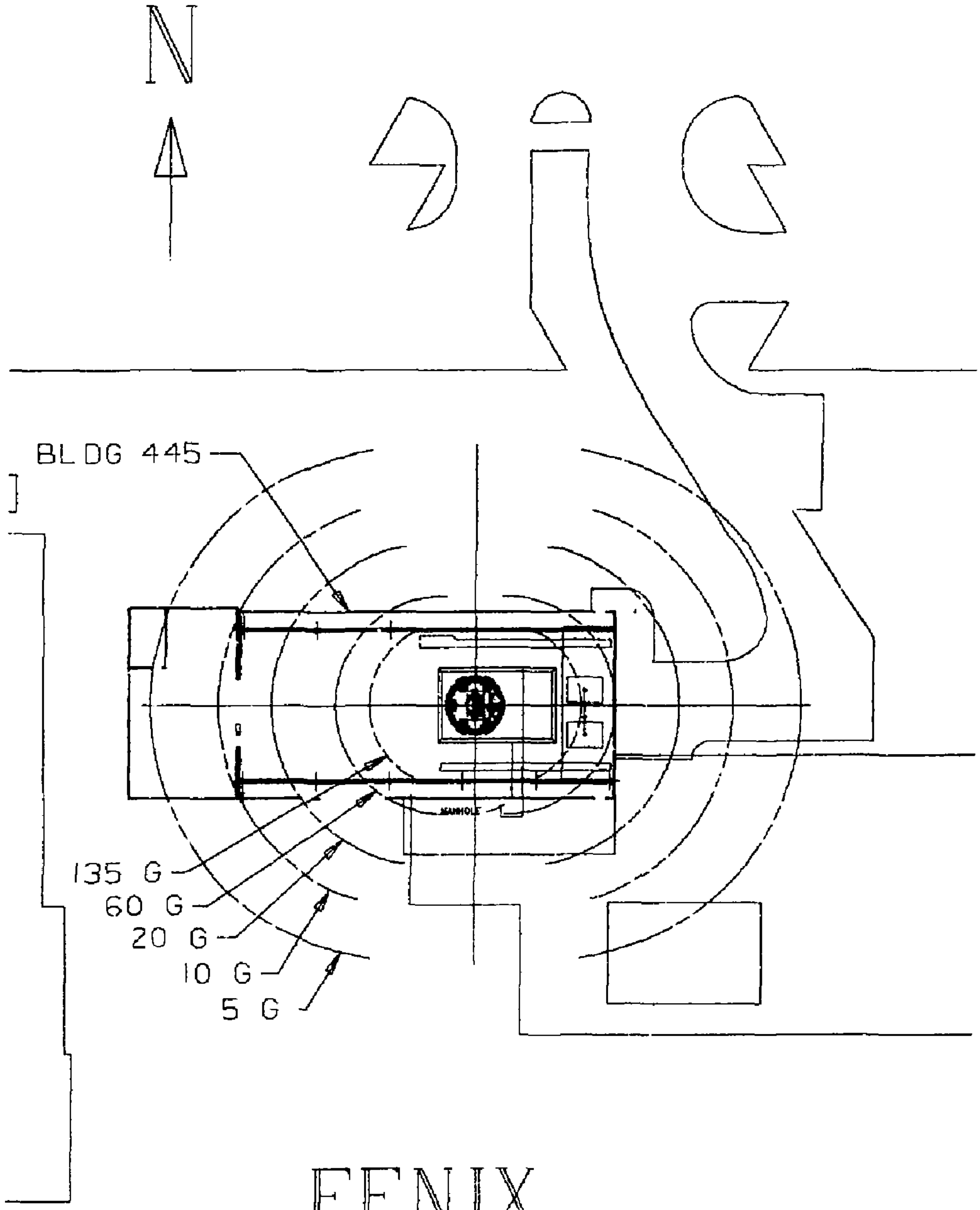


Figure 4. FENIX Test Well Field Plot

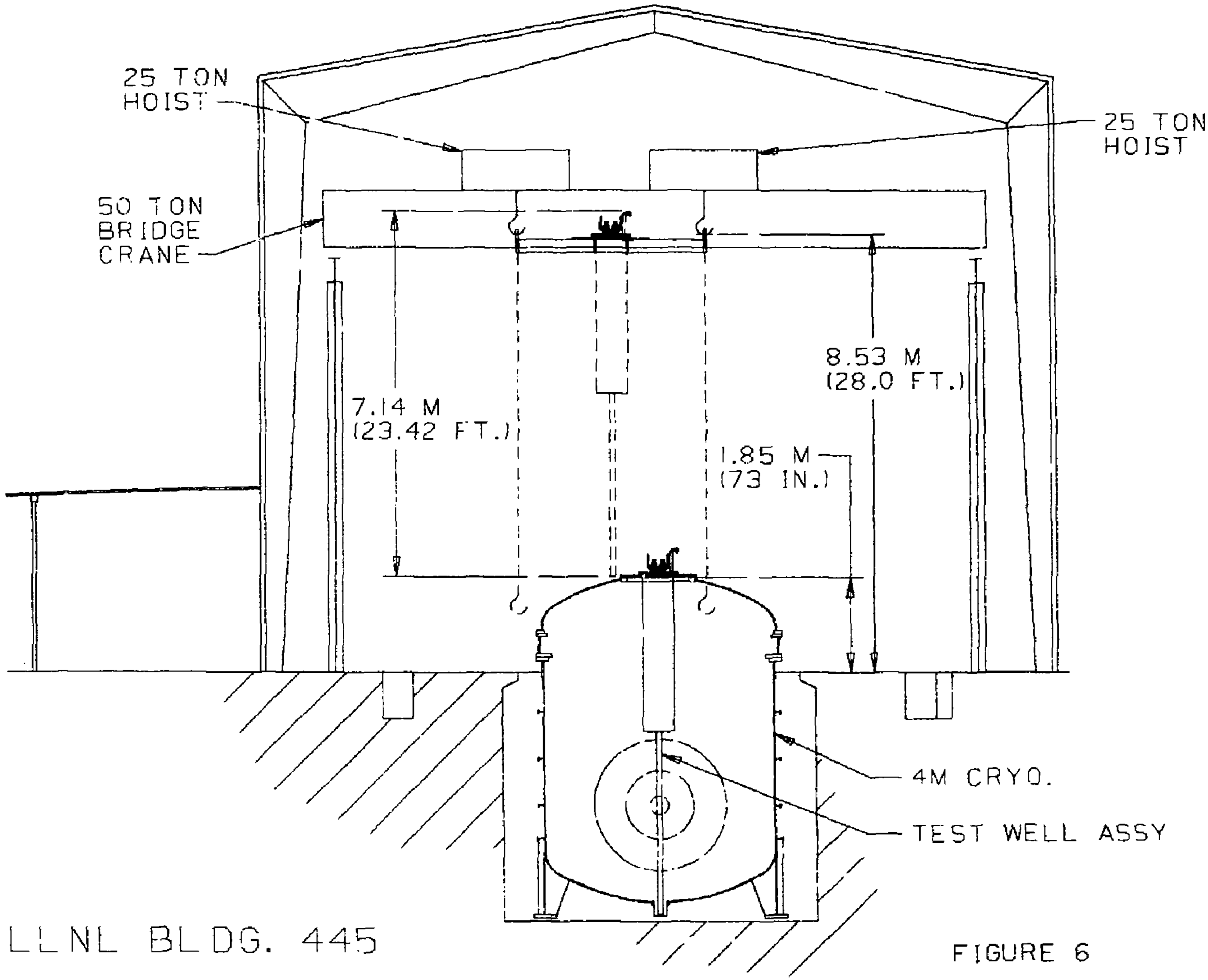


FENIX

MAGNETIC FIELD LINES FOR
BORE AXIS EAST-WEST

FIGURE 5

LLL.FENIX.BLDG-445.MAGNETIC-FL



LLNL BLDG. 445

FIGURE 6

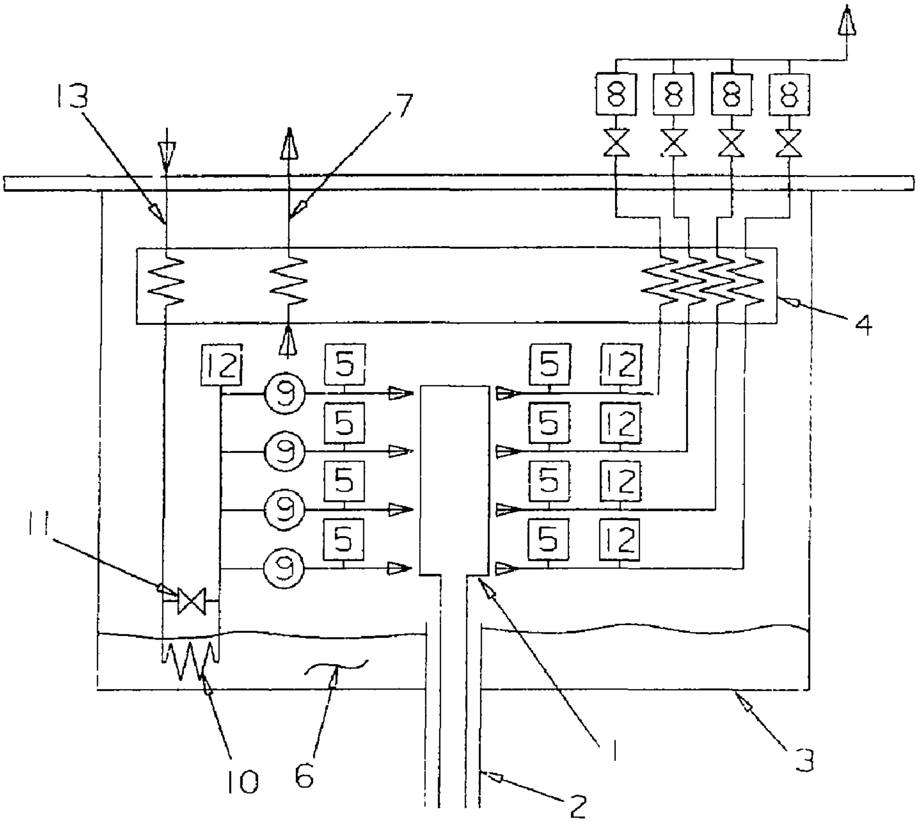
LLL.FENIX.BLDG-445.TEST-WELL-CLEARANCE

General Description of the FENIX Magnet Set

Magnet configuration:	Two independent units, each comprising a Nb_3Sn insert and a NbTi outsert. Each coil is separately encased.
Gap width:	100 mm
High-field wiring, i.d.:	360 mm
Maximum field in test volume:	14.0 T (100-mm gap, iron cores)
Total cold mass:	Approximately 75 ton
Total stored energy:	Approximately 180 MJ

Figure 7

CRYOGEN SERVICE TO TEST CONDUCTOR SCHEMATIC



1. TEST CONDUCTOR
2. CONDUCTOR TEST WELL
3. UPPER TEST WELL
4. HEAT EXCHANGER
5. TEMP. SENSORS
6. LH_e BATH IN TEST WELL
7. BATH BOIL OFF RETURN
8. FLOW METERS
9. HEATERS
10. COLD SINK COIL
11. BY PASS VALVE
12. PRESSURE TAPS
13. H_e AT -300° K

FIGURE 8

LLL.FENIX.SAMPLE-WELL.CRYOGEN-SERVICE