Hans J.
Schneider-Muntau
NHMFL

"Status and Mission of the NHMFL"

Ask me about

FLORIDA'S MAGNETIC NORTH

PARTNERS IN TECHNOLOGY: FLORIDA AND NSF

OPERATED BY: FLORIDA STATE UNIVERSITY
UNIVERSITY OF FLORIDA
LOS ALAMOS NATIONAL LABORATORY

SUPPORTED:
NATIONAL SCIENCE FOUNDATION
STATE OF FLORIDA

NATIONAL HIGH MAGNETIC FIELD LABORATORY

INSTITUTIONS:

- FLORIDA STATE UNIVERSITY
- UNIVERSITY OF FLORIDA
- LOS ALAMOS NATIONAL LABORATORY

MISSION STATEMENT:

TO ESTABLISH A STATE-OF-THE-ART HIGH MAGNET FIELD FACILITY DRIVEN BY AN INTERNATIONALLY COMPETITIVE IN-HOUSE RESEARCH AND DEVELOPMENT PROGRAM AND RESPONSIVE TO THE NEEDS OF THE USER COMMUNITY, I.E., THE CREATION OF A FACILITY CAPABLE OF SUPPORTING RESEARCH AT THE EXTREMES OF PARAMETER SPACE, E.G., P,T. AND B.

What?

*National and International User Facility to Support Research and Development

-Biology

-Bio-Medical

-Engineering

-Chemistry

-Materials Science

-Physics

*Investment into Technology and Science of the 21st Century.

-U.S. competitiveness is based on educational and innovative vision.

NHMFL R&D

*New Materials
- -Semiconductors
- -Superconductors
- -Polymers & Low Dimension Systems
- -Advanced Composites

(Engineered Materials)

*Nuclear Magnetic Resonance
- -MR Imaging
  (High resolution and imaging of other elements)

*New Technologies
- -Levitated transportations
- -Magnetic Separation
- -Magnetic Materials
- -Power Industry
  - Energy Storage
  - Protection Systems
  - Power Generation
- -Magnetic Ship Drives
- -Advanced Imaging

COUNCIL 100 horz

National High Magnetic Field Laboratory

Construction and Operating Support

Construction Costs	
State of Florida	$55.3M
NSF (DC Supply & Bus)	$9.5M
Universities & other sources	
Total Construction	$8.4M
	$73.2M

Annual Operating Budget	
NSF	$12.0M
State of Florida*	$7.4M

*includes $1.2M / yr for visitors program

Equipment (Central)	
State of Florida	$11.0M

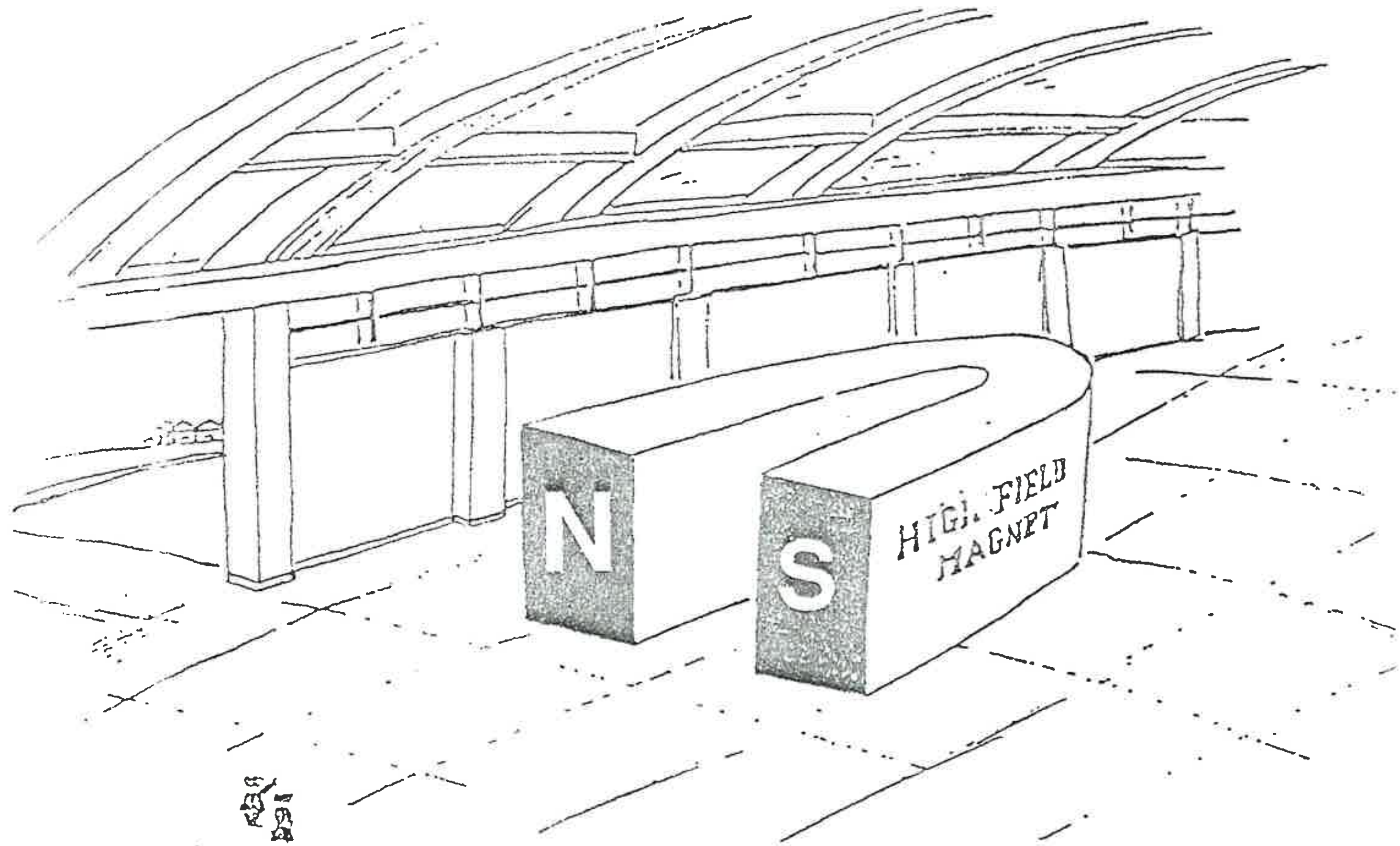
Staffing (~125 new positions)

- State Supported
  - 41 New Faculty / Scientist Positions
    - 4 Director, Deputy Director & other administration
    - 10-12mth Scientist Scholars
    - 27 Tenure Faculty Lines
      - 18 Experimental
      - 9 Theory
  - 20 Visiting Faculty (1.2 M/Yr Visitor Program)
  - 15 Technical Administrative Staff Support
- NSF Supported
  - 4 Faculty Positions
  - 35 Technical Support

MAGNET DEVELOPMENT
& TECHNOLOGY GROUP

PROJECTS

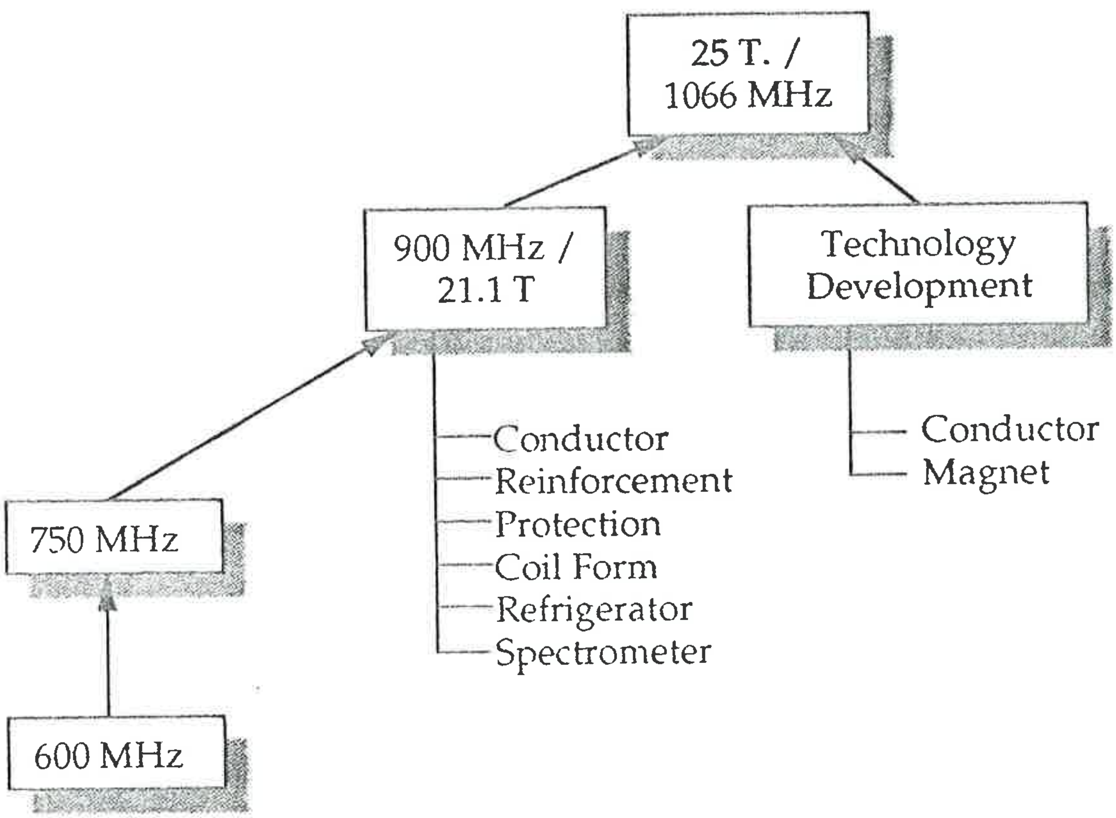
- 25T NMR (900MHz, 1GHz, 25T)
- 45T Hybrid
- 20-40T Resistive Magnets
- Cryogenics and HTS Development
- Pulsed Magnets Development
  (with NHMFL-LANL)
- Magnetic Materials Development



YOU TOLD ME THAT THE PRINCIPLE OF THE
TALLAHASSEE HIGH FIELD MAGNETS IS SIMPLE,
BUT STILL...
THIS IS HARDLY WHAT I EXPECTED...

NHMFL

Very High Field NMR
Program Structure

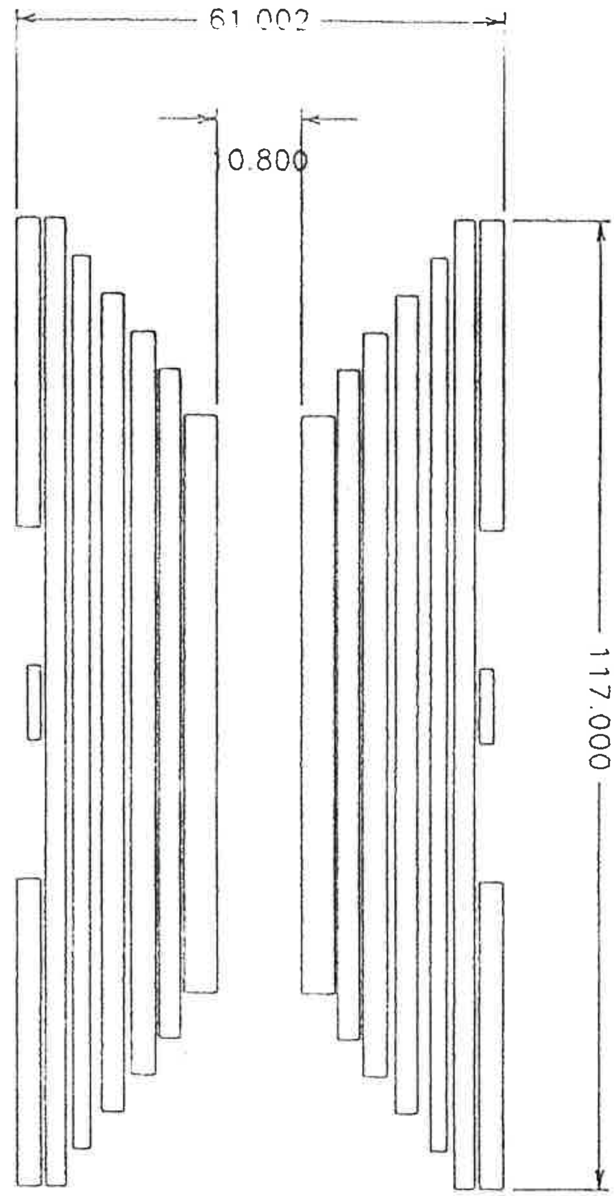


HIGH RESOLUTION NMR MAGNETS

CONDUCTOR WEIGHT AND STORED ENERGY vs. PROTON NMR FREQUENCY

f (MHz)	W (kg)	E(MJ)
600	140	0.8
750	470	5.4
850	1120	13.7
900	1400	20.0
1066	1650	26.8

1066 MHz SPECTROMETER MAGNET



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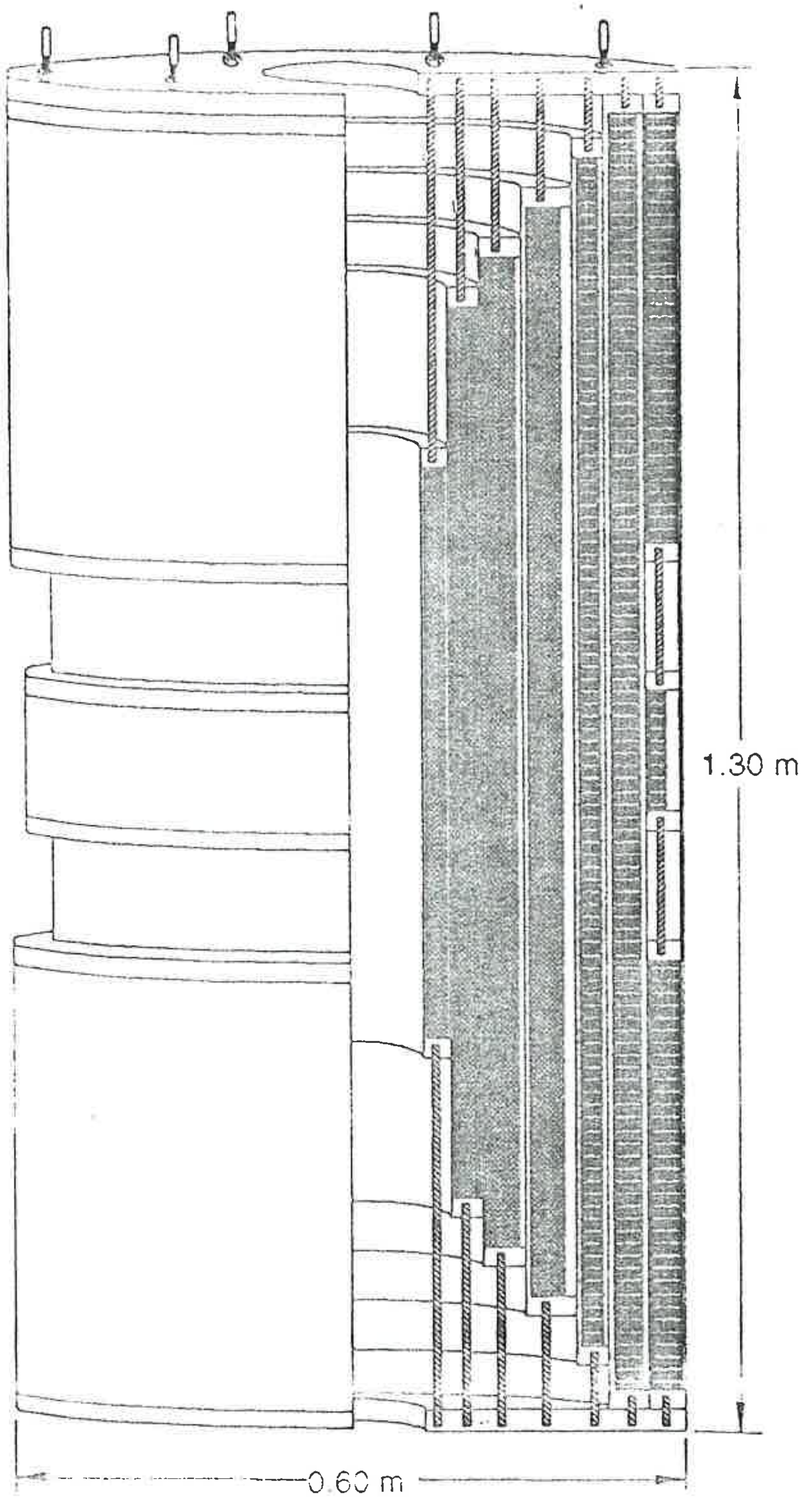
9/92 Vertical 3

900 MHz NMR MAGNET



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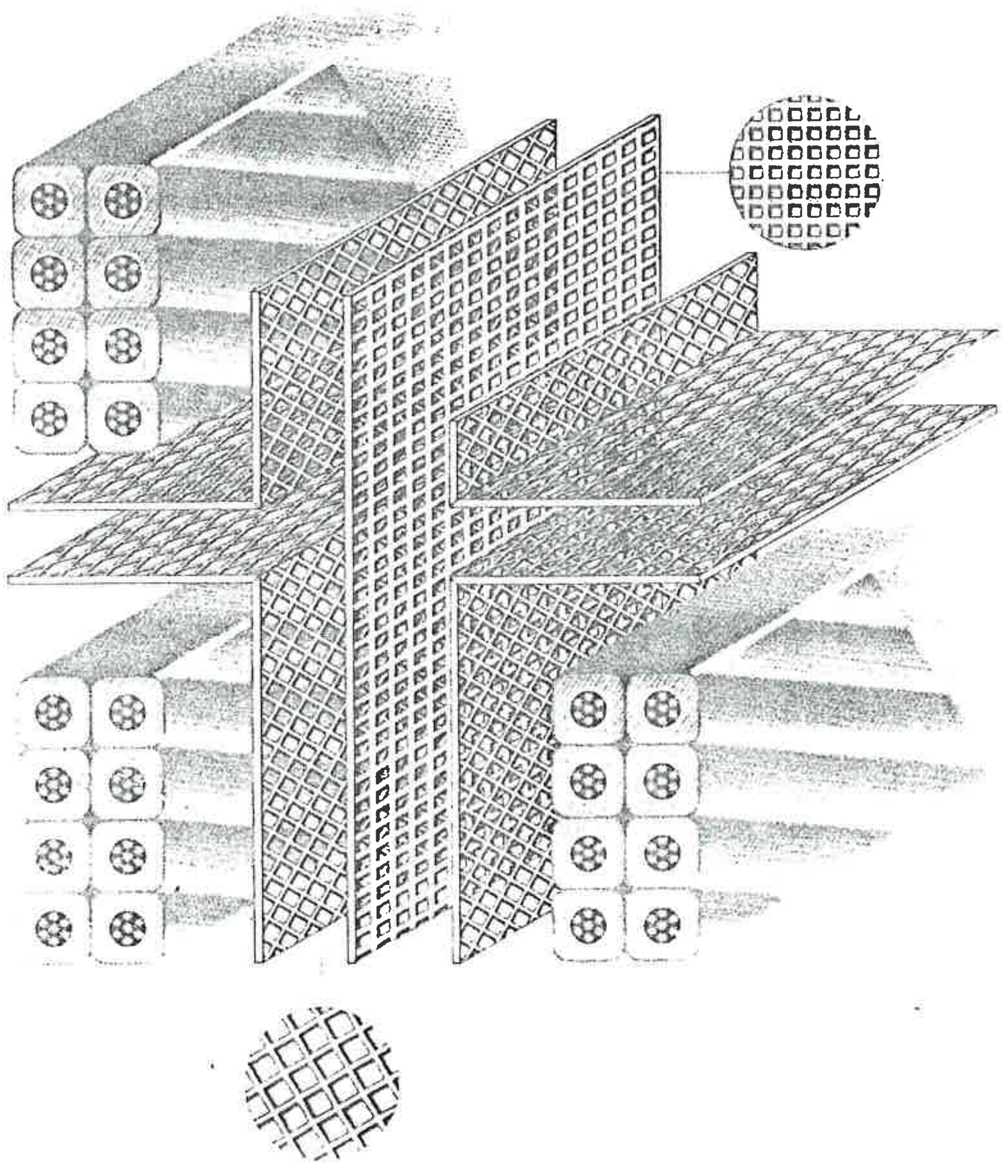
NMR MAGNET TECHNOLOGY DEVELOPMENT

- Jc CONDUCTOR SURVEY
- Jc vs. STRAIN, STRAND
- Jc vs. STRAIN, CABLE
- HIGH STRENGTH Nb_3Sn
- STRESS-STRAIN: STRAND, CABLE, WINDING BUNDLE
- EPOXY PROPERTIES, PROCESSING
- WINDING BUNDLE MECHANICAL PROPERTIES
- COIL FORM SUSCEPTABILITY
- QUENCH HEATER CHARACTERISTICS
- QUENCH PROPAGATION RATE
- SIZING REMOVAL
- ALTERNATIVE INSULATION
- BONDED TERMINALS
- THIN BORE TUBE SUPPORT
- MACHINABLE THICK BORE TUBE
- AXIAL COMPRESSION EFFECTS
- HOTSPOT ANALYSIS
- CABLE DEVELOPMENT PROGRAM
- PERSISTENT JOINTS



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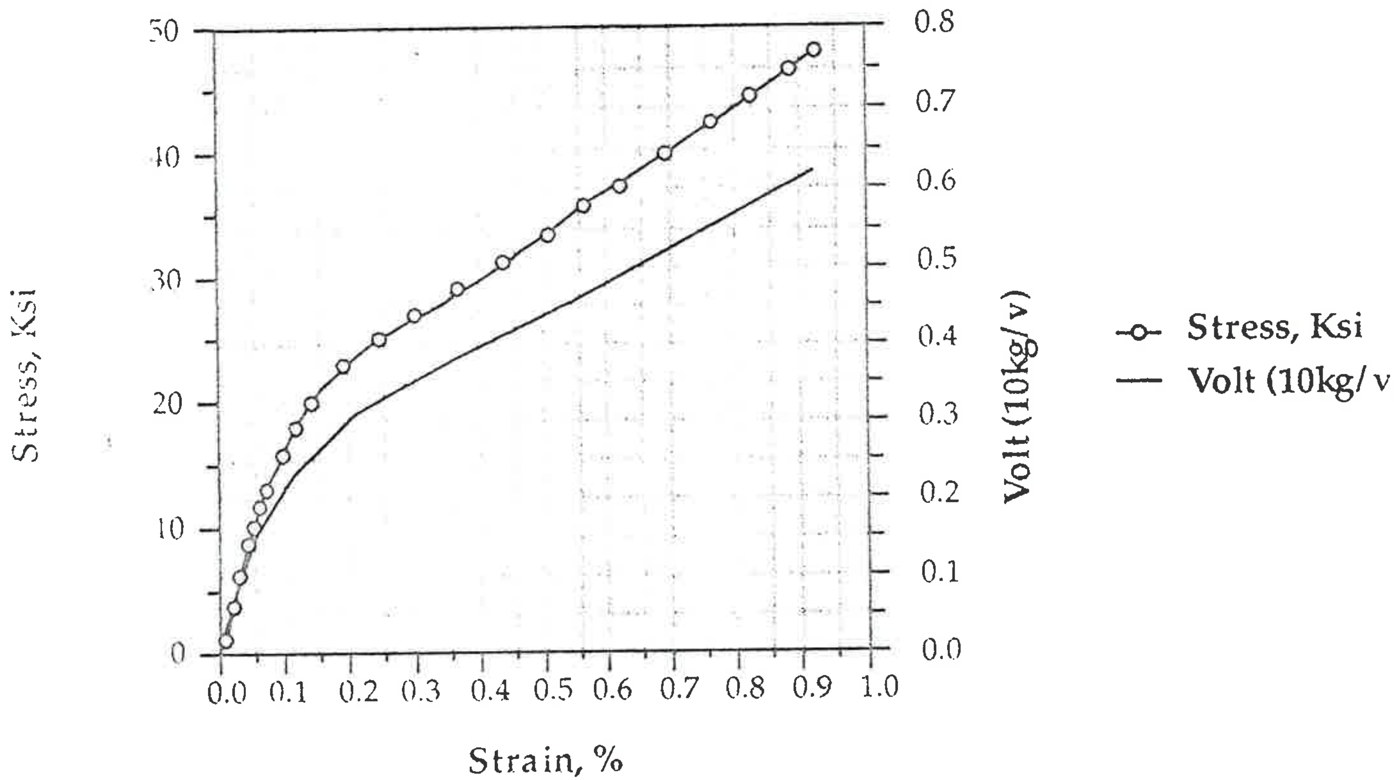
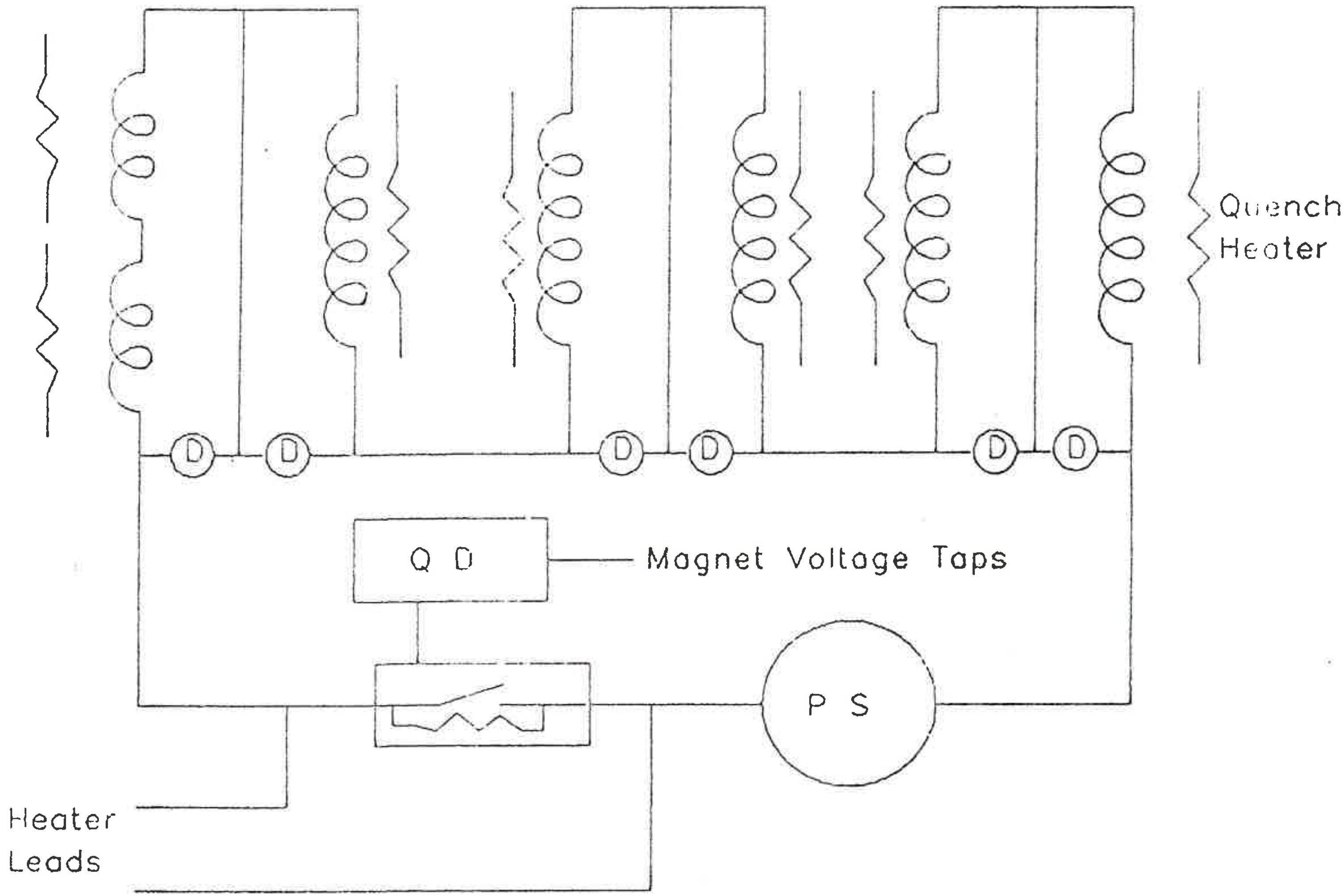
10/92 Markiewicz

IGC .01" dia. Nb3Sn(Ti), 4K (3/88)





HSM 003 9/22/92

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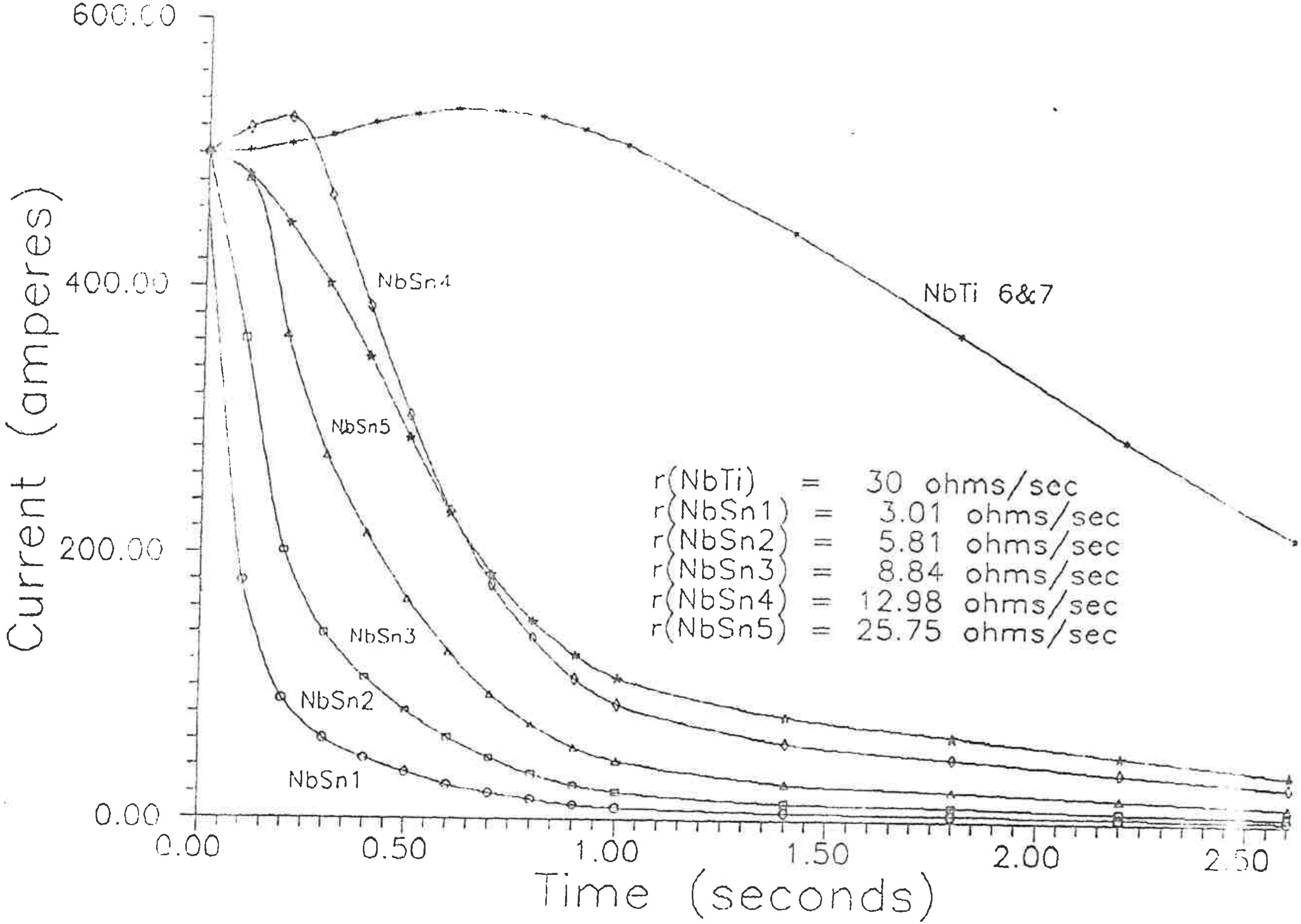
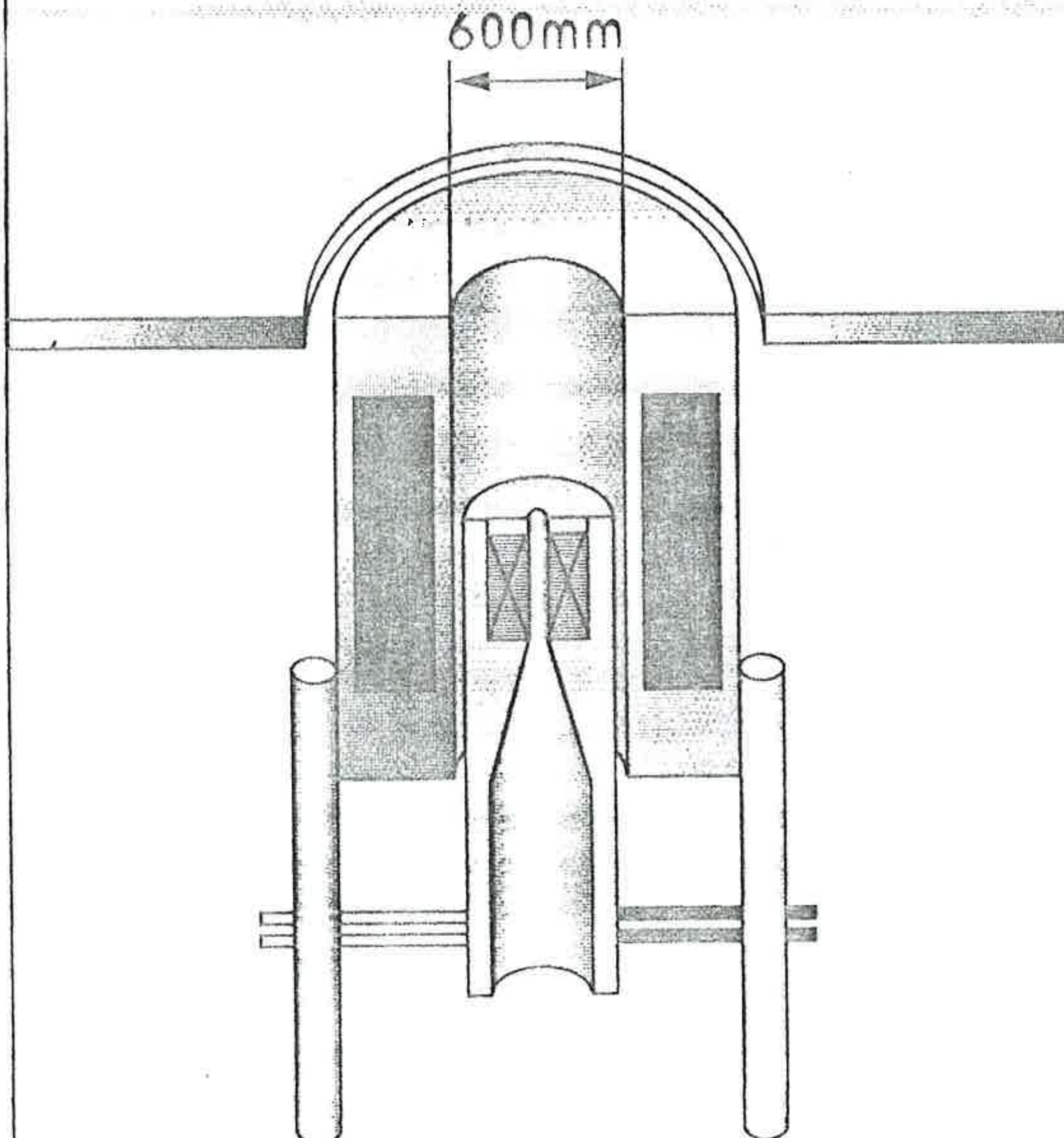


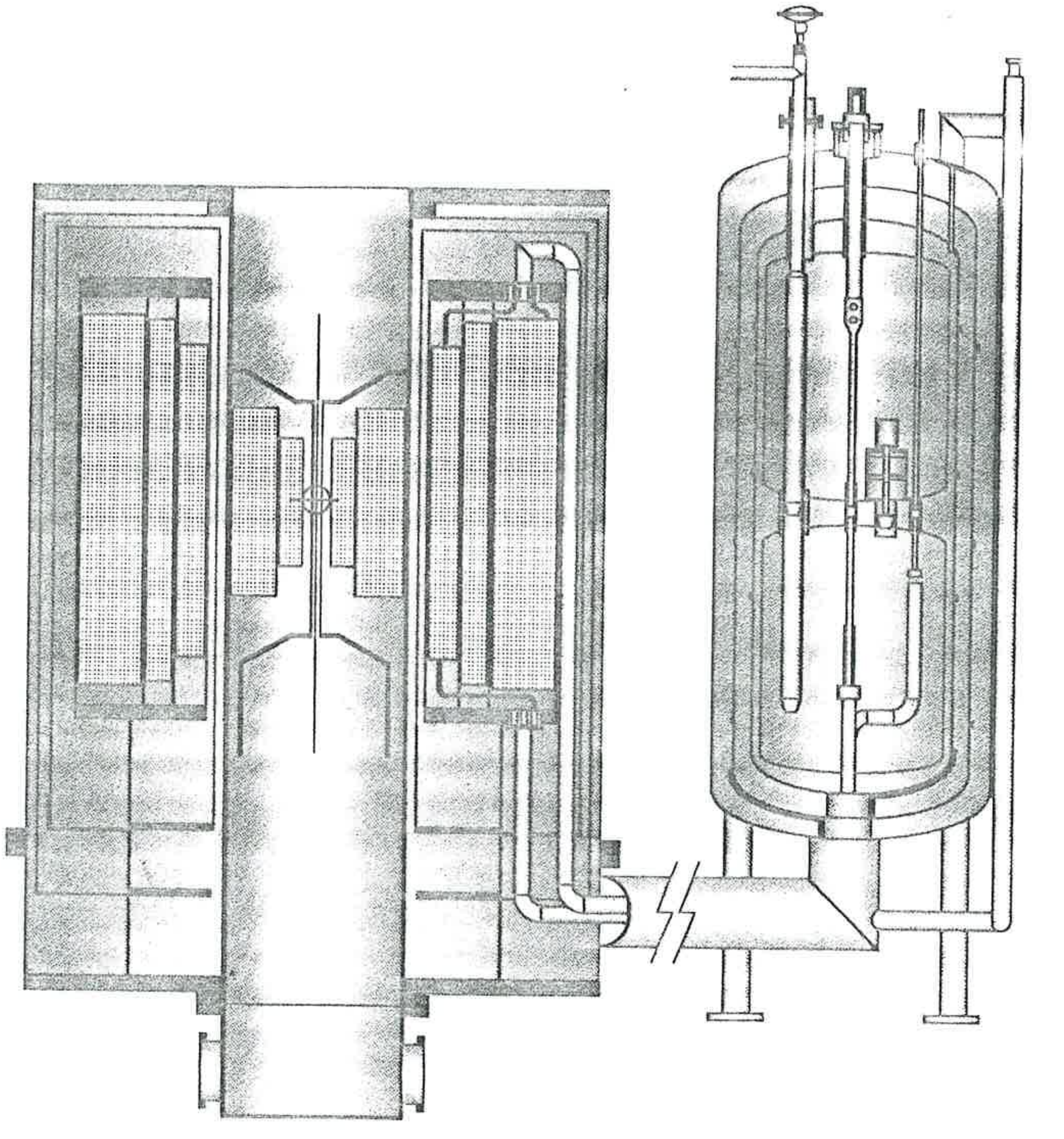
HSM 002 9/22/92

NATIONAL HIGH MAGNETIC FIELD LABORATORY



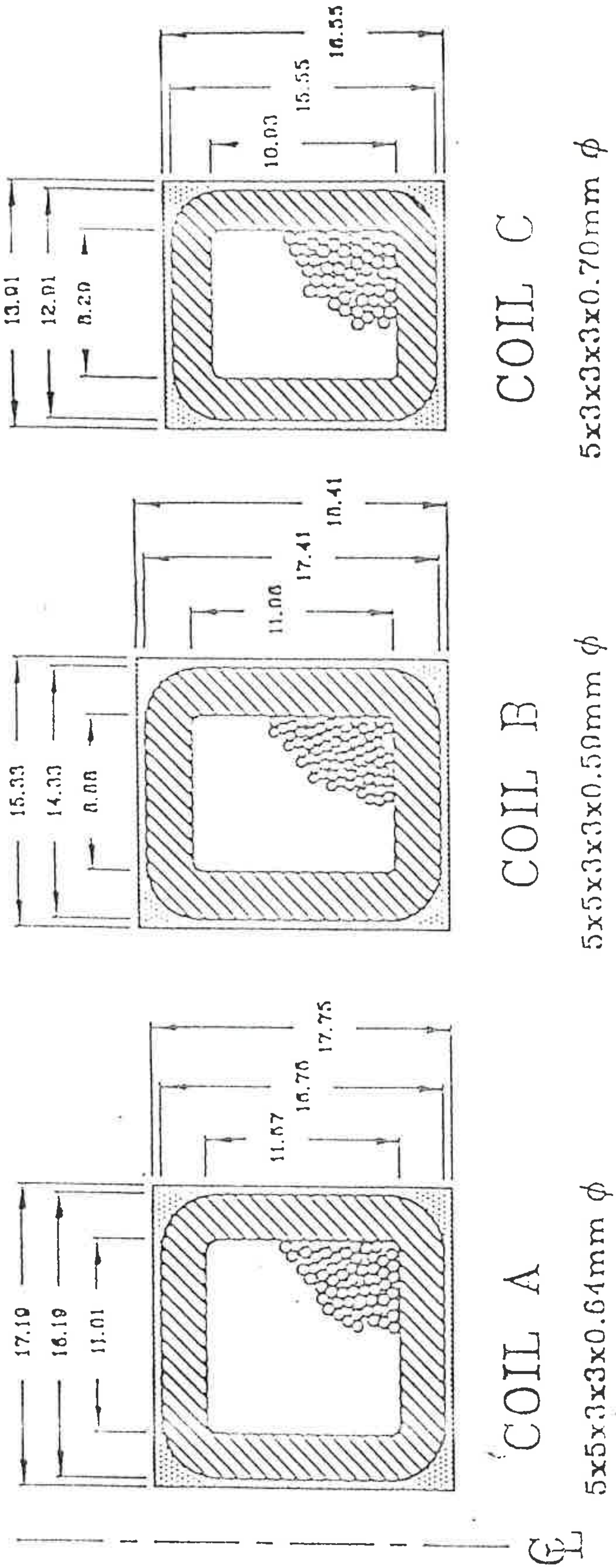
NHMFL HYBRID MAGNET

National High Magnetic Field Laboratory

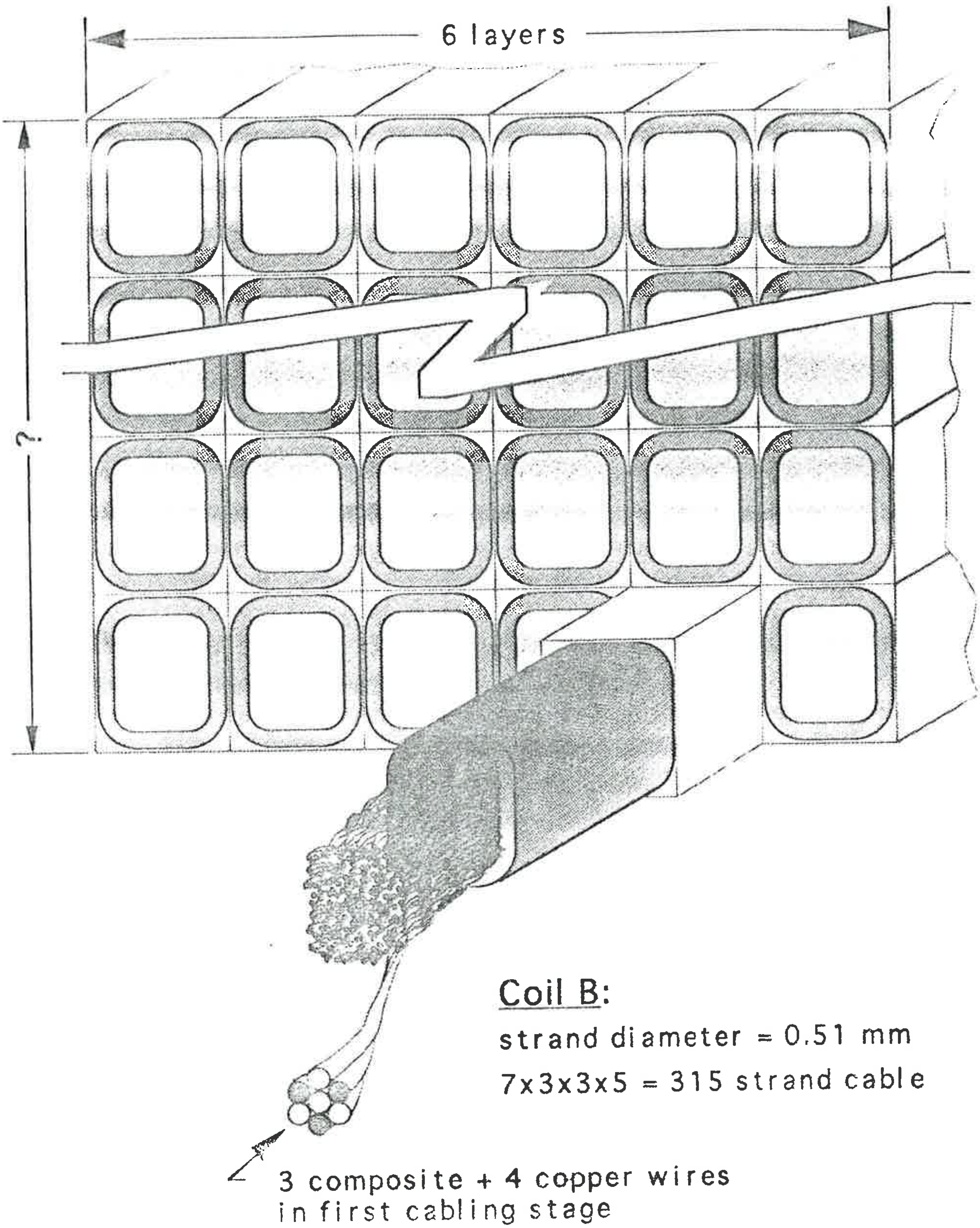


VII. Summary o[illegible] electromagnetic parameters (fields, current densities, inductances,
ne Design.

Normal operating current, insert on or off (kA):		10.00		
Current after trip of 32 MW insert (kA):		10.95		
Outsert self inductance (H):		2.12		
Discharge voltage (kV):		(term.-term.)	(term.-grnd.)	
normal operation		4.24	2.12	
after insert trip		4.64	2.32	
	on axis	coil A (1st layer)	coil B (1st layer)	coil C (1st layer)
Field on the mid-plane (T):				
outsert only charged	14.22	14.97	11.82	6.95
outsert and insert charged	49.14	13.39	10.82	6.39
outsert overcurrented after insert trip	15.64	16.46	13.00	7.64
Winding pack current density (A/mm2):		coil A	coil B	coil C
normal operation		32.95	35.60	43.65
after insert trip		36.07	38.98	47.79
Cable space current density (A/mm2):				
normal operation		79.16	94.79	111.28
after insert trip		86.66	103.77	121.83

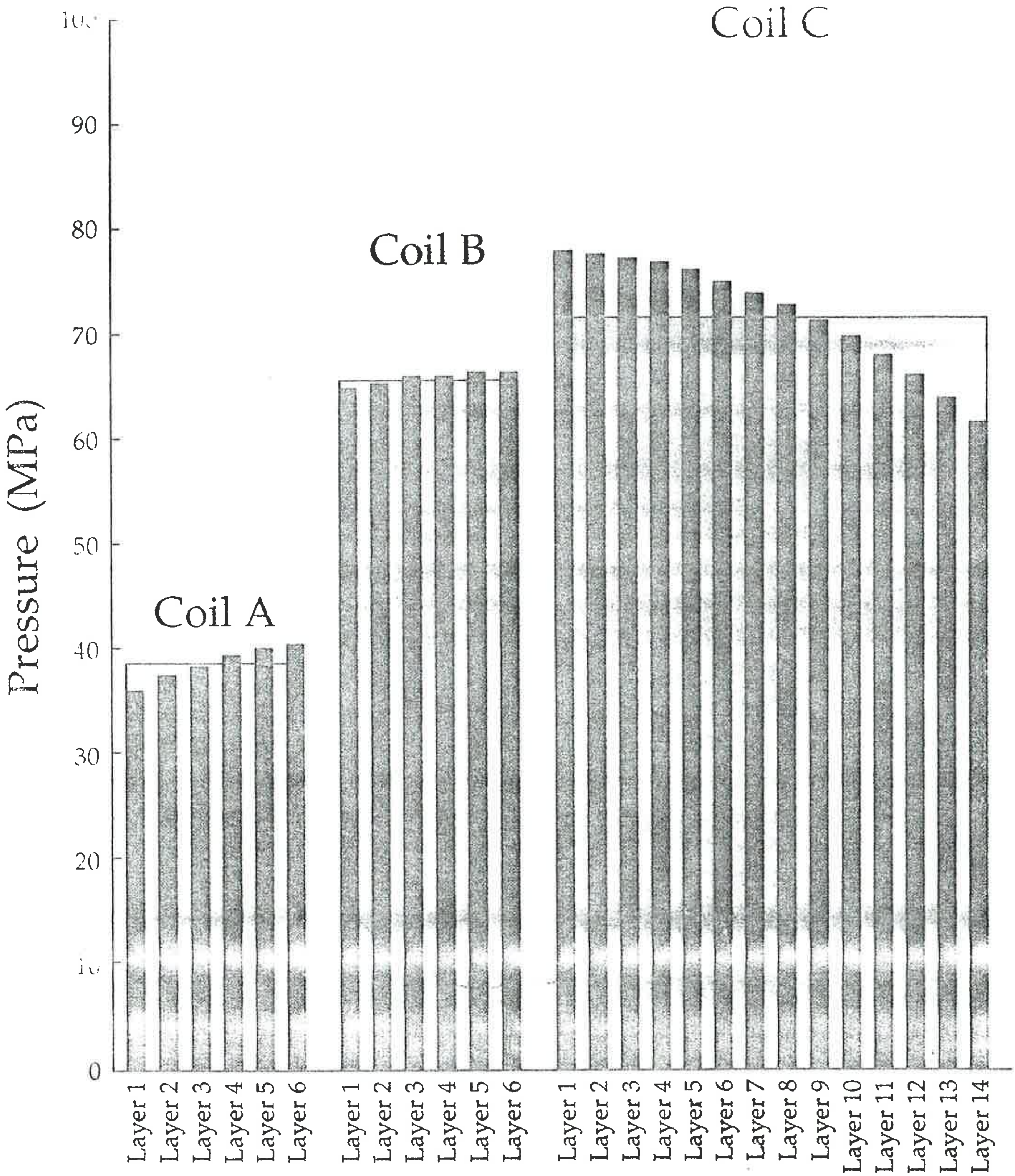


cable-in-conduit conductors for the three outsert subcoils

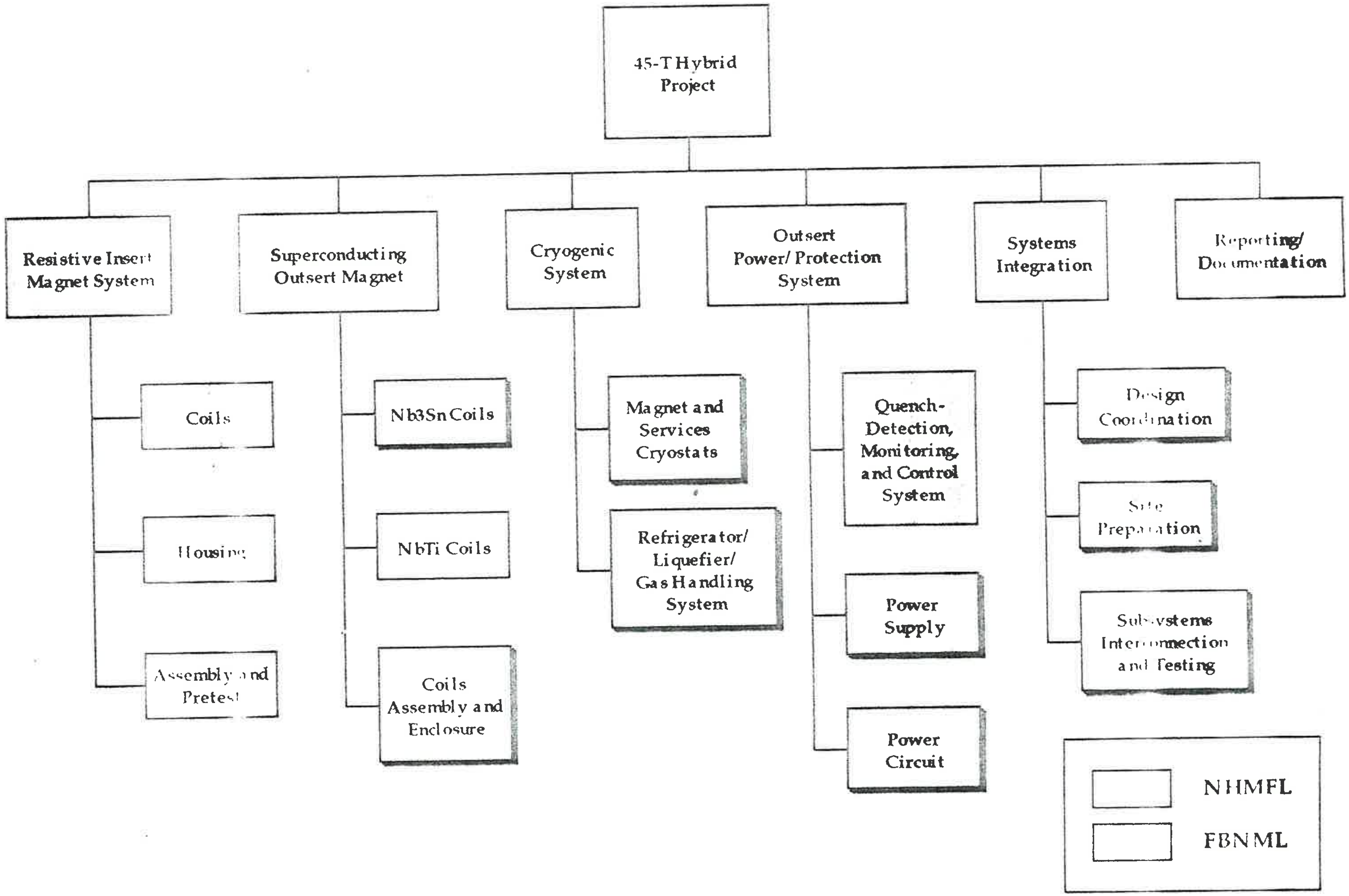


6 layers
?
Coil B:
strand diameter = 0.51 mm
7x3x3x5 = 315 strand cable
3 composite + 4 copper wires
in first cabling stage

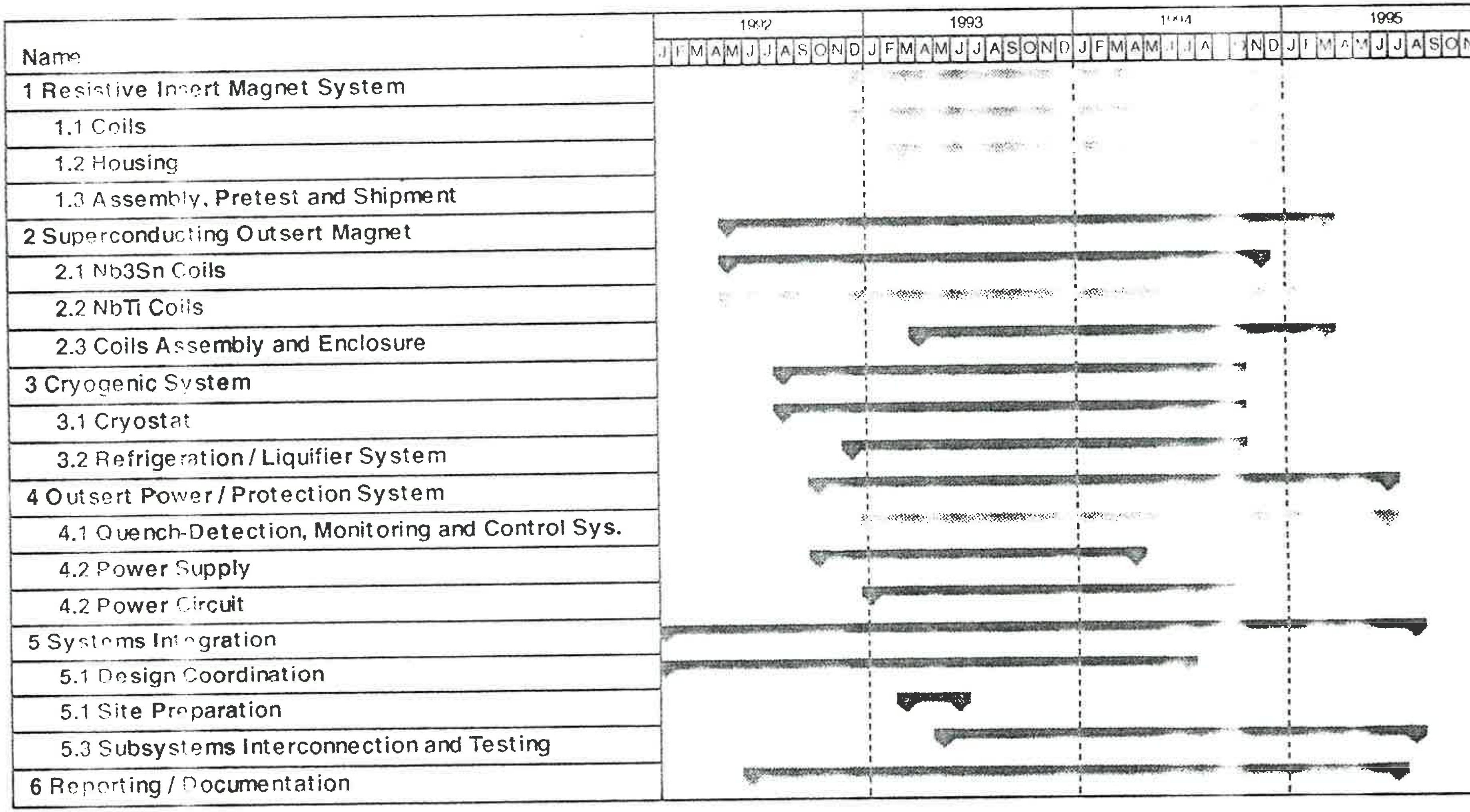
June 1992 Revision



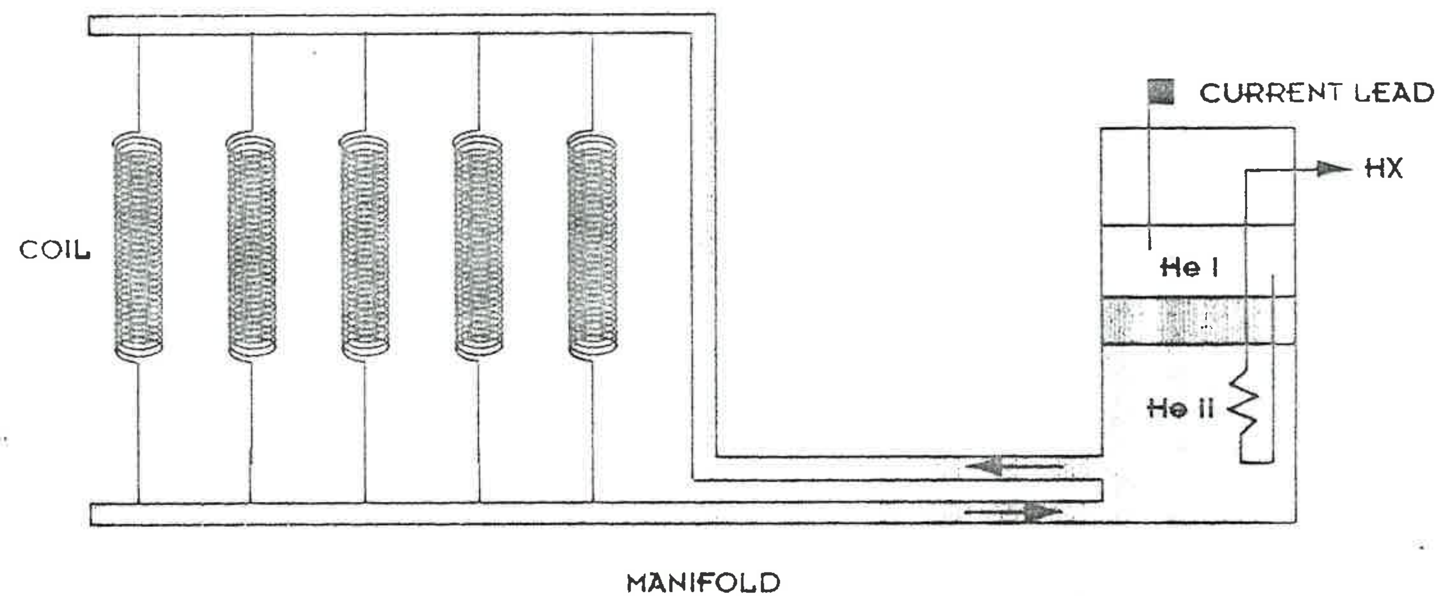
Pressure Graph June



Schedule (Pro) 1/93.MP [1]


Name
1992
1993
1995
1 Resistive Insert Magnet System
1.1 Coils
1.2 Housing
1.3 Assembly, Pretest and Shipment
2 Superconducting Outsert Magnet
2.1 Nb3Sn Coils
2.2 NbTi Coils
2.3 Coils Assembly and Enclosure
3 Cryogenic System
3.1 Cryostat
3.2 Refrigeration / Liquifier System
4 Outsert Power / Protection System
4.1 Quench-Detection, Monitoring and Control Sys.
4.2 Power Supply
4.2 Power Circuit
5 Systems Integration
5.1 Design Coordination
5.1 Site Preparation
5.3 Subsystems Interconnection and Testing
6 Reporting / Documentation

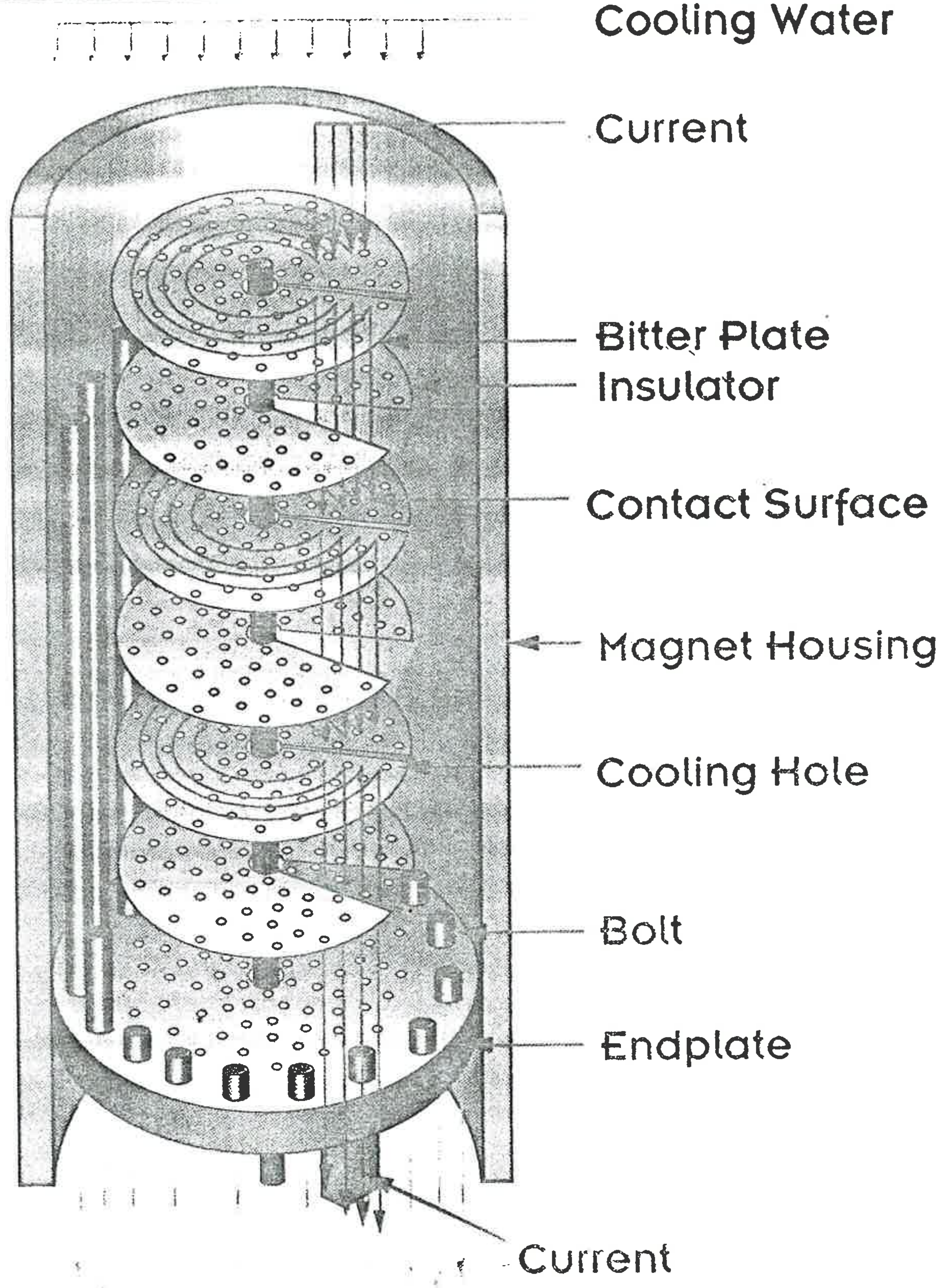
1.8K CRYOGENIC SYSTEM for 45T ICCS-HYBRID

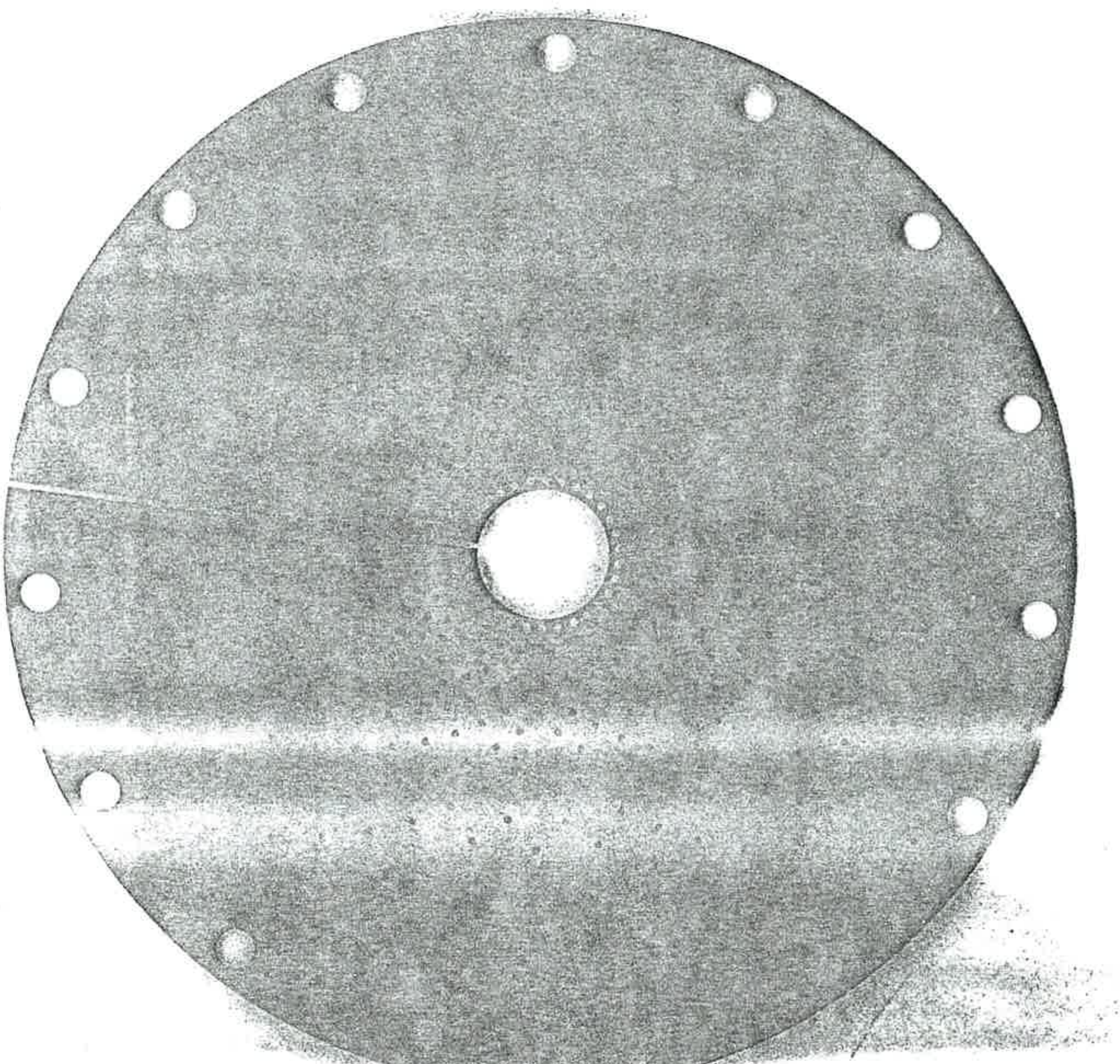


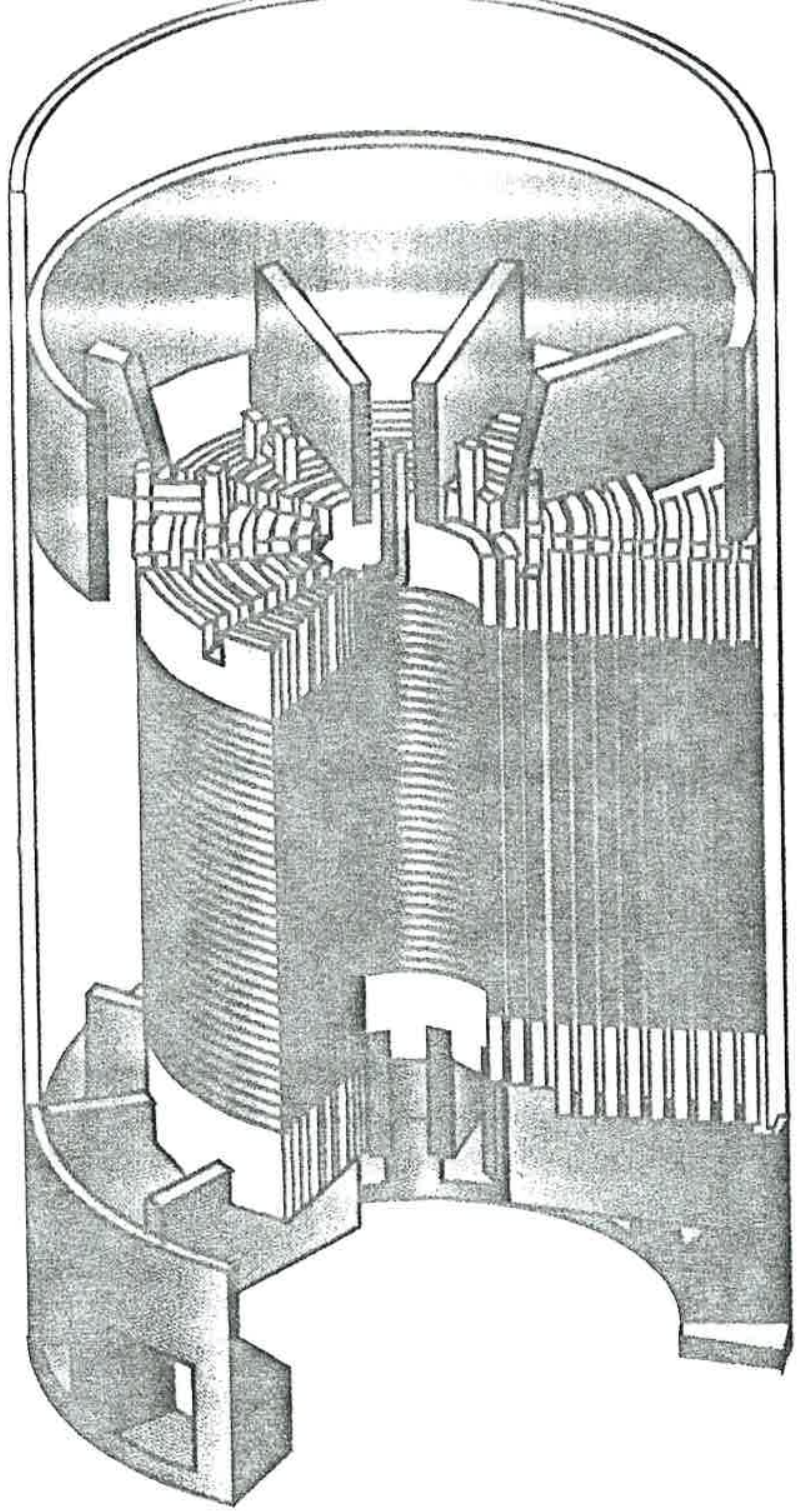
General features:

- Static He II within manifold & coils.

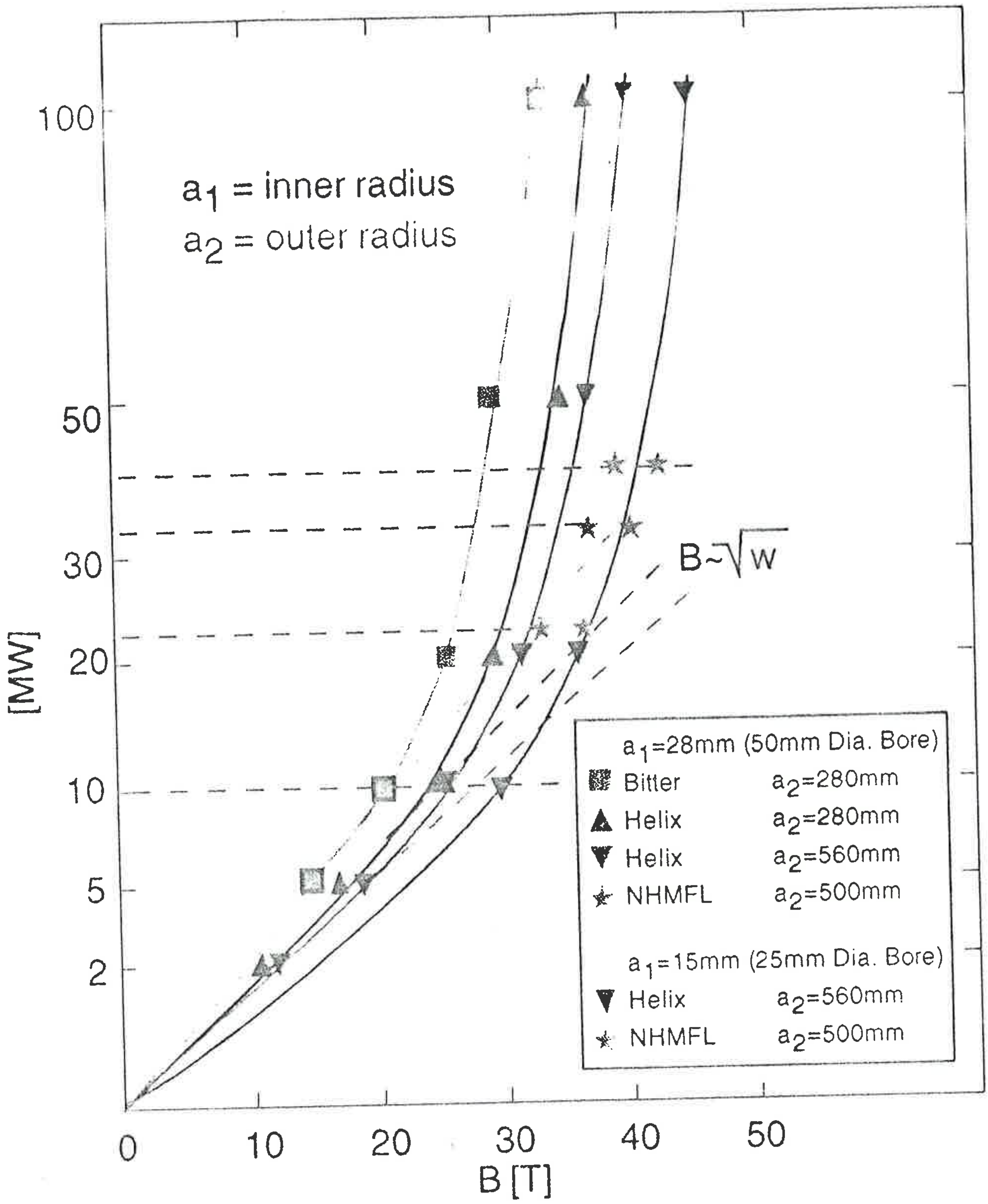
- Cryogenic Systems & Instrumentation in Separate Cryostat.


Cooling Water
Current
Bitter Plate
Insulator
Contact Surface
Magnet Housing
Cooling Hole
Bolt
Endplate
Current





NATIONAL HIGH MAGNETIC FIELD LABORATORY


a1 = inner radius
a2 = outer radius
B~√W
[MW]
100
50
30
20
10
5
2
0
10
20
30
40
50
B [T]
a1=28mm (50mm Dia. Bore)
Bitter a2=280mm
Helix a2=280mm
Helix a2=560mm
NHMFL a2=500mm
a1=15mm (25mm Dia. Bore)
Helix a2=560mm
NHMFL a2=500mm

NHMFL POWER SUPPLY

Performance Requirements

Ripple and noise (0-500 Hz):	10 ppm
Stability including ripple:	100 ppm
Repeatability including ripple:	100 ppm
Resolution between adjacent steps:	10 ppm
Accuracy (current calibration):	1000 ppm

Power Ratings

Nominal rating	**24 MW**	**32 MW**	**40 MW**
Voltage	400 V	500 V	500 V
Current	17 kA	17 kA	20 kA
Maximum rating	4x6.8 MW 27.2 MW	4x8.5 MW 34 MW	4x10 MW 40 MW
Maximum operating time	infinite	12 hours	1 hour

Cooling Circuit

4 pumps, each 30 bars, 100 l/s

4 chillers, each 7 MW, storage tank $3.8 \cdot 10^3$ m^3 = 56 MWh

7°C, 10 MΩ cm, gas free, low vibration level

TALLAHASSEE

Average installed power 500 MW

Population 130,000

installed power per capita ~ 4 kW

NHMFL

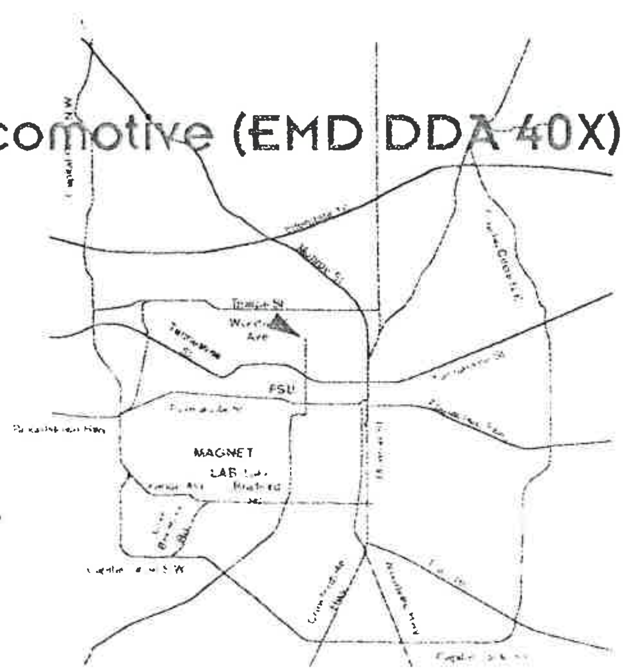
Installed power ~ 40 MW

≙ 10,000 people

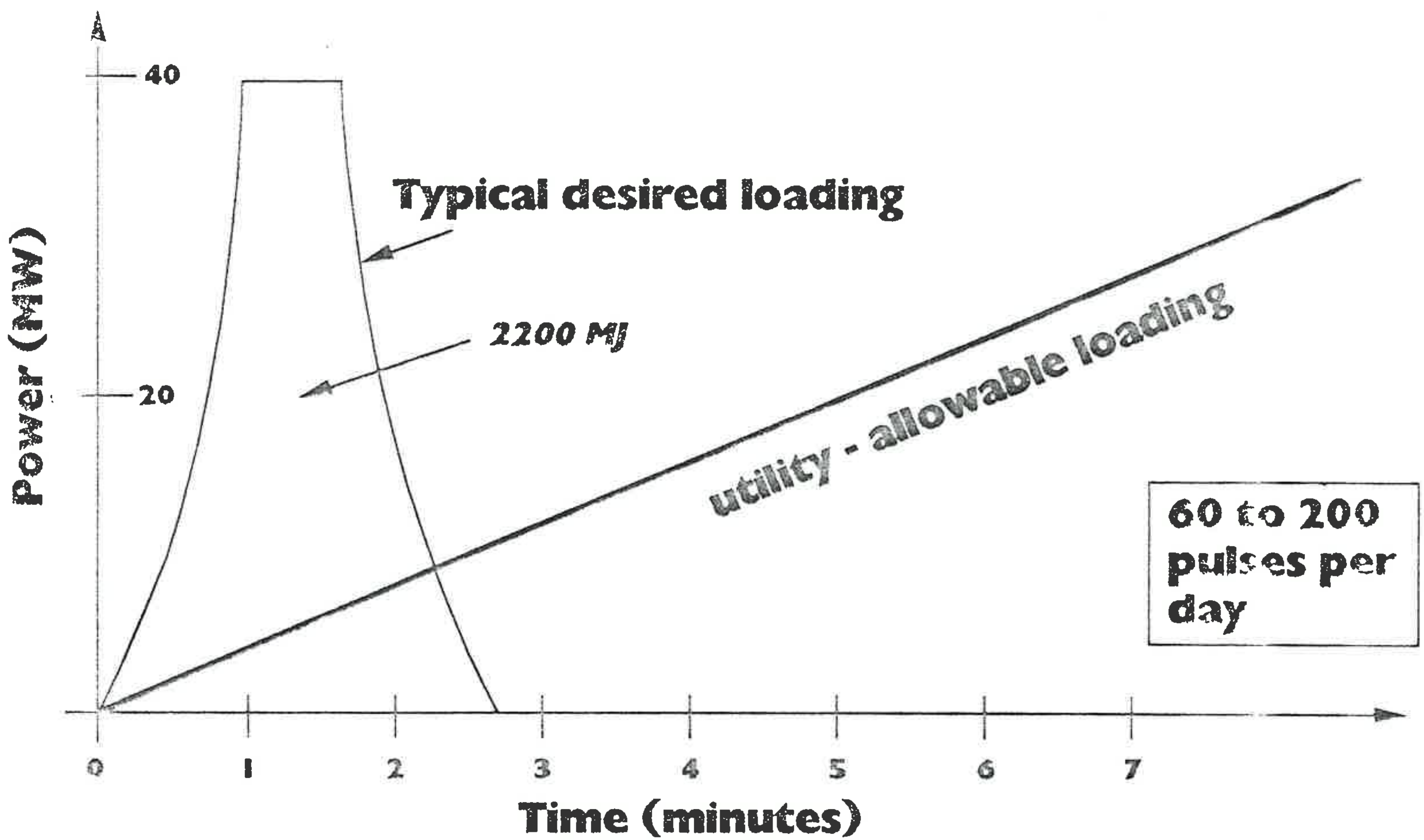
≙ 8% of Tallahassee

TRAIN

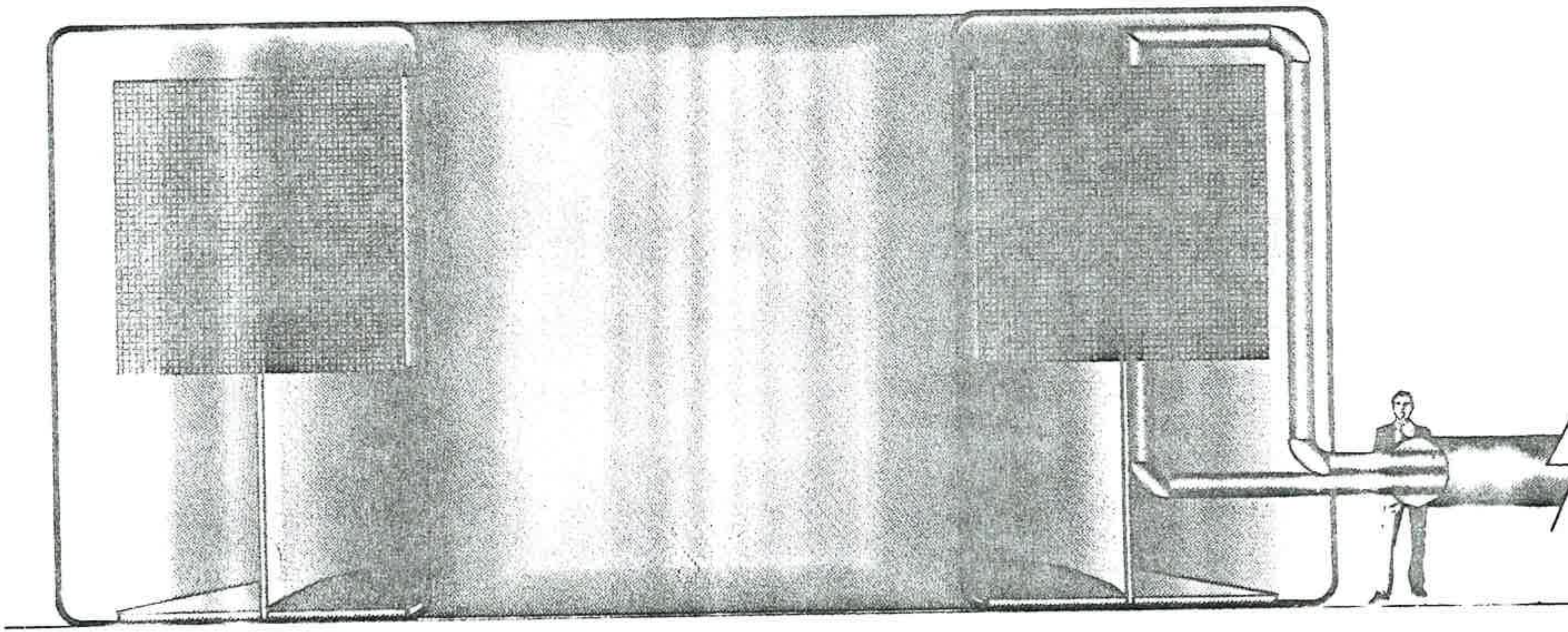
1 Locomotive (EMD DDA 40X) 5 MW



NHMFL SMES UNIT
Energy and Power Requirements



NHMFL SMES UNIT



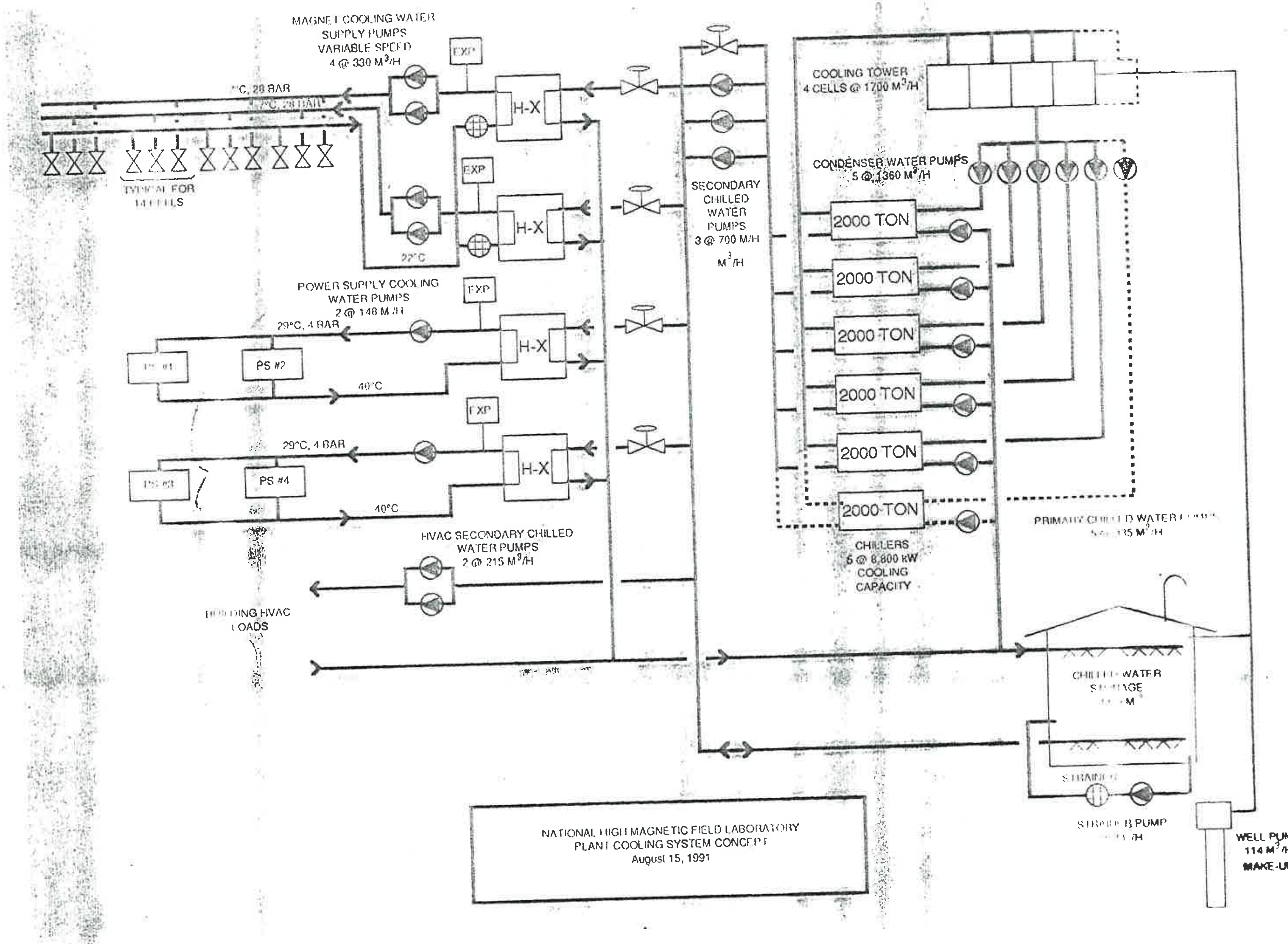
NATIONAL [illegible] FIELD LABORATOR

SMES Units

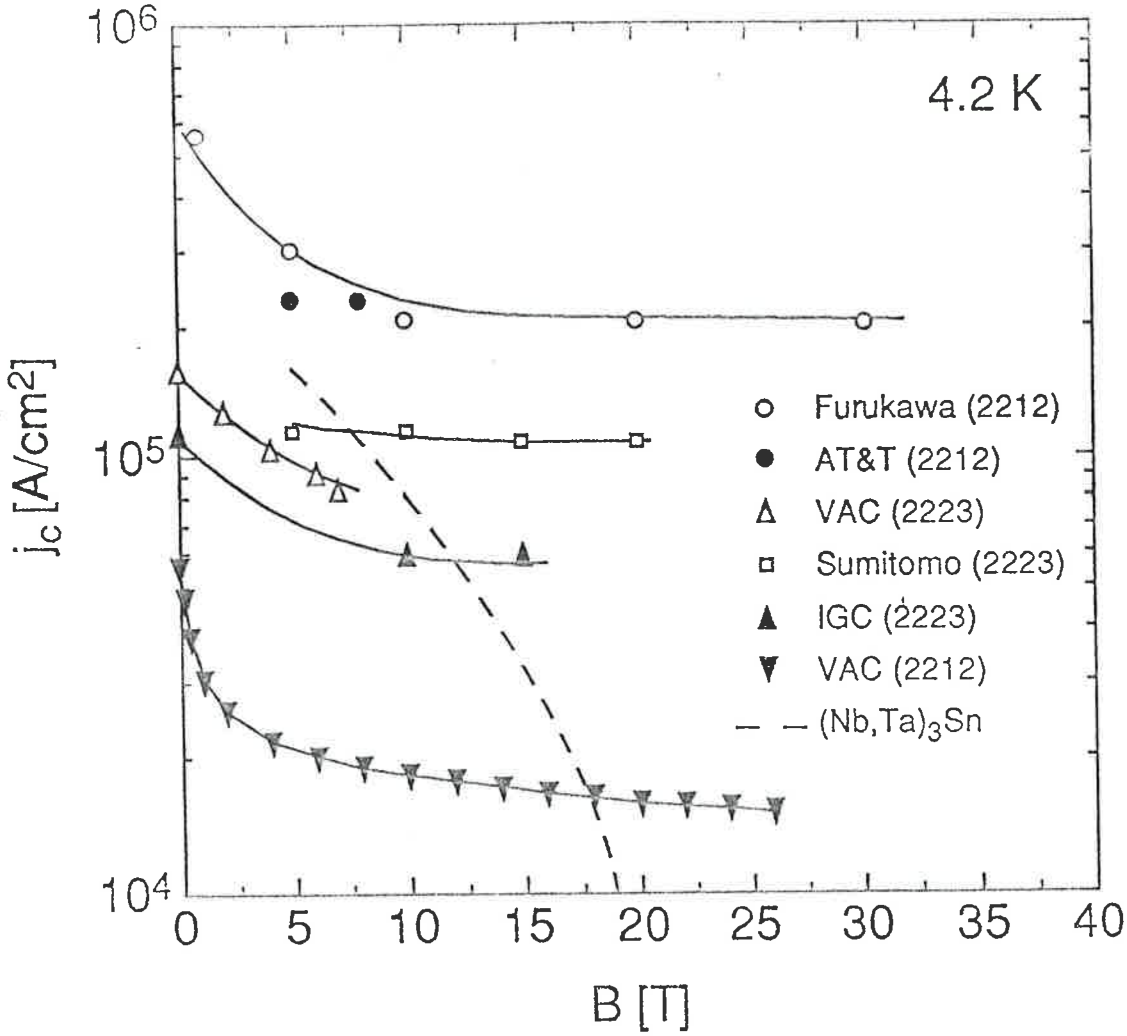
	Tacoma BPA / LANL	45T Hybrid NHMFL	NHMFL 1 MWh
Energy (MJ)	30 (8.3kWh)	100	3600 (1MWh)
Current (kA)	5	10	20
Voltage (kV)	±2	±0.02	±2
Dump Voltage (kV)	5	5	5
Power (MW)	10	0.2	40
Inductance (H)	2.5	2	18
Temperature (K)	4.2	1.8	1.8
Peak Field (T)	3	16	10
Outer Diameter (m)	3.1	1.6	10
Inner Diameter (m)	2.0	0.7	5
Height (m)	1.3	1.0	2.5
Coil Construction	solenoid	solenoid	solenoid (torus)
Year of Operation	1983	1995	1996?

Characteristics of Several Actual / Planned Magnetic Systems

	Cold Mass (t)	Stored Energy (MJ)	Equivalent 4.5 k Heat Load (W)	Distance to 10 - G line (m)
LCP	240	600	1500	(toroid)
MFTF-B	1200	1200	11000	40
FENIX	75	180	150	18
45-T Hybrid	11	100	**150**	13
GEM	**870**	**2400**	**1500**	**80**
1 MWh SMES	**810**	**3600**	**400**	55



NATIONAL HIGH MAGNETIC FIELD LABORATORY
PLANT COOLING SYSTEM CONCEPT
August 15, 1991



CURRENT DENSITY IN SUPERCONDUCTORS

Materials Related Magnet Development Issues

- Coil Winding Techniques (eg. wind and react)
    - Effect on Superconductor Properties
    - Heat Treatment
    - Reinforcement
- Coil Form Fabrication
- Low Resistance Joint Development
- Lead Development (including high Tc)
- Insulation (eg. fiberglass or ceramics)
- Structural materials selection

High Bc2 Technology Development Program

Facilities to be installed

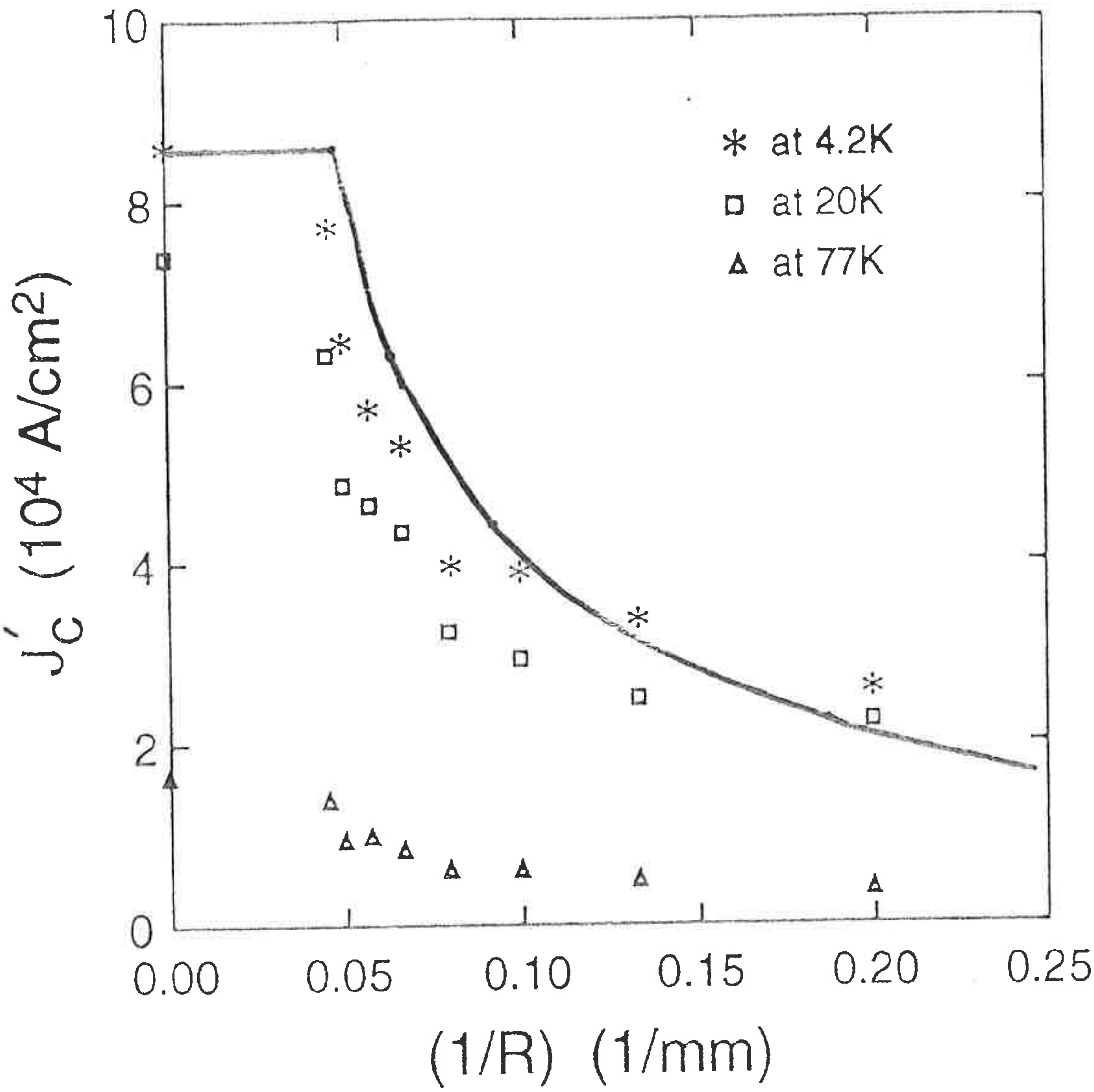
- Conductor characterization
  - Electrical
  - Mechanical
- Coil test station
  - Small coils in 20 T background field
  - Medium bore high field coils (5T)

Collaborative programs

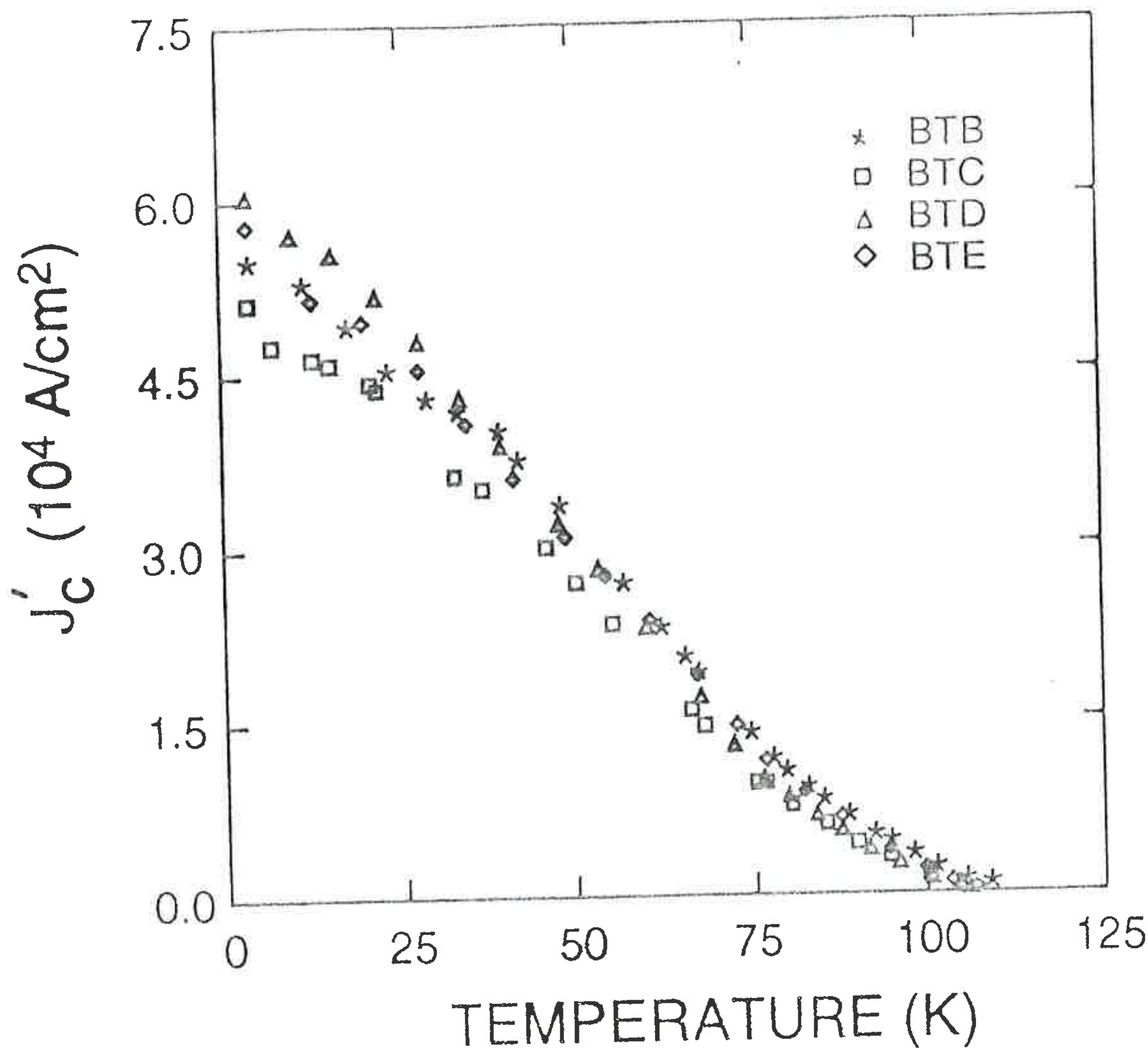
- Laboratory
  - LANL
  - ANL
  - ORNL
- Industry
  - IGC, program is formulated
  - GE
  - other

In house development

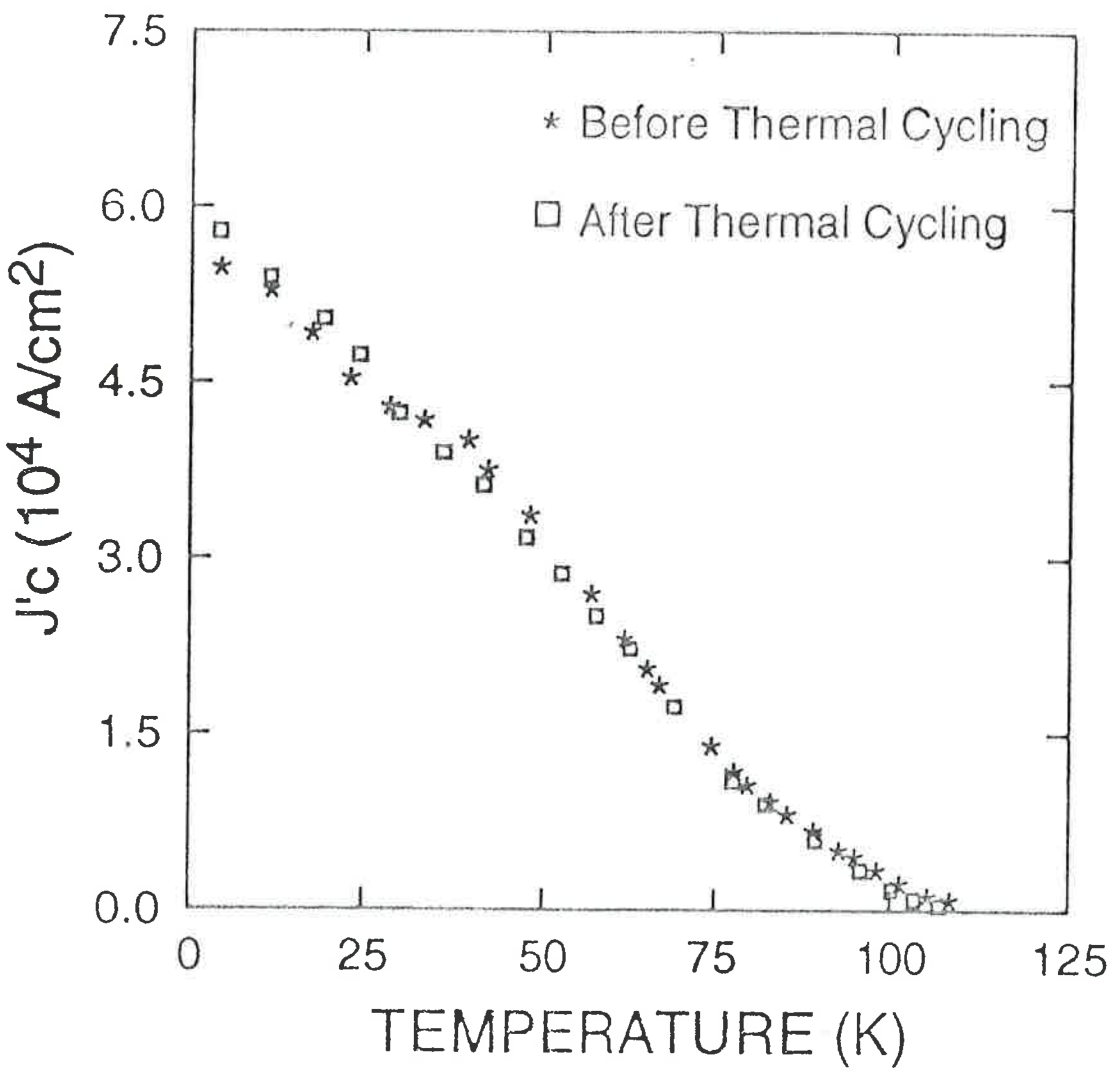
Understanding of small coil behavior
Mechanical, electrical, thermal stabilities
Feedback into:
Fundamental processes
Manufacturing technology issues



J'c (10^4 A/cm^2)
(1/R) (1/mm)
* at 4.2K
□ at 20K
▵ at 77K
0
2
4
6
8
10
0.00
0.05
0.10
0.15
0.20
0.25



Critical current density to the superconductor area (J'_c) versus temperature for four of BSCCO/Ag tapes.



J'_c versus temperature for a BSCCO/Ag tape. Two sets of data represents J'_c's before and after thermal cycling. This particular sample was cycled 20 times between 77K and room temperature.

NHMFL MATERIALS RESEARCH AND DEVELOPMENT PROGRAM

Research and Development Program

- Development and characterization of high strength, high conductivity alloys for resistive dc and pulsed coil applications
- Characterization and development of high strength insulating and structural materials for use in resistive dc, pulsed, and superconducting magnets
- Characterization and processing of low and high temperature superconducting materials
- Evaluation of the performance of cables, cable-in-conduit, and monolithic superconductors
- Evaluation of small, model coil performance in the large bore 12-T magnet

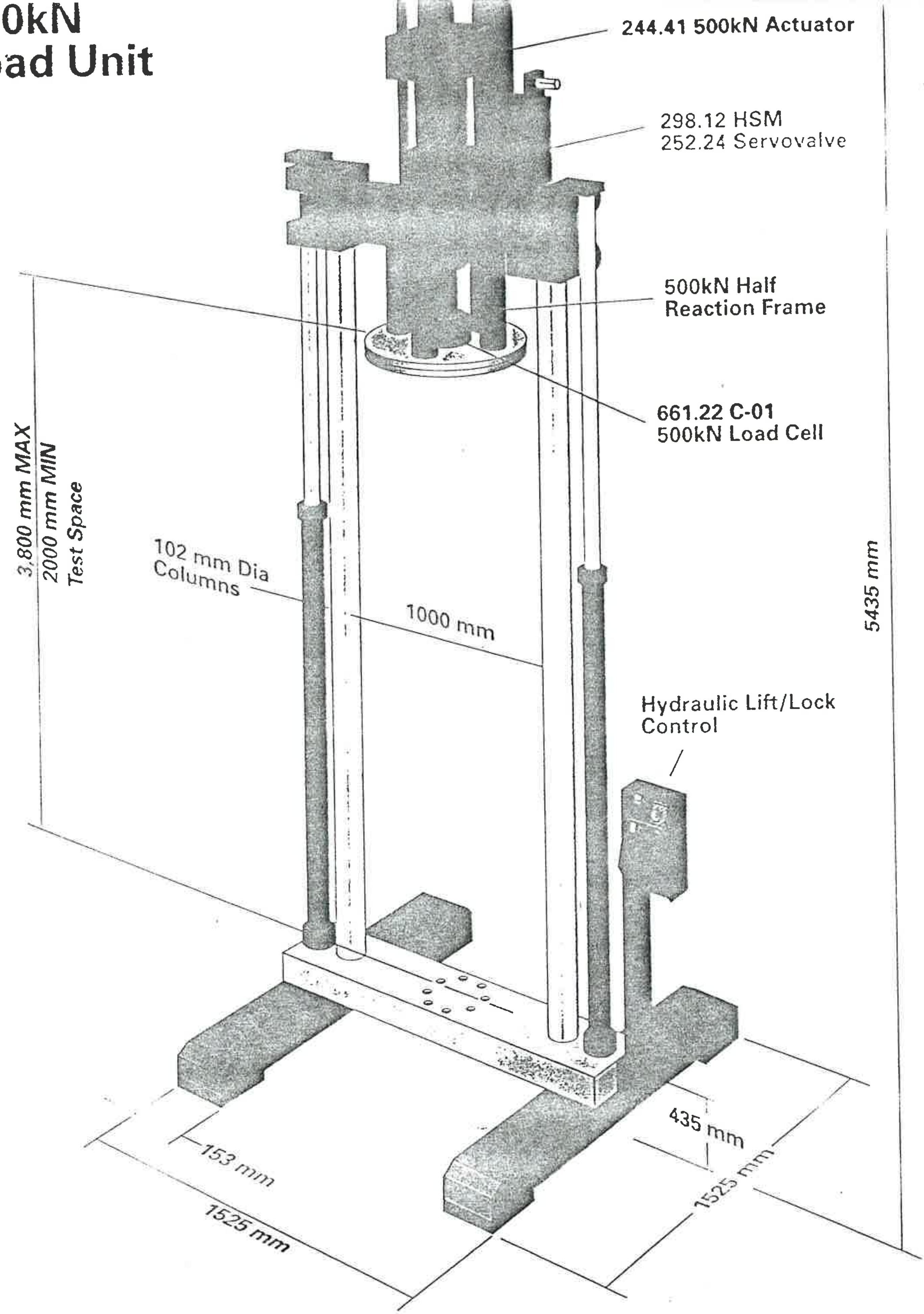
NHMFL MATERIALS RESEARCH AND DEVELOPMENT PROGRAM

Facilities:

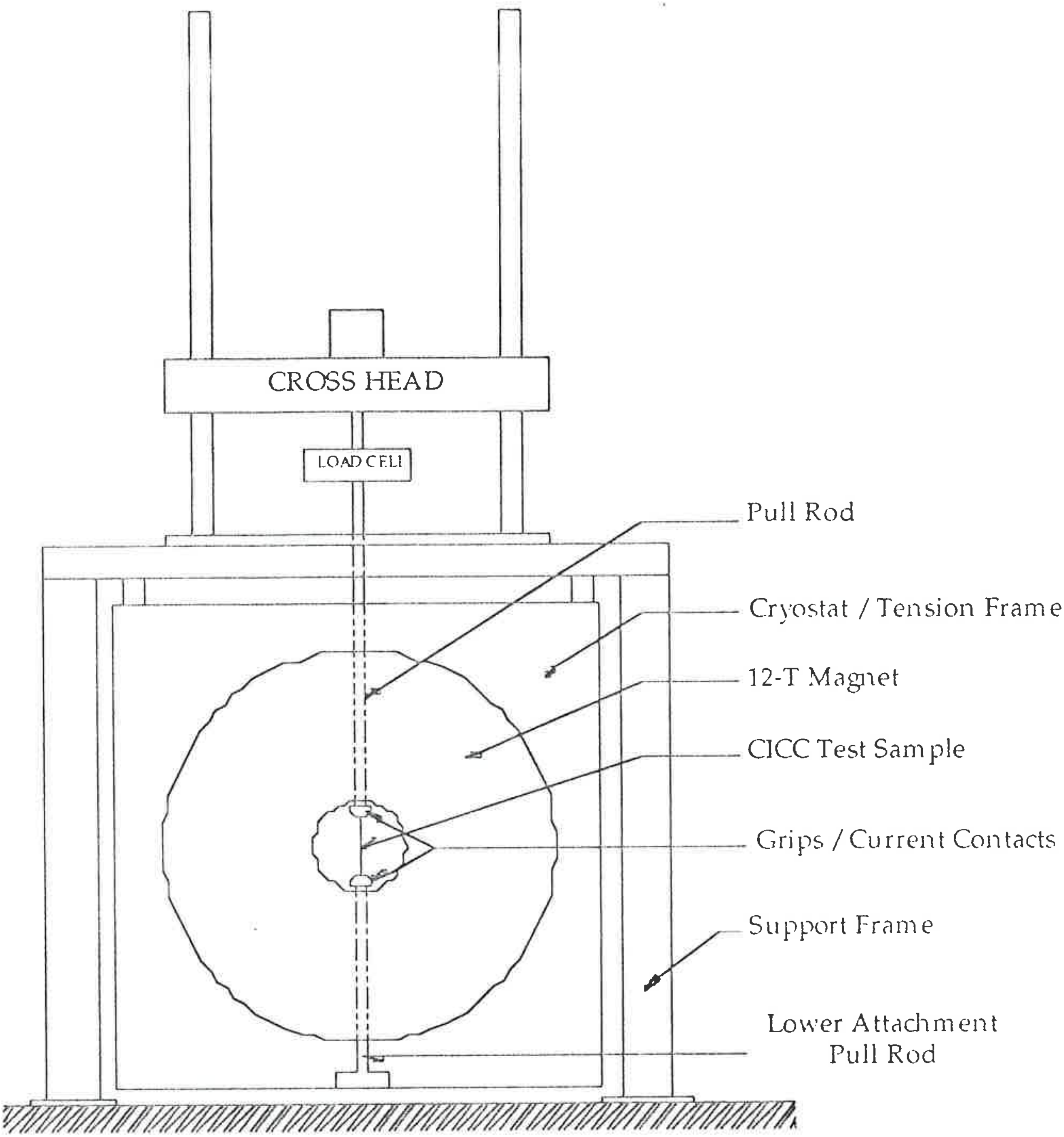
State-of-the-art equipment for the characterization of magnet materials.
Studies of mechanical and electrical properties of structural, insulating, superconducting, and resistive materials in magnetic fields up to 14 T and temperatures from 4-400 K.

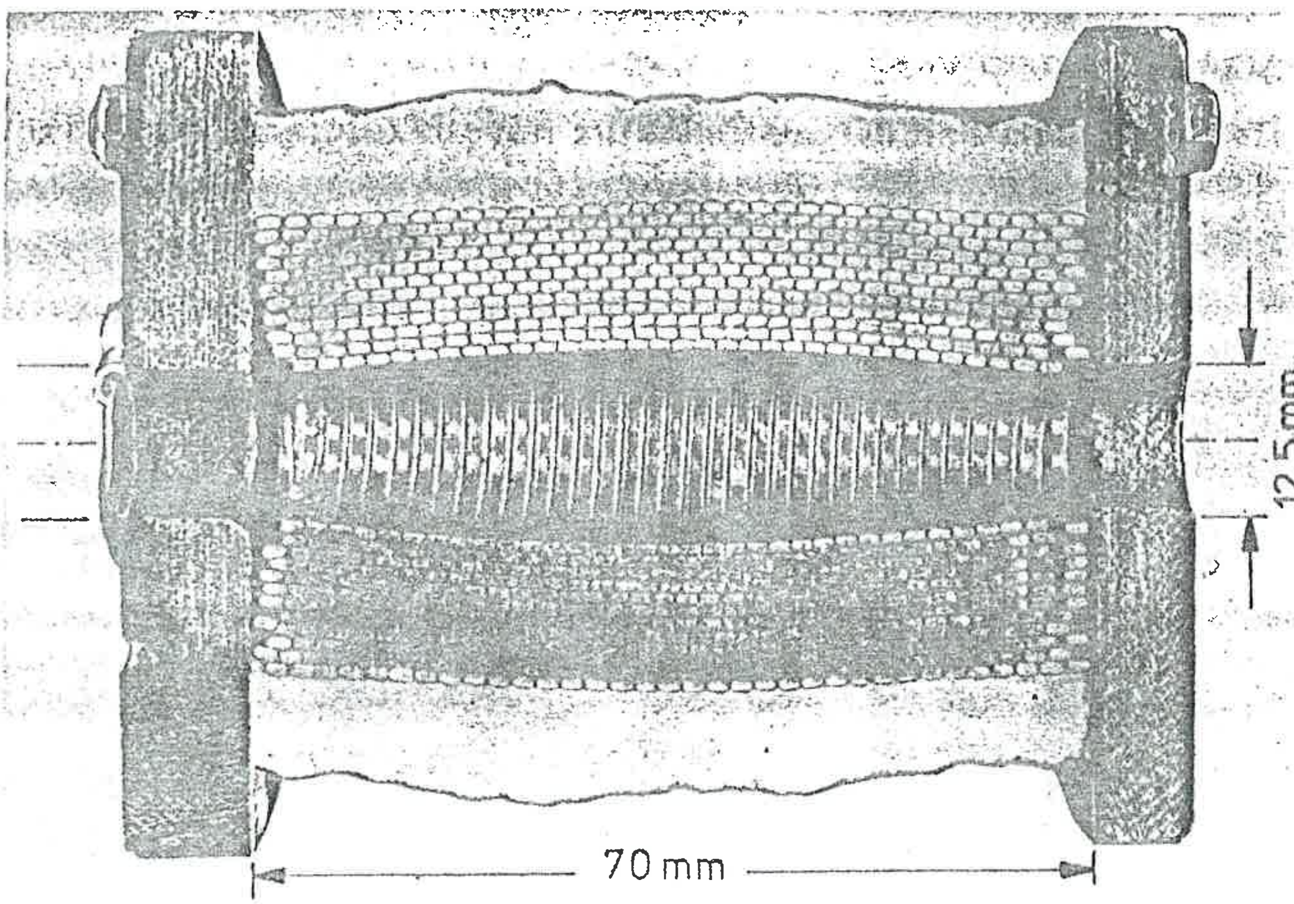
- high field magnets
  - 14-T split bore superconducting solenoid magnet
    50-mm bore
    10 x 20 mm radial access slot
  - 12-T (or greater) superconducting split bore
    (detailed design features TBD)
    bore 100 mm
    adjustable radial access slot 20 x 30 mm

500kN Load Unit



500-kN Tension Tester and 14-T Magnet

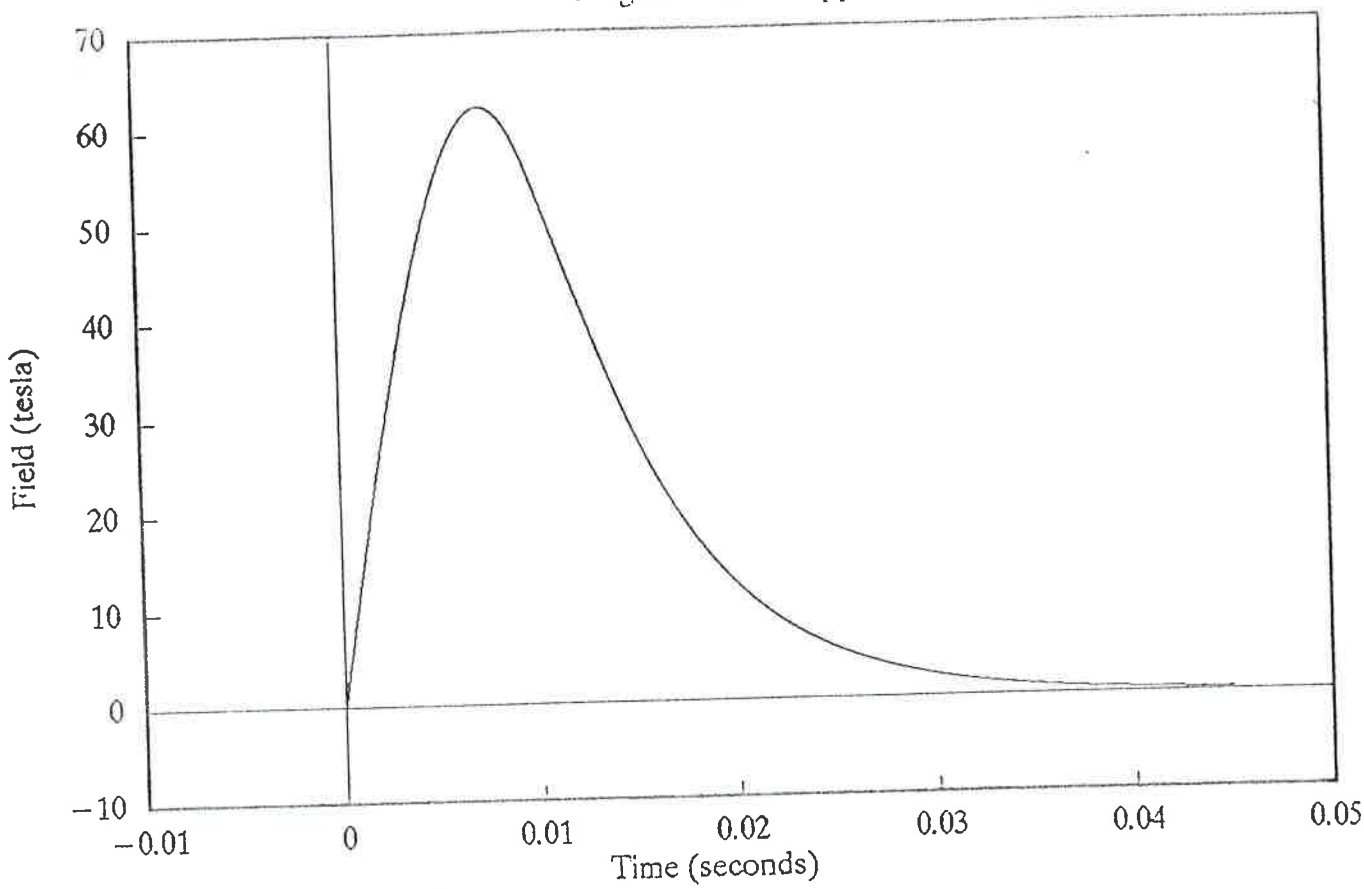




12,5 mm
70 mm

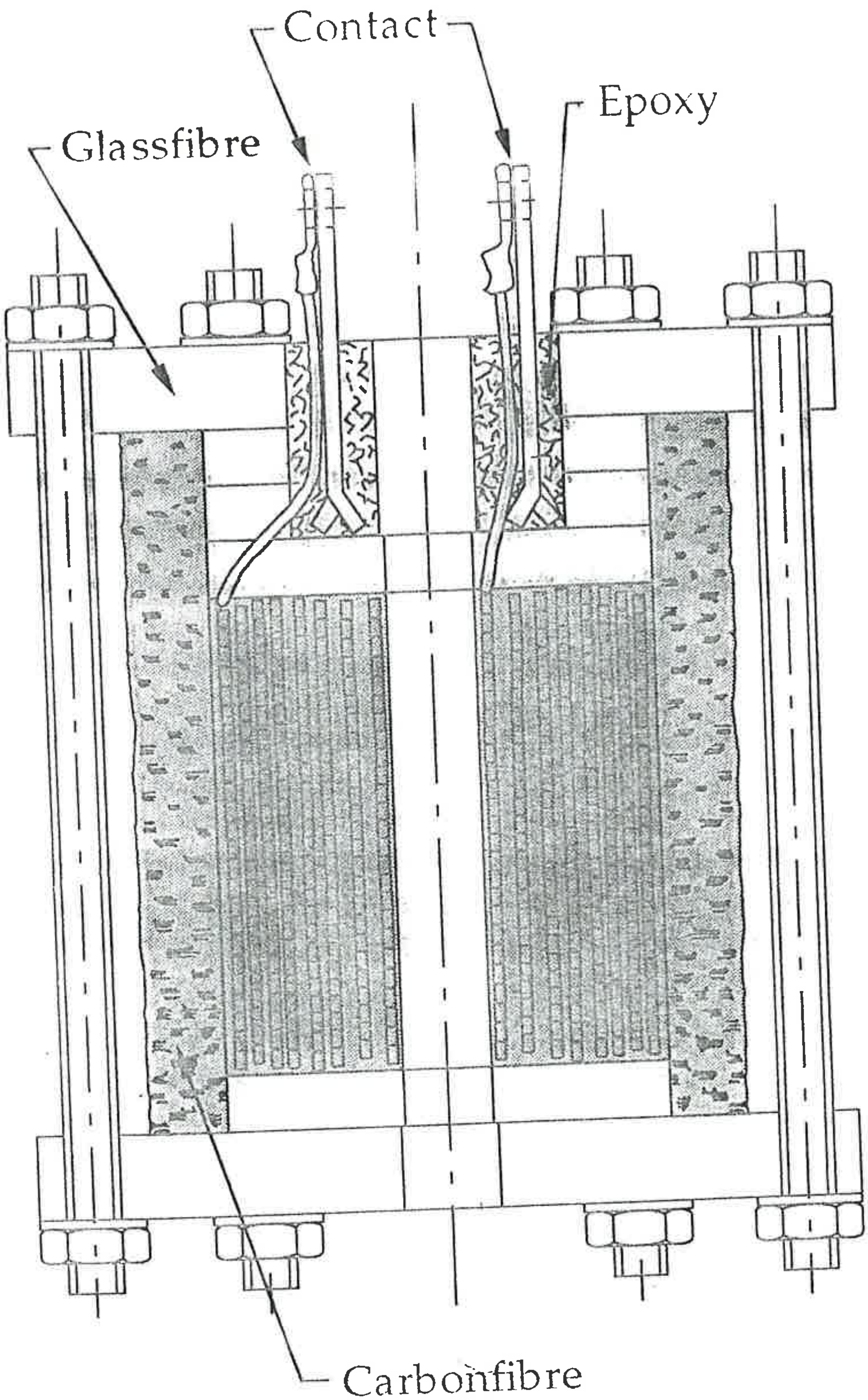
Field versus time for shot 16 of Mel25 test

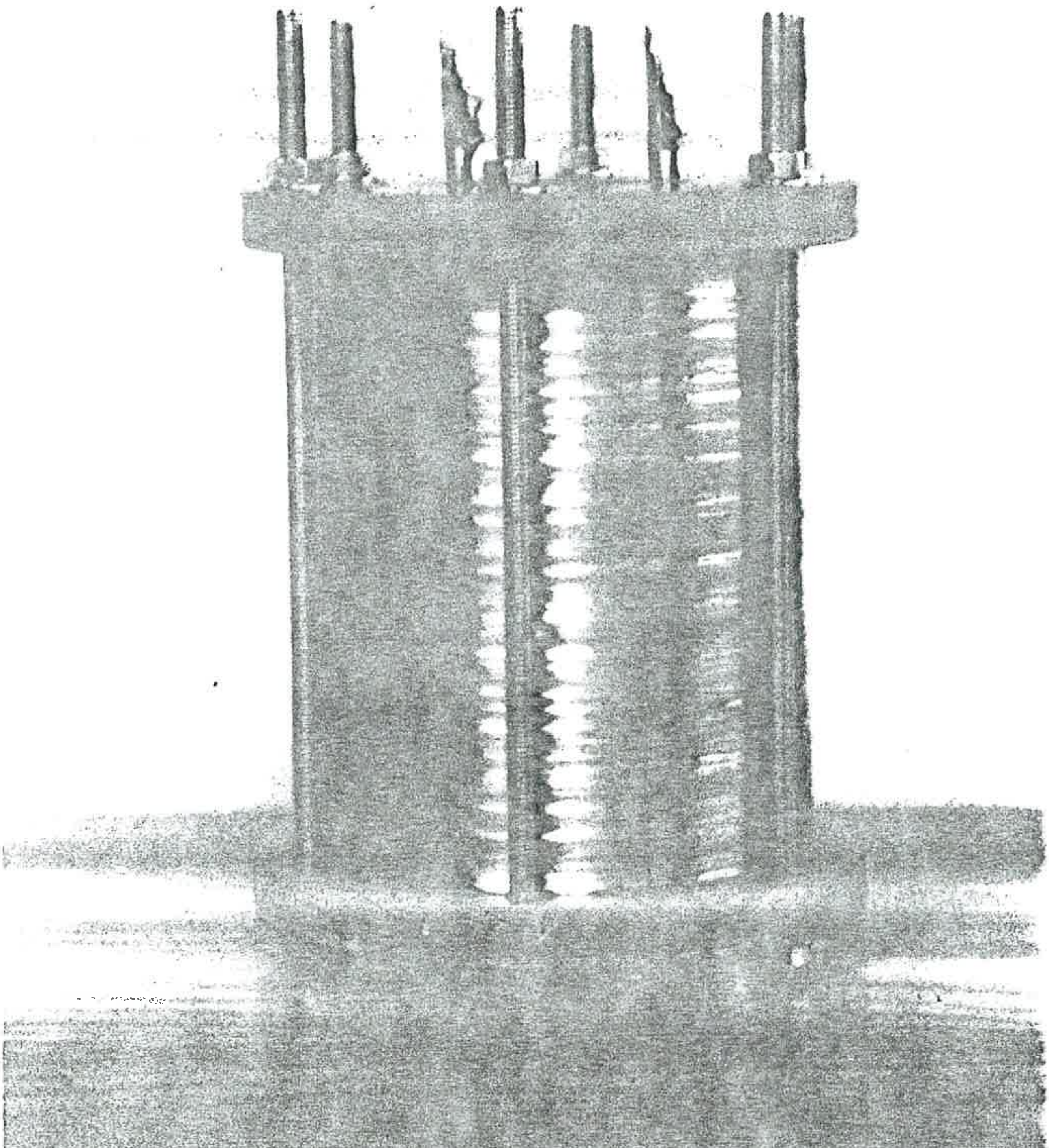
August 14 1992 ppw

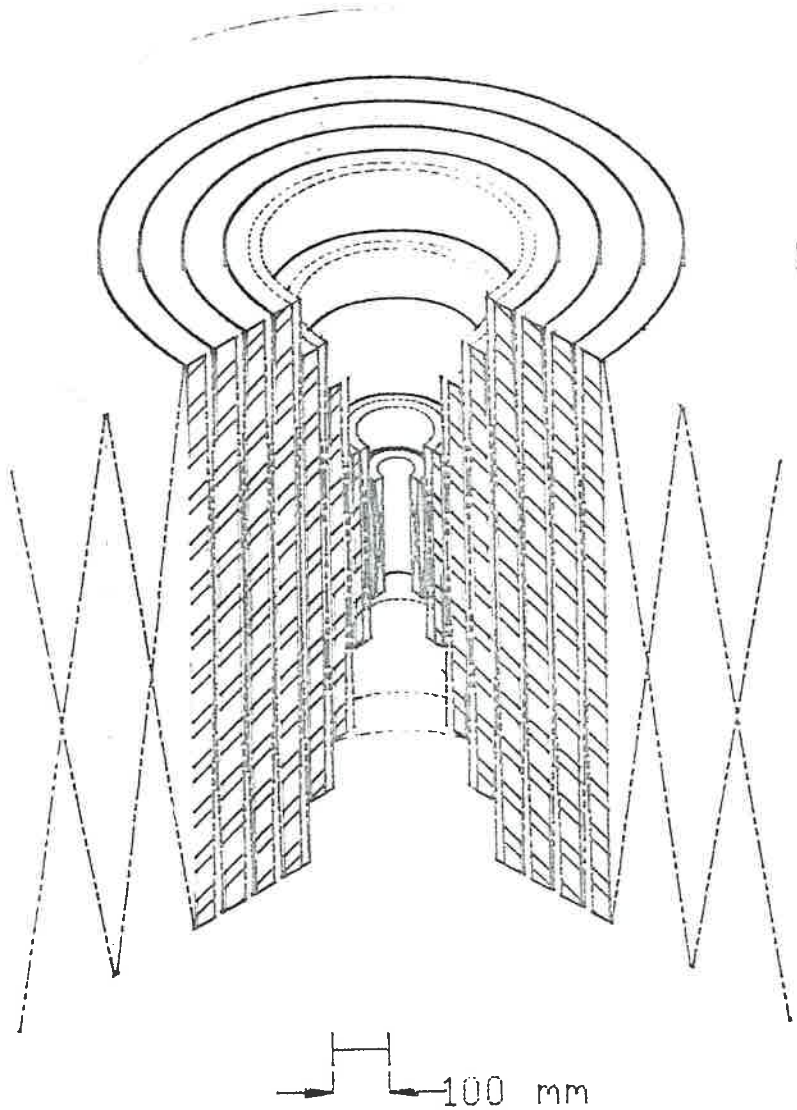


Bmax = 62.21 tesla @7.44 mS

62 Tesla Magnet
Tested Spring 1992

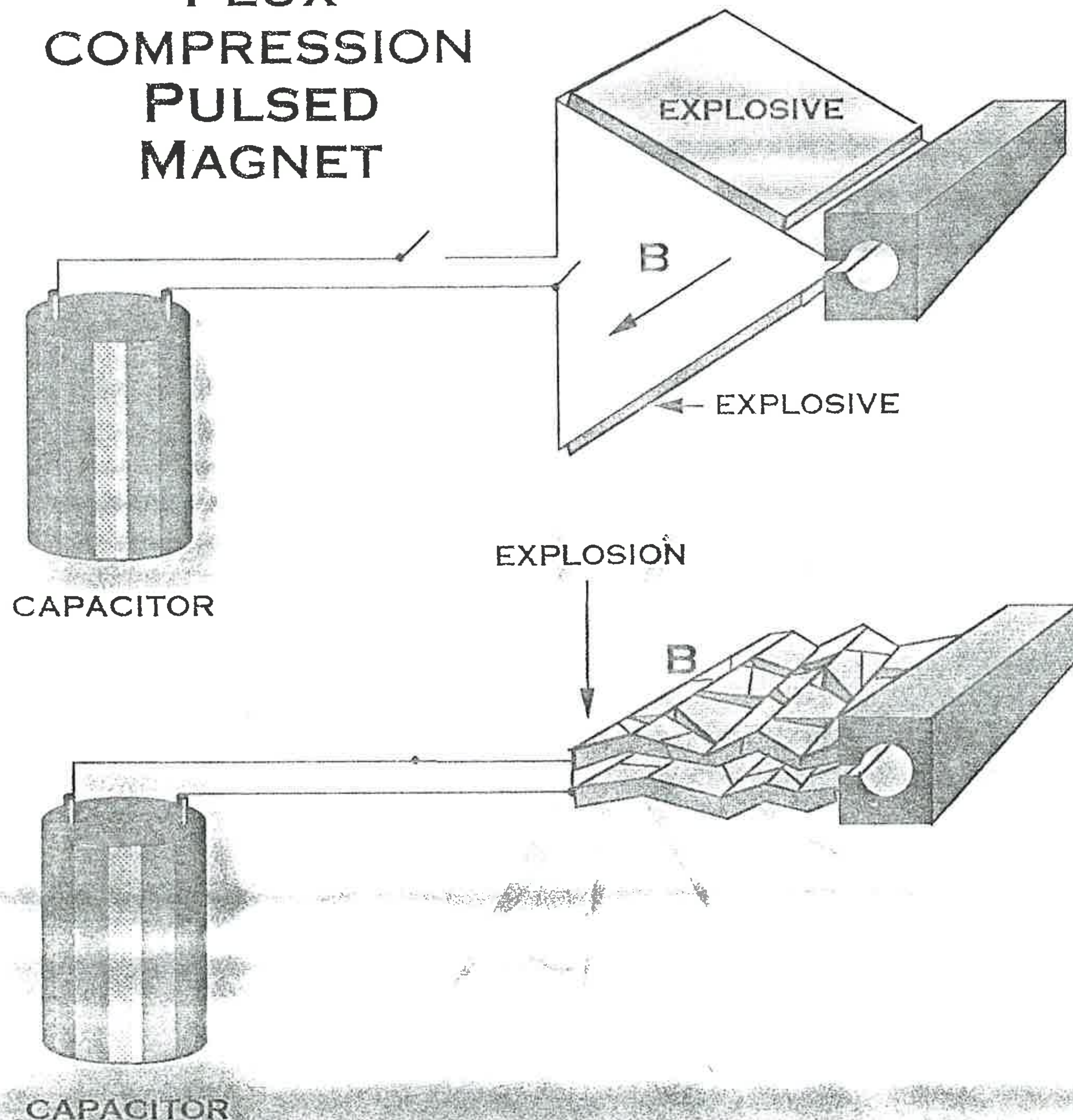

Contact
Epoxy
Glassfibre
Carbonfibre



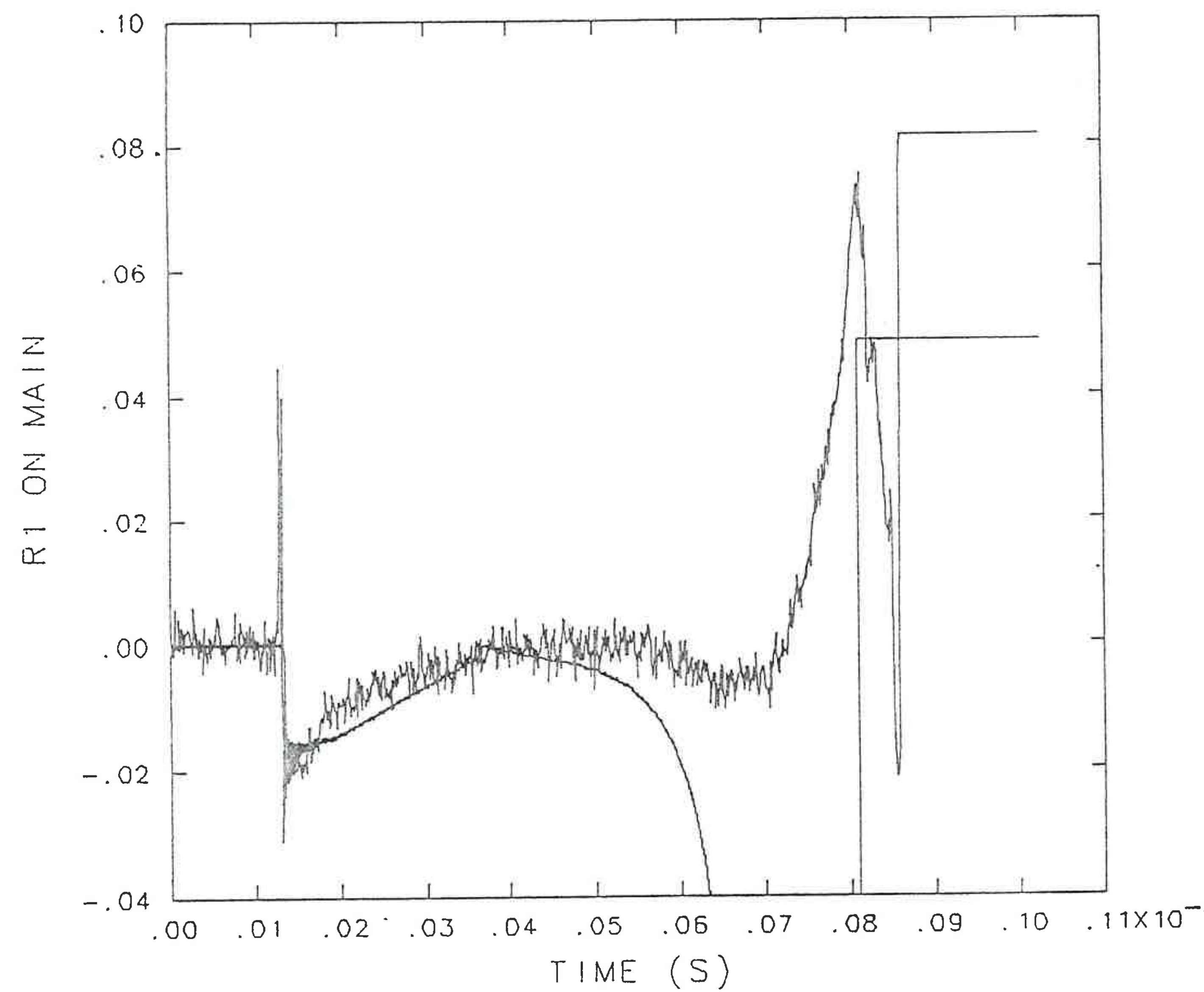

100 mm

NATIONAL HIGH MAGNETIC
FIELD LABORATORY

100-1000 T FLUX COMPRESSION PULSED MAGNET



HC2-4**02/11/92**HC2 DIGITIZER-F/O 1



FUTURE PROJECTS

- **1 GHz NMR Magnet (LANL)**
- **50-55T Insert for Hybrid Magnet I**
- **Hybrid Magnet II** (17T, 600 mmϕ, 6M$/10T, 400 mmϕ, 1M$)
- **Axion Experiment** (16T, 600mmϕ, 4M$)
- **SMES** (1-3MWh, 4.6-7.6mϕ, 11-9T, 25-100M$)
- **25-30T HTS Magnet**
- **80T Pulsed Magnet**
- **100T Quasi-Continuous Magnet**
- **12T-40cm MRI Magnet (UF)**