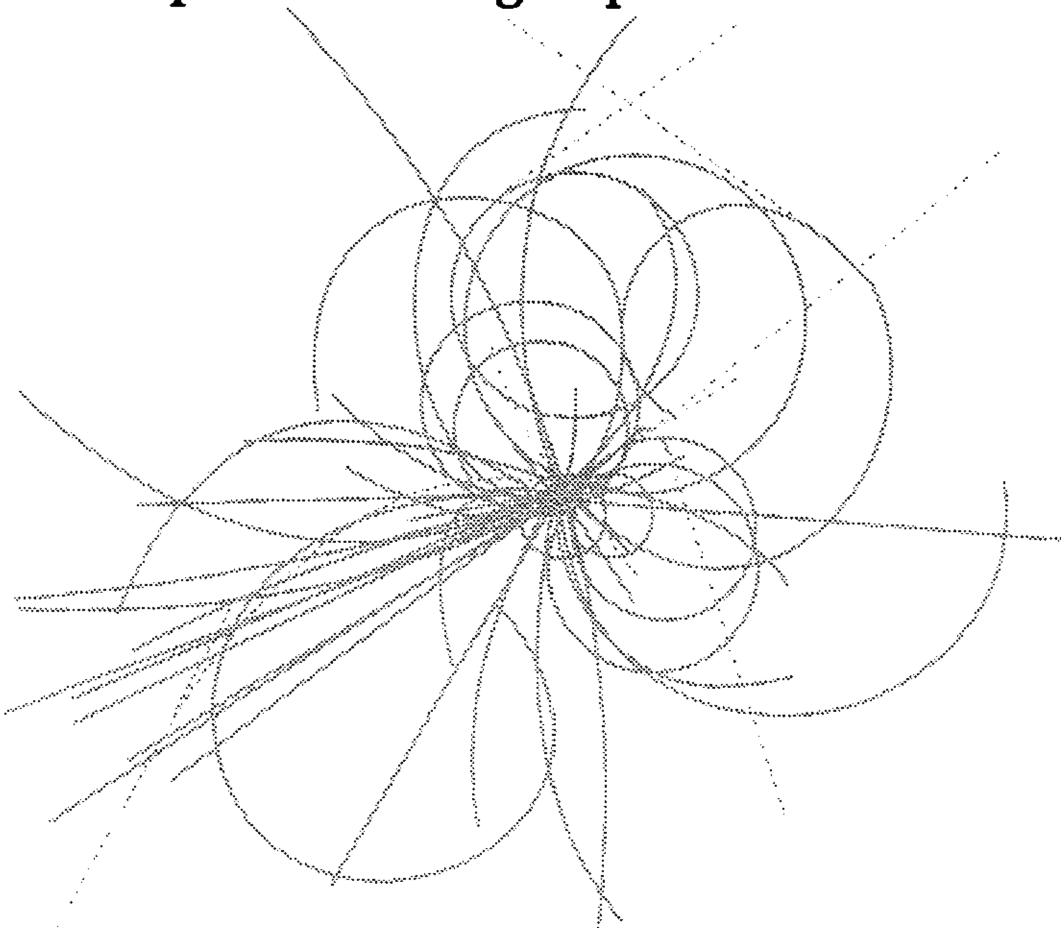
SSC-5

Superconducting Super Collider Laboratory

SSC-5



Workshop on SSC Commissioning and Operations

P. Limon, E. Paterson, M. Harrison, and P. VanderArend

January 1985

WORKSHOP ON SSC COMMISSIONING AND OPERATIONS

UC BERKELEY 14-18 JANUARY 1985

PHOTOCOPIES OF TRANSPARENCIES

Monday Morning 14 Jan 1985

Peter Limon

Ewan Paterson

Mike Harrison

Peter VanderArend

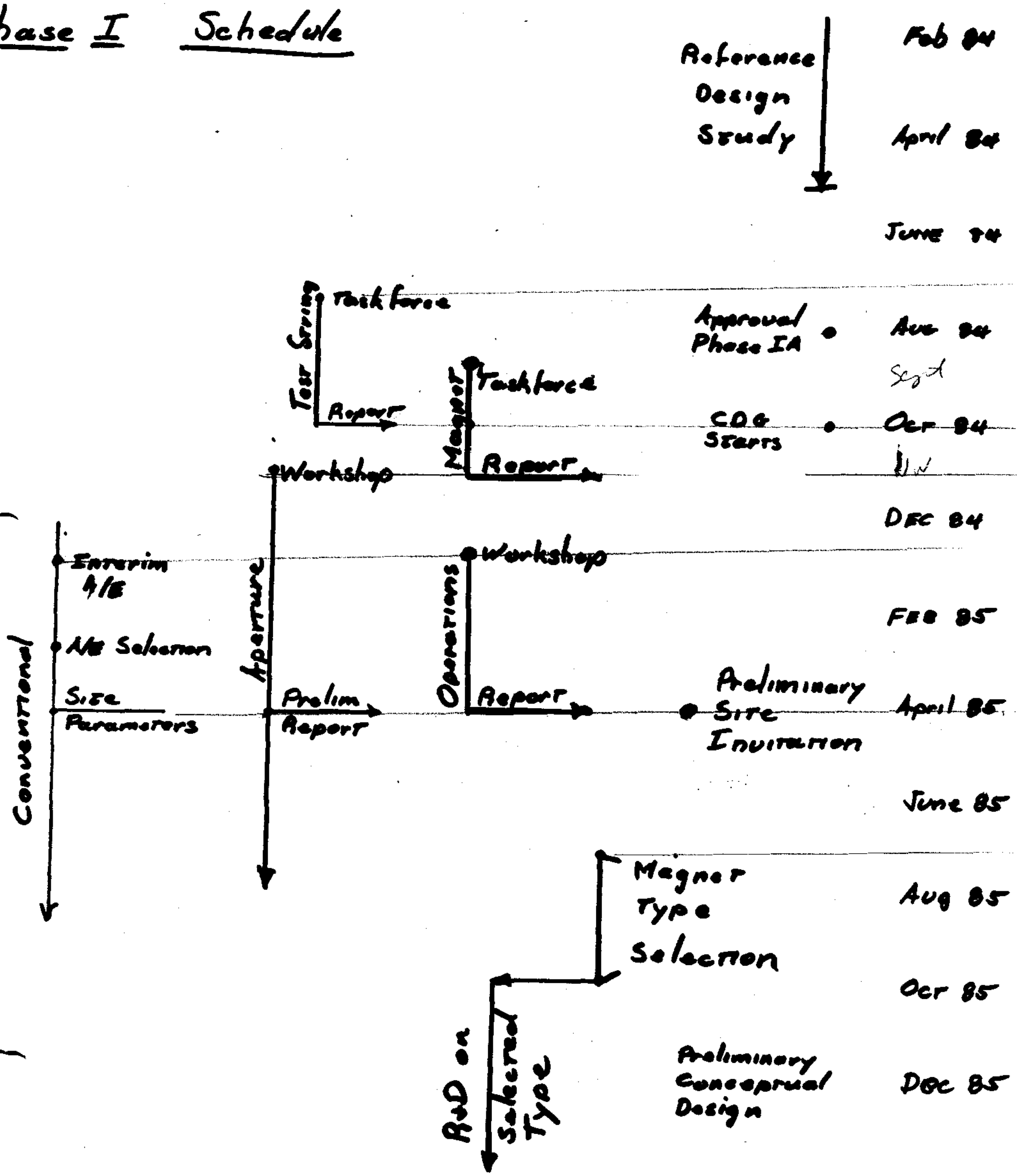
SSC C&O Workshop
Peter Limon Mon. 14 Jan 85

STUDY OPERATIONS AND COMMISSIONING

I. NECESSARY INPUT FOR CHOICE OF MAGNET TYPE.

II. EARLY STEP IN MACHINE DESIGN.

Phase I Schedule



WORKSHOP ON COMMISSIONING AND OPERATION OF THE SSC

II. RESULT OF WORKSHOP SHOULD BE:

- TO DETERMINE THE IMPORTANCE OF VARIOUS MAGNET FEATURES TO THE EFFICIENT OPERATION AND/OR COMMISSIONING OF THE MACHINE. GRADED FROM 0 TO 10, SUCH THAT:

  0 = IRRELEVANT
  5 = IMPORTANT
  10 = CRUCIAL

- TO DETERMINE HOW WELL A MACHINE BUILT WITH A PARTICULAR MAGNET TYPE ACCOMMODATES THOSE FEATURES. GRADED FROM 0 TO 10, SUCH THAT:

  0 = NOT AT ALL
  5 = POSSIBLE
  10 = EXCEPTIONALLY WELL

- TO ASSIGN AND SCHEDULE COMPLETION OF THE WORK BY APRIL 1, 1985.

RESOURCES

375 Le Conte

Debra Brewer
Karen Larsen

Secretarial Help
- Quick Type
- Xerox
- Transparency
- Message Board

Document Library
- Reference Design Reports
- Other COG Reports
- Some Preprints

Large Scale Word Processing

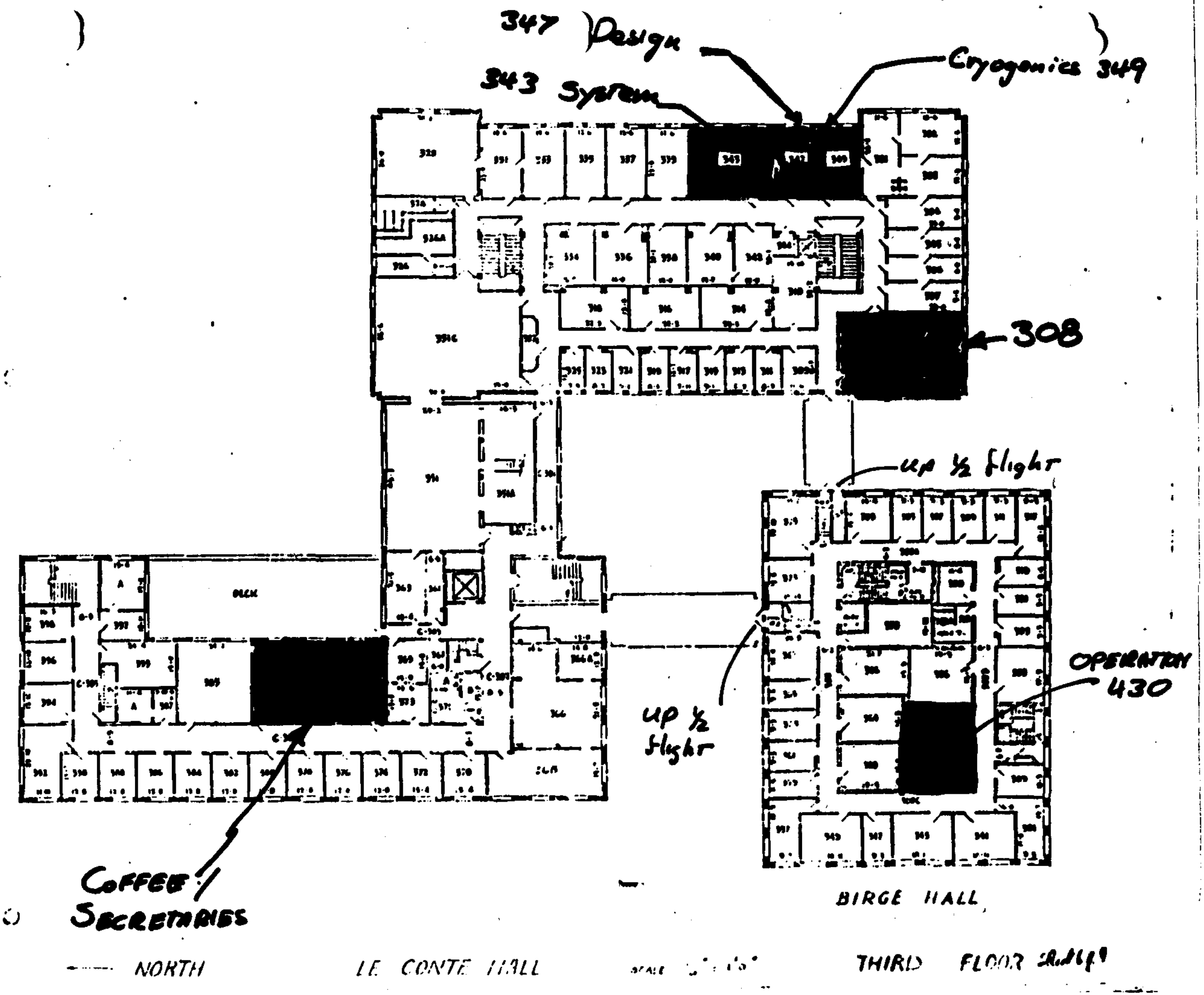
Tech. Info. Division of LBL is available.

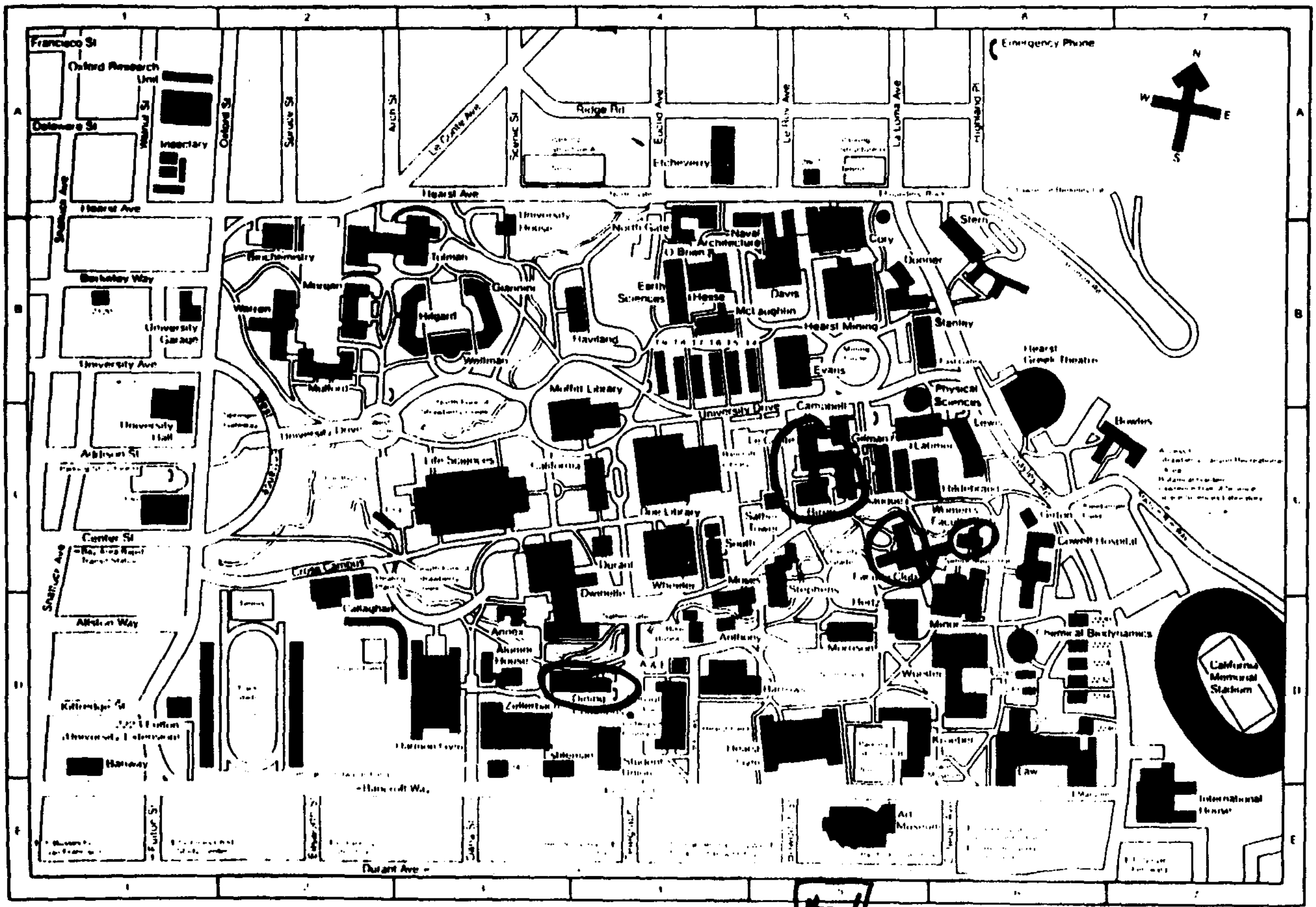
Workshop on SSC Commissioning and Operations

January 14-18, 1985

Meeting Rooms

WHAT	WHEN	WHERE
News Reports	T, W, Th 8:30-9:30	308 LeConte
Summary Session	Friday 8:30-Noon	308 LeConte
Cryogenics Workroom	Always	349 LeConte
Cryogenics Reports	T, W, Th 11:00-Noon	308 LeConte
Operations Workroom	Always	430 Birge
Operations Reports	T, W, Th 1:30-2:30	308 LeConte
Design Workroom	Always	347 LeConte
Design Reports	T, W, Th 2:45-3:45	308 LeConte
Systems Workroom	Always	343 LeConte
Systems Reports	T, W, Th 4:00-5:00	308 LeConte
Coffee Break	9:30-10:00	375 LeConte
Secretarial	8:30-5:00	375 LeConte


347 Design
343 System
Cryogenics 349
308
up ½ flight
up ½ flight
OPERATION 430
Coffee / Secretaries
BIRGE HALL
NORTH
LE CONTE HALL
THIRD FLOOR



Francisco St
Oxford Research Unit
Delaware St
Walnut St
Oxford St
Spruce St
Arch St
Le Conte Ave
Scenic St
Ridge Rd
Euclid Ave
Le Roy Ave
La Loma Ave
Highland Pl
Emergency Phone
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Hearst Ave
Shattuck Ave
Berkeley Way
University Garage
University Ave
University Hall
Addison St
Center St
Allston Way
Kittredge St
Haviland
Moffitt Library
Life Sciences
California
Doe Library
Durant
Wheeler
Dwinelle
Callaghan
Cross Campus
Annex
Alumni House
Zellerbach
Sproul
Eshleman
Student Union
Anthony
Moses
Stephens
Morrison
Wurster
Kroeber
Minor
Law
International House
Art Museum
Durant Ave
Hancock Way
Fulton St
Dana St
Chemical Biodynamics
Cowell Hospital
Women's Faculty Club
Hildebrand
Latimer
Gilman
Physical Sciences
Campanile
University Drive
Evans
Hearst Mining
McLaughlin
Davis
Cory
Donner
Stern
Stanley
Hearst Greek Theatre
Bowles
Naval Architecture
North Gate
O'Brien
Earth Sciences
Hesse
Tolman
Giannini
Hilgard
Wellman
Mulford
Warren
Biochemistry
Morgan
University House
Etcheverry
Haas
Hertz
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TODAY'S SPEAKERS

Ewan Paterson - SLAC

Reliability in Storage Rings

Mike Harrison - Fermilab

Aperture Requirements

Due to Operational Considerations

Peter Vander Arend - CCI

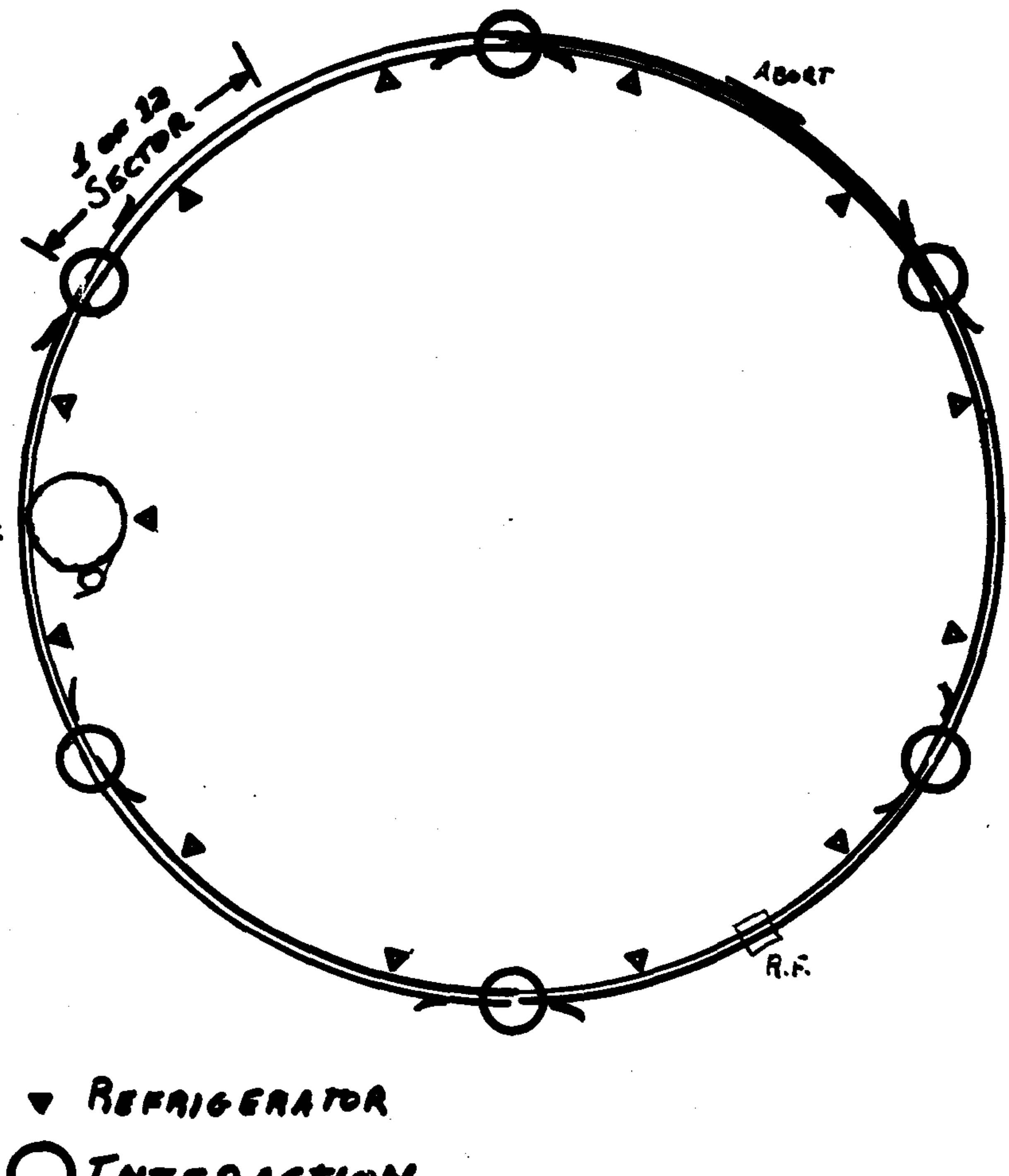
Introduction to SSC

Cryogenics

BUT FIRST:

Introduction to SSC

Operations.


1 of 12
SECTOR
ABORT
INJ.
R.F.
REFRIGERATOR
INTERACTION
REGION

Cryogenic Questions

- Large Scale Cooldowns
  Time, cost, how often?

- Magnet Replacement
  Time required, beam valves, how is it done, how often?

- Steady State Operation
  Removing heat from synchrotron radiation and ramping.

- Two Phase Flow
  Is it stable?

- One Phase Flow
  What do the recoolers look like?

- Quench Recovery
  Two-in-one implications.

- Separate Cryogenics
  Should one-in-one magnets have separate cryostats?

Design Questions

- **Magnet Selection**

  Is it desirable? What are the two-in-one implications?

- **Fractional Testing**

  During commissioning, how many magnets will have to be changed?

- **Field Level**

  What is the difference between very large and ultra large rings?

- **Optics Restrictions**

  How do they depend on magnet type? How important are they?

- **Beam Crossing**

  Problems related to magnet type.

- **Correction Elements**

  Problems related to magnet type. What level of redundancy?

Operations Questions

- **Installation**
  Questions related to magnet type.

- **Ramp Cycle Time**
  Is a slow ramp okay? What about eddy currents?

- **Beam Injection and Abort**
  Questions related to magnet type, and side-by-side/over-under configurations.

- **Quenches**
  How often might we expect them? Are they at injection or high field?

- **Beam Conditioning**
  How long does it take to fill, accelerate, condition, collide, etc.?

- **Partial Acceleration**
  Is it possible to accelerate one beam while injecting the other? Is it useful?

- **Overall Complexity of Machine Operation**
  Related to magnet type.

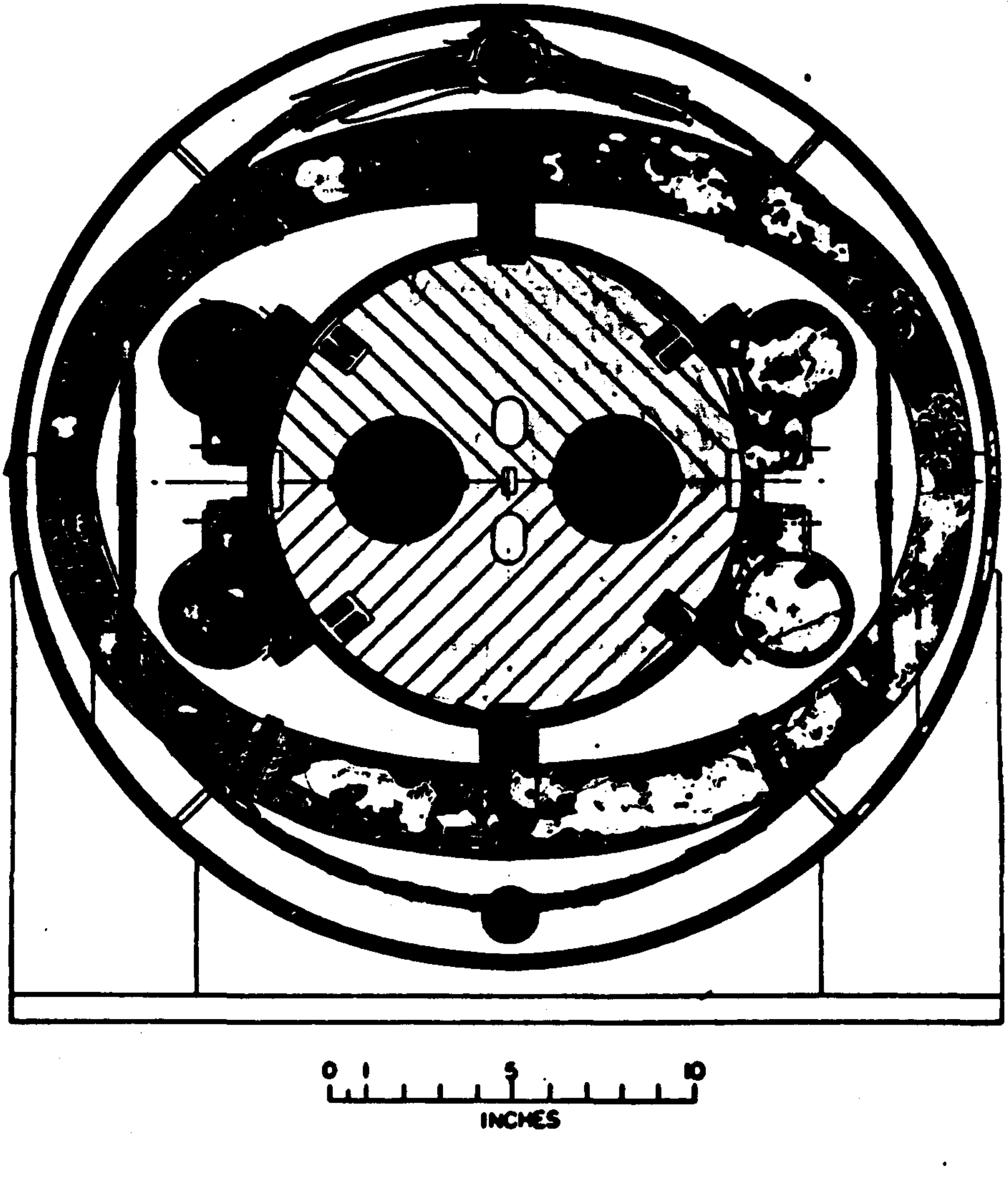
Systems Questions

- **Quench Detection and Protection**
  Different methods for different magnet types.

- **Power Supply Configurations**
  Related to magnet type.

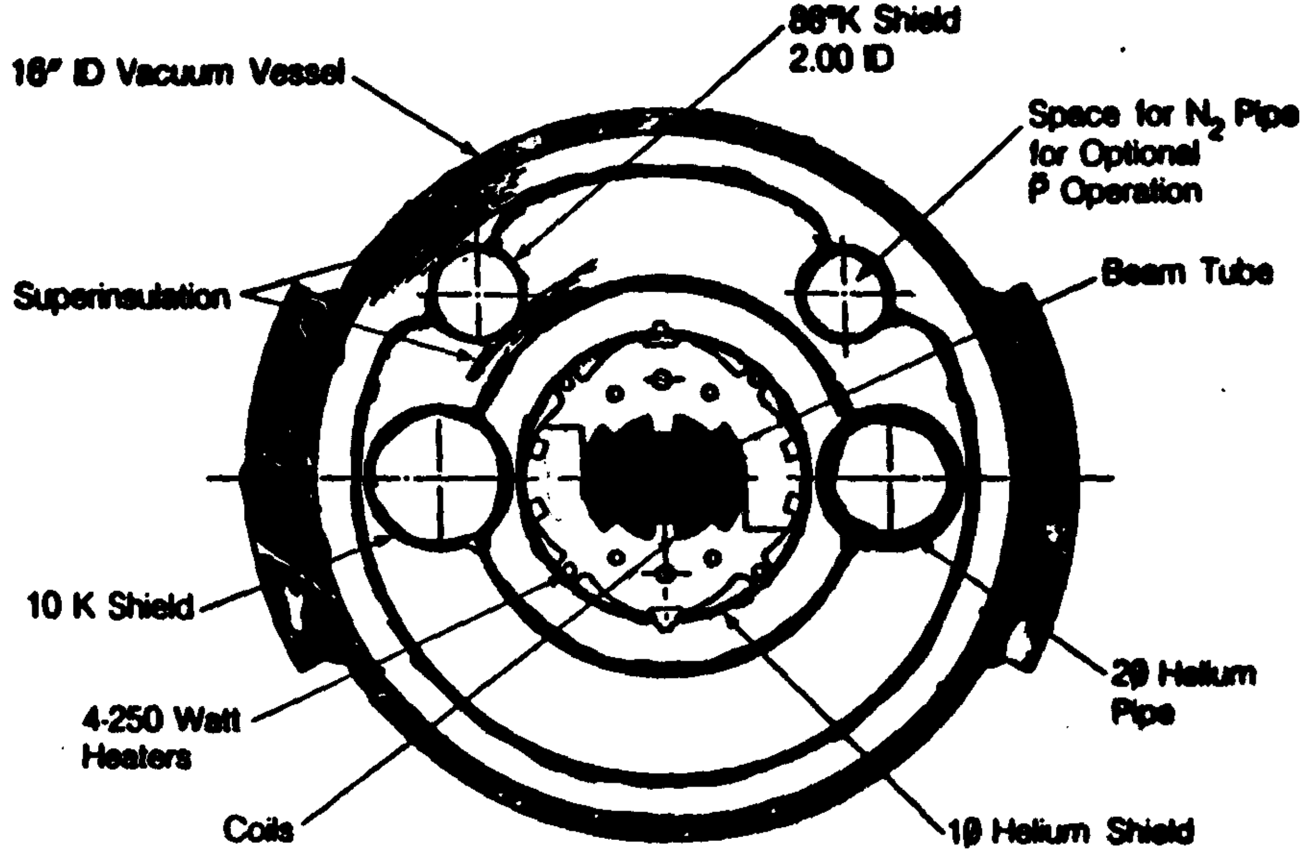
- **Regulation Requirements**
  Electromagnetic coupling. Transmission line effects.

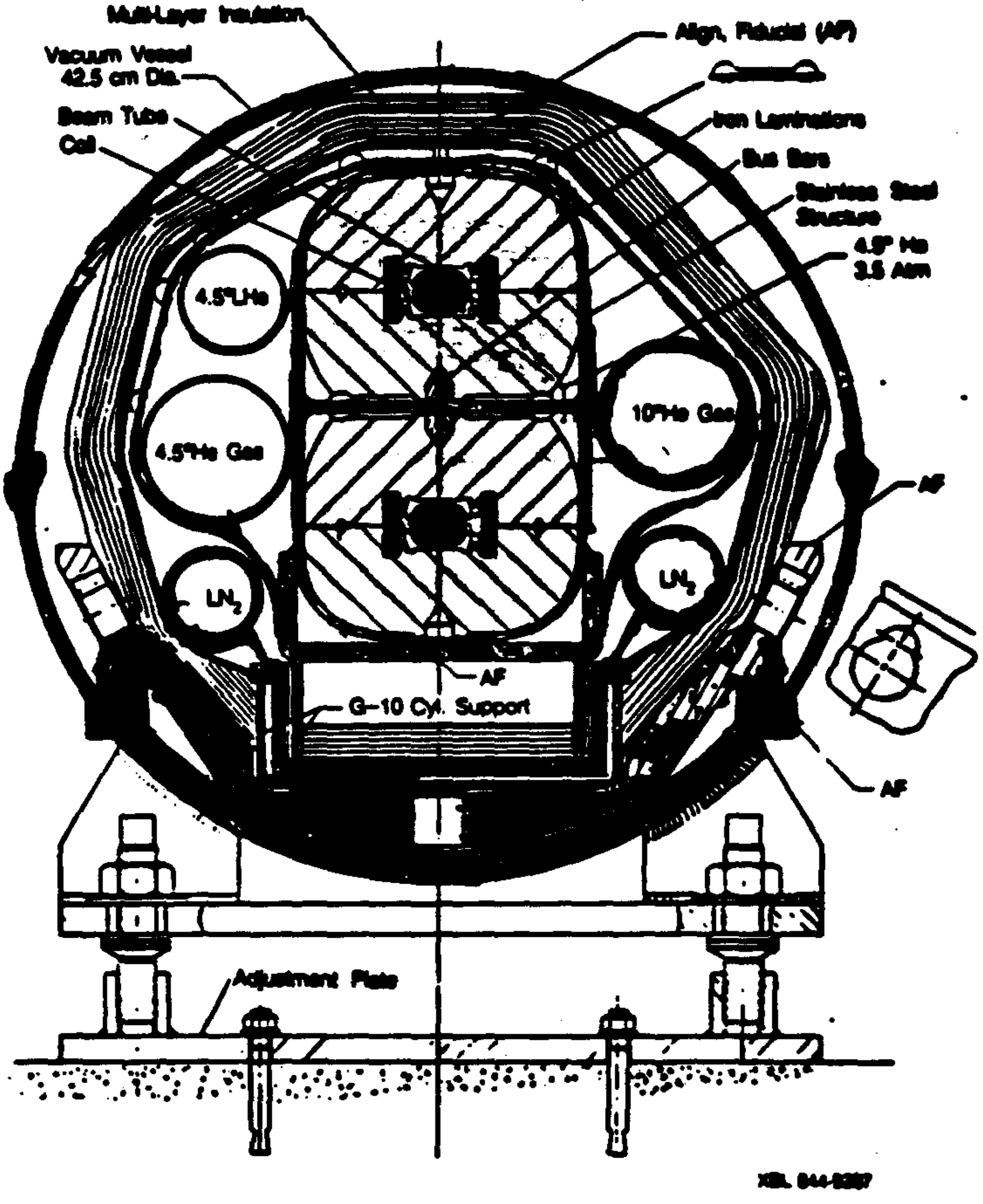
- **Vacuum System, Control System**
  Differences related to magnet type.



0 1 5 10
INCHES

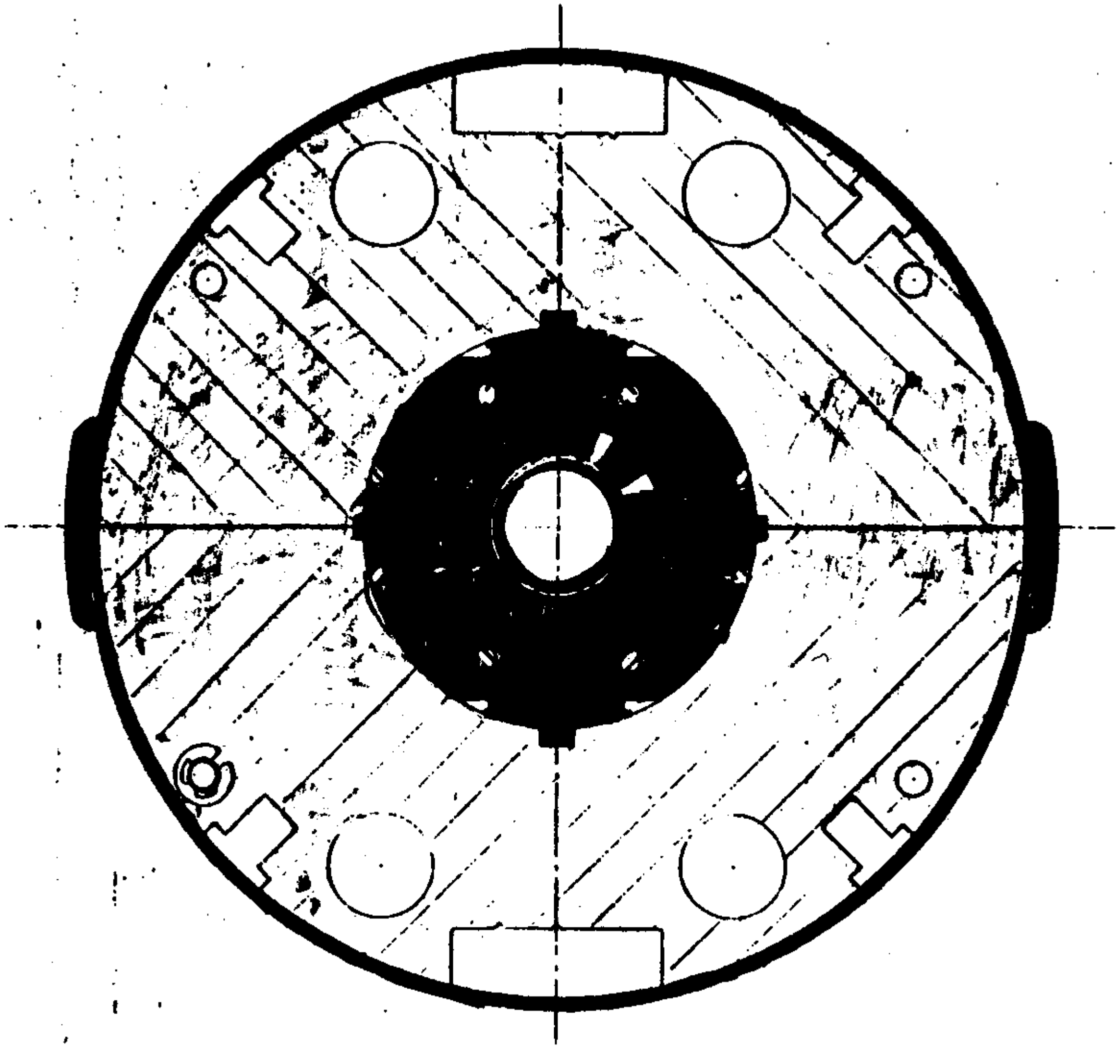
5-Tesla Iron-Free SSC Dipole Magnet (FNAL Design)





3-Tesla Superferric SSC Dipole Magnet
(Texas Design)

22-00.250-3



SECTION A A

FULL SIZE

					3SC 22.00	~	~

BROOKHAVEN NATIONAL LABORATORY
UPTON N Y

MAGNETS, GENERAL
3SC 4CM, C-5 1:1 DIPOLE MAGNET
MAGNET CROSS-SECTION

12-20-84	SEE B MADE	FULL	3

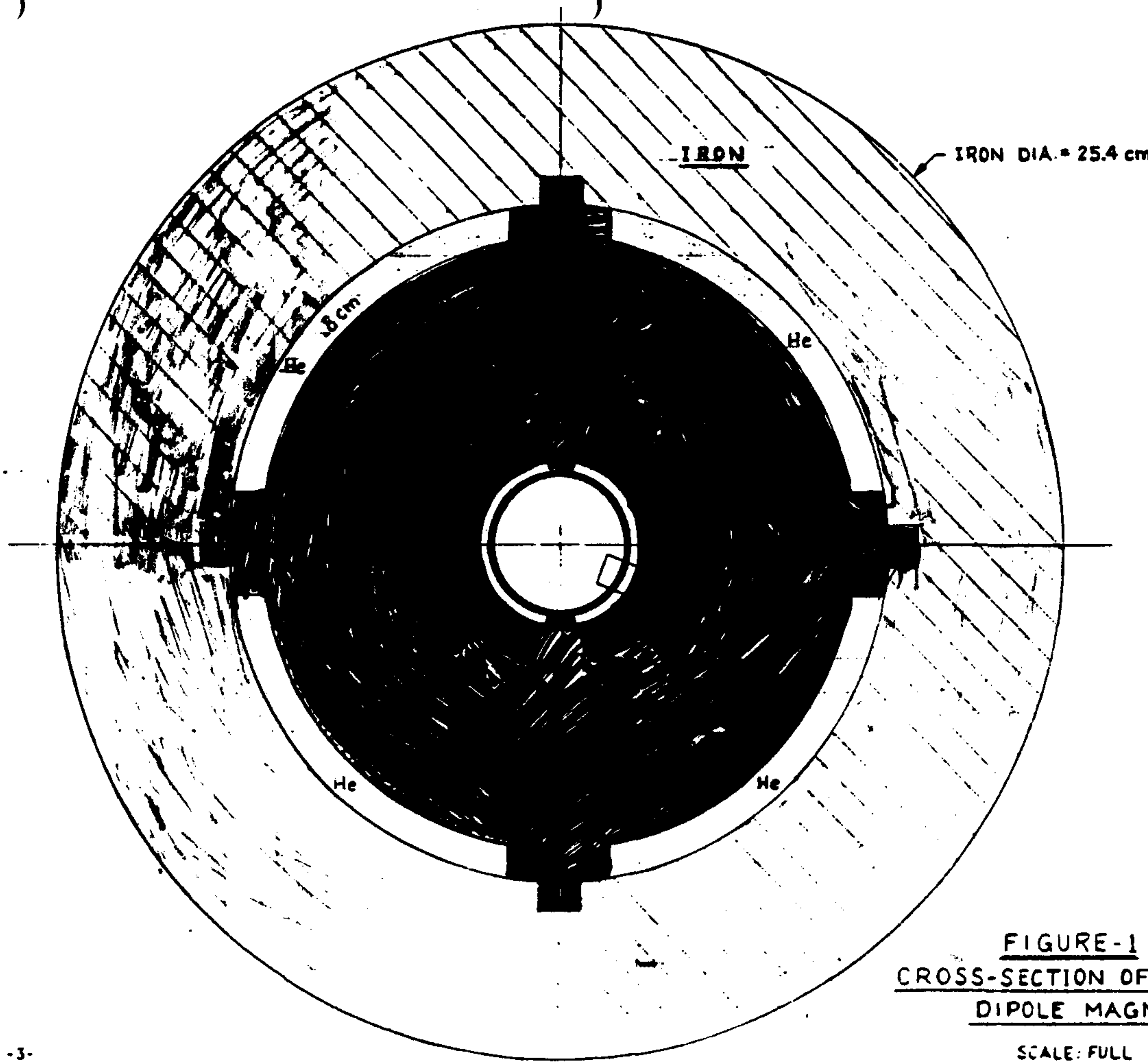


FIGURE-1
CROSS-SECTION OF COLD IRON DIPOLE MAGNET

SCALE: FULL

Workshop on SSC Commissioning and Operations

January 14 - 18, 1985

Participants

Workshop Coordination

Don Groom	University of Utah
Peter Limon	Central Design Group
Karen Larsen	Lawrence Berkeley Laboratory

Cryogenics Group

William Fowler, Coordinator	Fermi National Accelerator Laboratory
Donald Brown	Brookhaven National Laboratory
Claus Rode	Fermi National Accelerator Laboratory
Peter VanderArend	Cryogenics Consultants, Inc.
John Van Sloan	Air Products & Chemicals, Inc.
Richard Wolgast	Lawrence Berkeley Laboratory

Design Group

Christoph Leemann, Coordinator	Lawrence Berkeley Laboratory
Alex Chao	Central Design Group-SSC
Ernest Courant	Brookhaven National Laboratory
Don Edwards	Fermi National Accelerator Laboratory
Eugene Fisk	Fermi Natoinal Accelerator Laboratory
Albert Hoffman	Stanford Linear Accelerator Center
Steve Peggs	Central Design Group-SSC
Jack Peterson	Lawrence Berkeley Laboratory

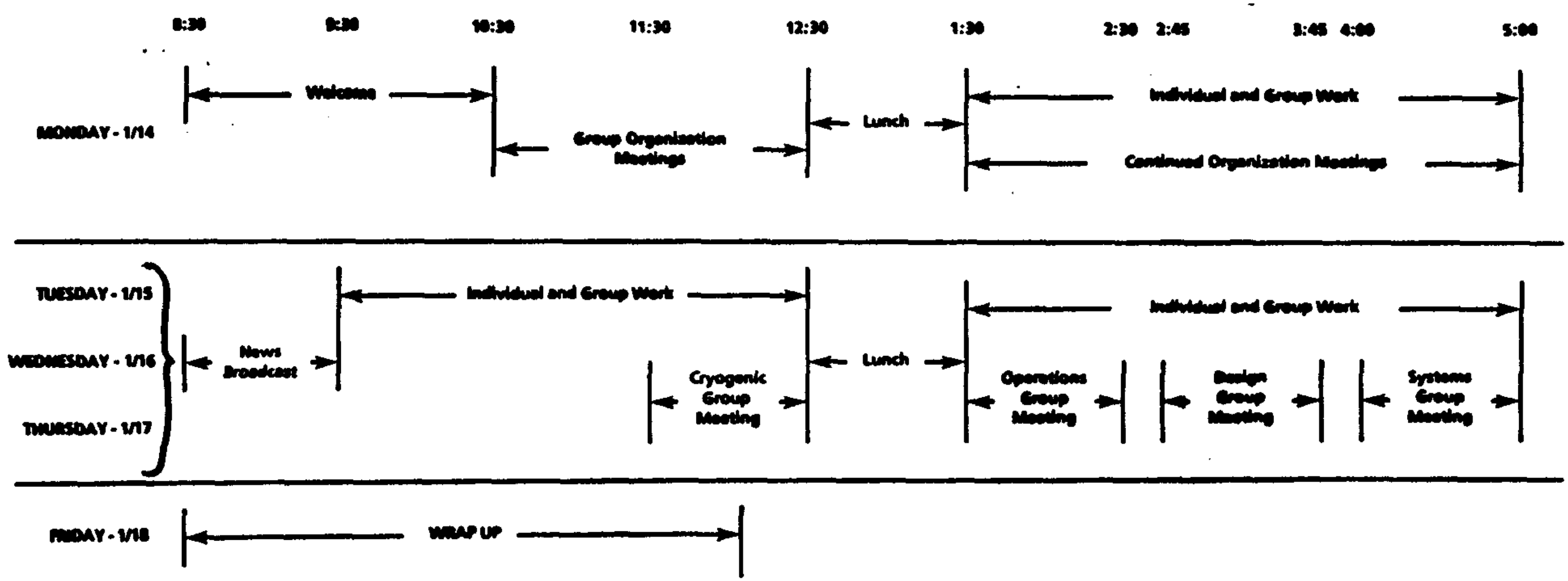
Operations Group

Paul Reardon, Coordinator	Brookhaven National Laboratory
Phil Bryant	CERN
Lyn Evans	CERN
Mike Harrison	Fermi National Accelerator Laboratory
Russ Huson	Texas Accelerator Center
Andrew Hutton	Stanford Linear Accelerator Center
Derek Lowenstein	Brookhaven National Laboratory
Robert Mau	Fermi National Accelerator Laboratory
Rich Orr	Fermi National Accelerator Laboratory
John Poole	CERN
Luc Vos	CERN
Peter Wanderer	Brookhaven National Laboratory

Systems Group

Donald Hartill, Coordinator	Cornell University
Dixon Bogert	Fermi National Accelerator Laboratory
Richard Cassel	Stanford Linear Accelerator Center
Karl Koepke	Fermi National Accelerator Laboratory
Gerry Tool	Fermi National Accelerator Laboratory
John Zeigler	Texas Accelerator Center

WORKSHOP ON COMMISSIONING AND OPERATIONS OF THE SSC
Daily Schedule



SSC CRO workshop
Ewan Paterson 01/14

RELIABILITY APPLIED TO THE SSC

Q Is the SSC in any way different from other large accelerator complexes

A YES

a) Probably all new from ground up (or ...)

Other systems grew gradually using existing developed and debugged hardware (accelerators) at least in part.

b) Much larger

Possibly more things to fail! (Not clear)

Logistics of maintenance & repair

c) More expensive

Cost cutting engineering using more new technology — initial reliability!

Public awareness of performance!

WHAT CAN BE DONE TO DESIGN IN RELIABILITY

Be conservative — Can't afford it!

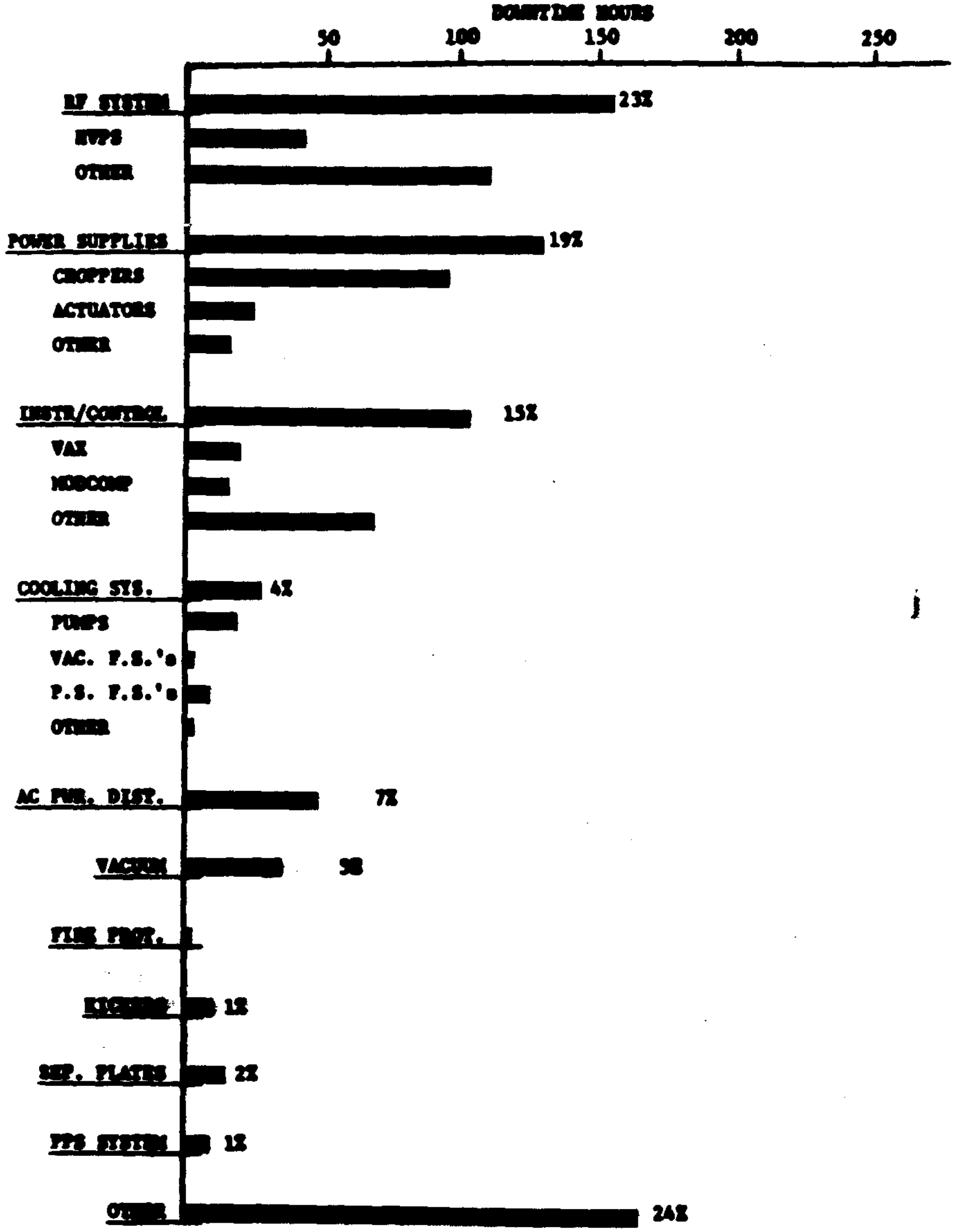
Use redundancy — Can't afford it!

Fault analysis must be an important part of engineering design and cost optimization.

Consequences of a fault must be understood and impact on operation analysed.

For example – a system that faults once a day causing an abort (even if it is fixed or replaced in 60 seconds) has a bigger impact than a system that blows up once per year shutting down operation for 24 hours.

PEP DOWNTIME DISTRIBUTION
OCTOBER 1, 1983 THROUGH APRIL 30, 1984



SCHEDULED OPERATING HOURS = 4,454
RING DOWNTIME HOURS = 682 15%
LINAC DOWN 12%

WHAT DO I CONCLUDE?

SHORT TERM FAULTS DOMINATE IMPACT.

COMPLEX SYSTEMS THAT REQUIRE PROTECTION INTERLOCKS DOMINATE.

CAN WE DESIGN SMARTER MORE RELIABLE SYSTEMS? (FOR LESS MONEY OF COURSE)

CAN PROTECTION INTERLOCKS BE SMART?

- EARLY WARNING
- ERROR CHECKING LOGIC
- CONTROLLED SHUTDOWN

CAN WE DESIGN AUTOMATIC CORRECTION TO AVOID BEAM LOSS?

SHOULD SYSTEMS BE DESIGNED TO ALLOW ON-LINE MAINTENANCE AND OR REPLACEMENT.

- TO THIS GROUP THE ABOVE MAY BE OBVIOUS AND TOGETHER WE COULD MAKE A MORE COMPREHENSIVE LIST.

- HOWEVER THE SSC SYSTEMS WILL BE DESIGNED IN MANY DETAILS BY PEOPLE WHO DON'T UNDERSTAND THE IMPACT OF THEIR DESIGN DECISIONS.

- WE WILL NEED A SYSTEM WHICH REQUIRES A DIALOGUE BETWEEN ENGINEERS AND ACCEL PHYSICISTS ON OPERATIONAL RELIABILITY.

Harrison 01/14/85 AM

WORKING GROUP B

— EDWARDS, BISOGNANO, HARRISON, KEIL, LEEMAN, MONTH, NEUFFER, SCHONFELD

AIMS

i) DEVELOP A PERFORMANCE SPECIFICATION AND TRANSLATE INTO APERTURE REQUIREMENTS

ii) PROPOSE AN ALGORITHM FOR MAGNET EVALUATION BASED ON (i)

n.b. ONLY CONCERNED AT THIS TIME WITH DIPOLES IN THE ARCS

ATTEMPT TO LOOK AT OPERATIONAL ASPECTS OF THE MACHINE AND ANALIZE IN TERMS OF APERTURE

i) <u>ABORT</u> — LOCAL APERTURE REQUIREMENT ONLY, MUST REFLECT MACHINE APERTURE NOT PLACE DEMANDS ON IT.

ii) <u>ACCELERATION</u> — SEE BEAM LOSS IN TEVATRON, ALMOST ALWAYS ASSOCIATED WITH INJECTION - BEAM FALLING OUT OF R.F BUCKETS. NO STRONG CORRELATION WITH APERTURE.

iii) <u>OPERATIONAL TOLERANCES</u> — CLOSED ORBIT, STABILITY ETC. CAN BE ESTIMATED AND MUST BE FACTORED IN

iv) <u>INJECTION</u> — MAY WELL DEFINE APERTURE. LOW ENERGY → LARGER BEAM SIZE, PERSISTANT CURRENTS, INJECTION OSCILLATIONS, DIPOLE FIELD MATCHING, 20 MINUTE STORAGE TIME.

BEAM AS A DIAGNOSTIC

CLOSED ORBIT BUMPS MUST BE LOCAL

v) BEAM MEASUREMENTS - REQUIRE SUFFICIENT LINEAR APERTURE TO MAKE THOSE MEASUREMENTS NEEDED FOR COMMISSIONING + DIAGNOSTICS + OPERATION, MIGHT WELL DEFINE HIGH FIELD APERTURE.

vi) INSTABILITIES - NO DIRECT DEMANDS ON APERTURE

vii) FIRST TURN CLOSURE - ALIGNMENT TOLERANCES, CORRECTION DIPOLE PLACEMENT DESIGN PROBLEM NOT APERTURE

viii) TWO BEAM EFFECTS - MIGHT NEED TO SEPARATE BEAMS AT LOW ENERGY. REQUIRE BEAM MANIPULATIONS TO BE LOCAL TO THE I.R.'s

ix) COLLISIONS + STORAGE - COULD NOT THINK OF ANYTHING SPECIFIC

REFERENCES

1. Hirst, E. and J. Carney, The ORNL Engineering-Economic Model of Residential Energy Use, ORNL/CON-24, Oak Ridge National Laboratory, July, 1978

2. U. S. Department of Commerce, Bureau of the Census, Annual Housing Survey, Current Housing Reports, Series H-170

3. Lin, W., E. Hirst and S. Cohn, Fuel Choices in the Household Sector, ORNL/CON-3, Oak Ridge National Laboratory, October, 1976.

4. Anderson, K., Residential Energy Use: An Econometric Analysis, R-1297-NSF, Rand Corporation, October, 1973.

5. Baughman, M., and P. Joskow, "The Effects of Fuel Prices on Residential Appliance Choice in the United States", Land Economics, February, 1975.

6. Hartman, R. and M. Hollyer, An Examination of the Use of Probability Modeling for the Analysis of Interfuel Substitution in Residential Fuel Demand, Energy Laboratory Working Paper No. MIT-EL 77-018WP, Massachusetts Institute of Technology, July, 1977.

APERTURE DEFINITION

1) $\Delta p/p = 0$

a) INITIAL AMPLITUDES UP TO $\sqrt{x^2 + y^2} = \boxed{10}$ mm AT β_{max} MUST BE STABLE AND NOT STRIKE THE PHYSICAL APERTURE

b) FOR AMPLITUDES UP TO $\boxed{50\%}$ OF THE ABOVE THE SMEAR OF THE X-Y PLOT SHOULD BE CONFINED WITHIN AN AREA OF LINEAR DIMENSION LESS THAN $\boxed{10\%}$ OF THE AMPLITUDE ($\Delta\nu \lesssim 0.003$)

2) $\Delta p/p = \boxed{\pm 10^{-3}}$ CONDITIONS CORRESPONDING TO (1) APPLY AT AMPLITUDES $\boxed{70\%}$ OF THOSE USED ABOVE.

SSC Commissioning & Operations Workshop
Peter Vander Arend
14 Jan 1985 AM

Cryogenic Problems of SSC magnets

1) Long distance transportation of refrigeration
2) Cooldown - warmup of cold iron magnets; magnet replacement
3) Flowdistribution in magnets and removal of synchrotron radiation
4) Handling of transients
5) 80°K shield cooling; N_2 versus He
6) Sizing of refrigerators, redundancy and reliability
7) Safety problems in tunnel

Long distance transportation of refrigeration

Large distance between refrigerators yields:

1) Large inventory of helium in the magnet system

2) Large time constants for removal of a transient.

Also:

1) Can system operate with one refrigerator down.

Cooldown of string of cold iron magnets

1) Use stored refrigeration (LIN) between 300 - 80°K.

2) Use turbines in He refrigerators between 80 - 20°K

3) Use stored refrigeration (Liq He) to cool and fill magnets.

Warm up and repair/replacement of a magnet.

1) Warm up with
a) electrical heat
b) flow of warm helium gas
c) mixture of a) and b)

2) Replace magnet by:
a) warming 2 and boxes
b) break vacuum with helium
c) repair/replace magnet
d) Establish beam tube vacuum

3) Largest problem above may be d)
Potential solution; cryopumps ~~in the~~ in magnets to establish high vacuum after roughing operation.

Flow distribution in magnets
and removal of synchrotron radiation

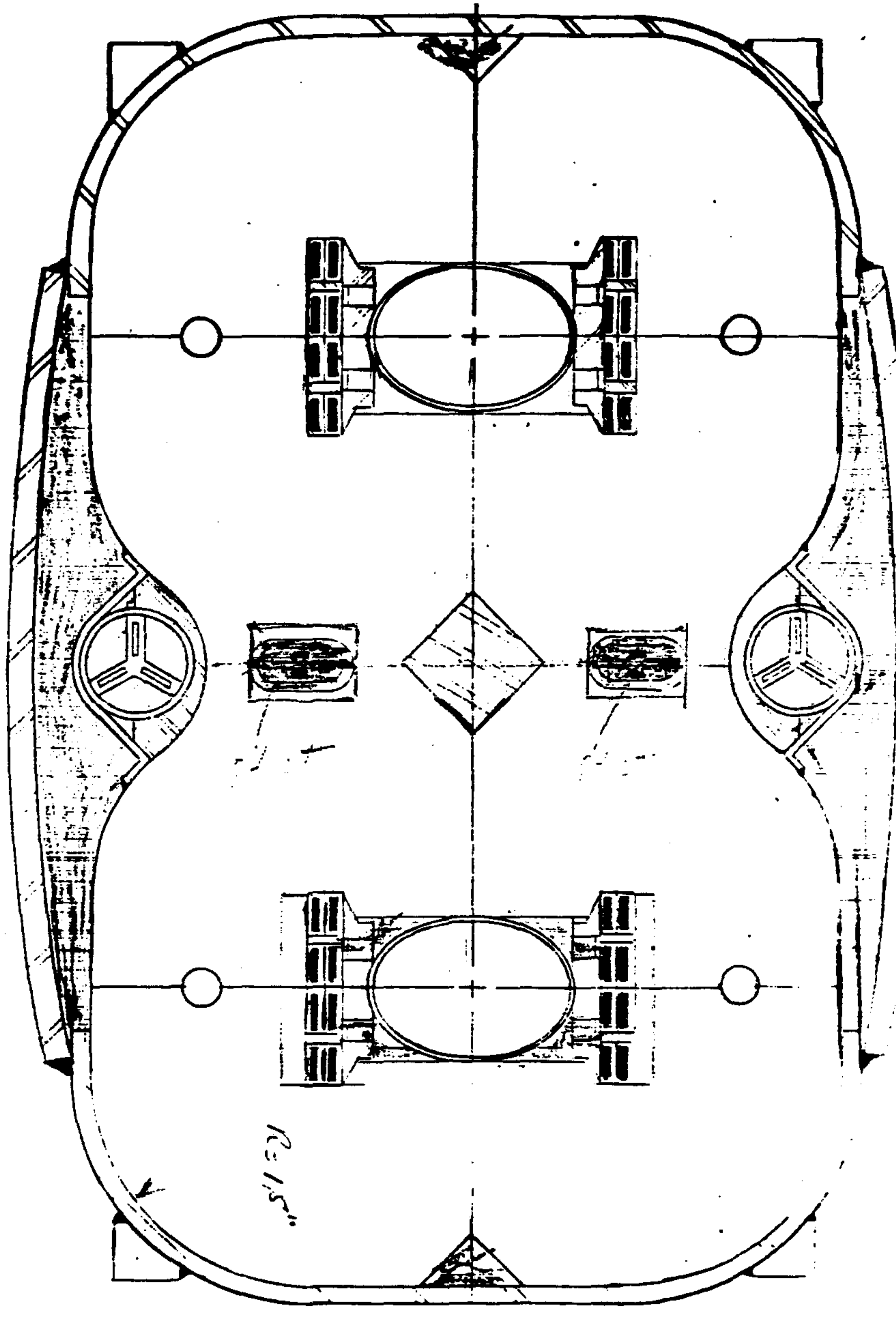
1) Beam tube area receives a small fraction of steady state flow.

2) Bulk of flow is through wide channel

3) Remove synchrotron radiation by:

a) Forced flow to beam tube area

b) Conduction through coils, collar, iron to large flow passages.



Handling of transients.

1) Liquid and gas blown out of magnets will be added to cold piping within the cryostat.

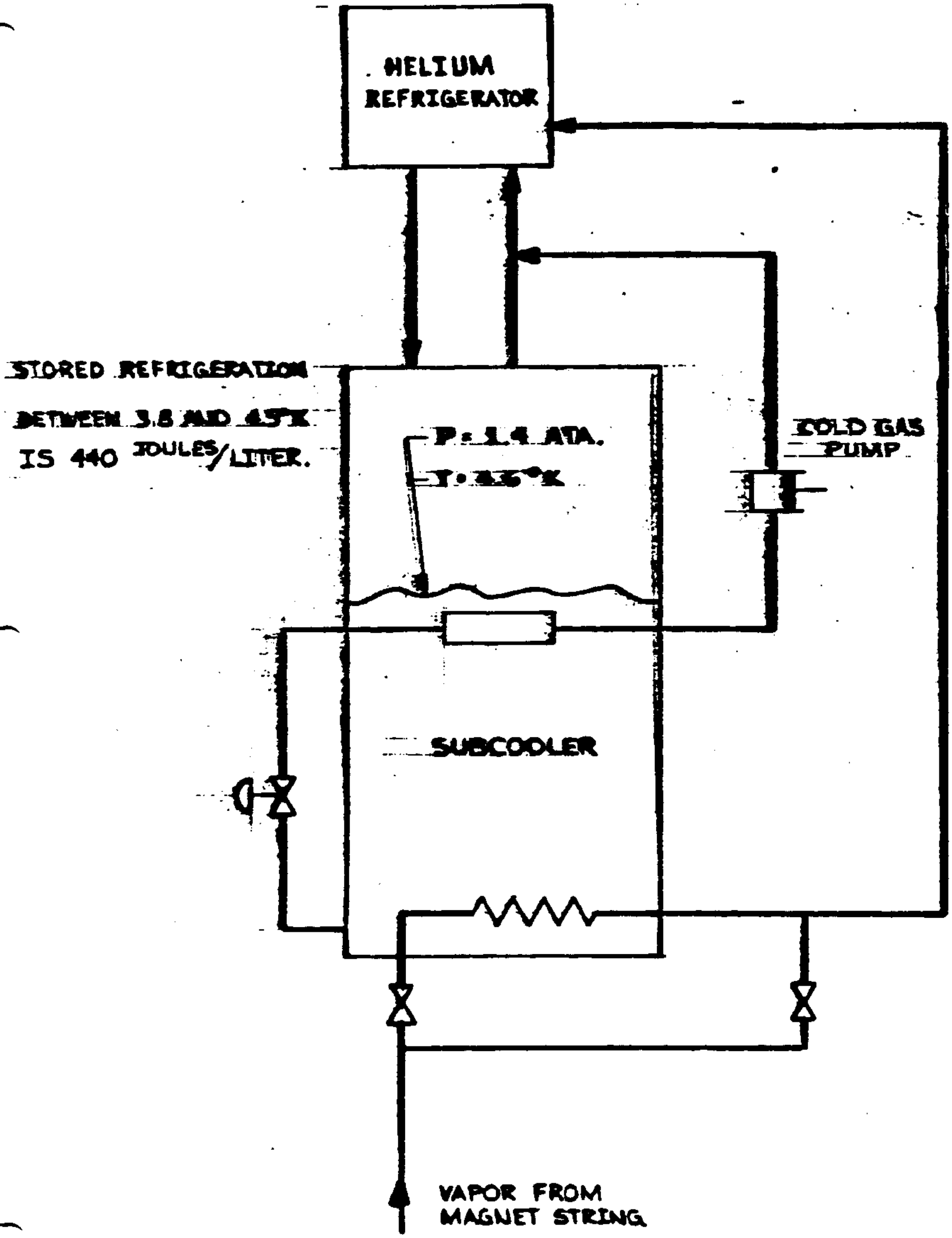
2) A "hot zone" travels at a relatively low velocity to the refrigerator.

3) Refrigerator will see a relatively large load for a short period of time

4) Use of a thermal "flywheel"

8

Thermal flywheel



80°K shield cooling

1) Liq N_2 with circulating pump driving subcooled liquid

2) High pressure helium driven by the He refrigerator compressor

3) Safety problems in tunnel from a large break

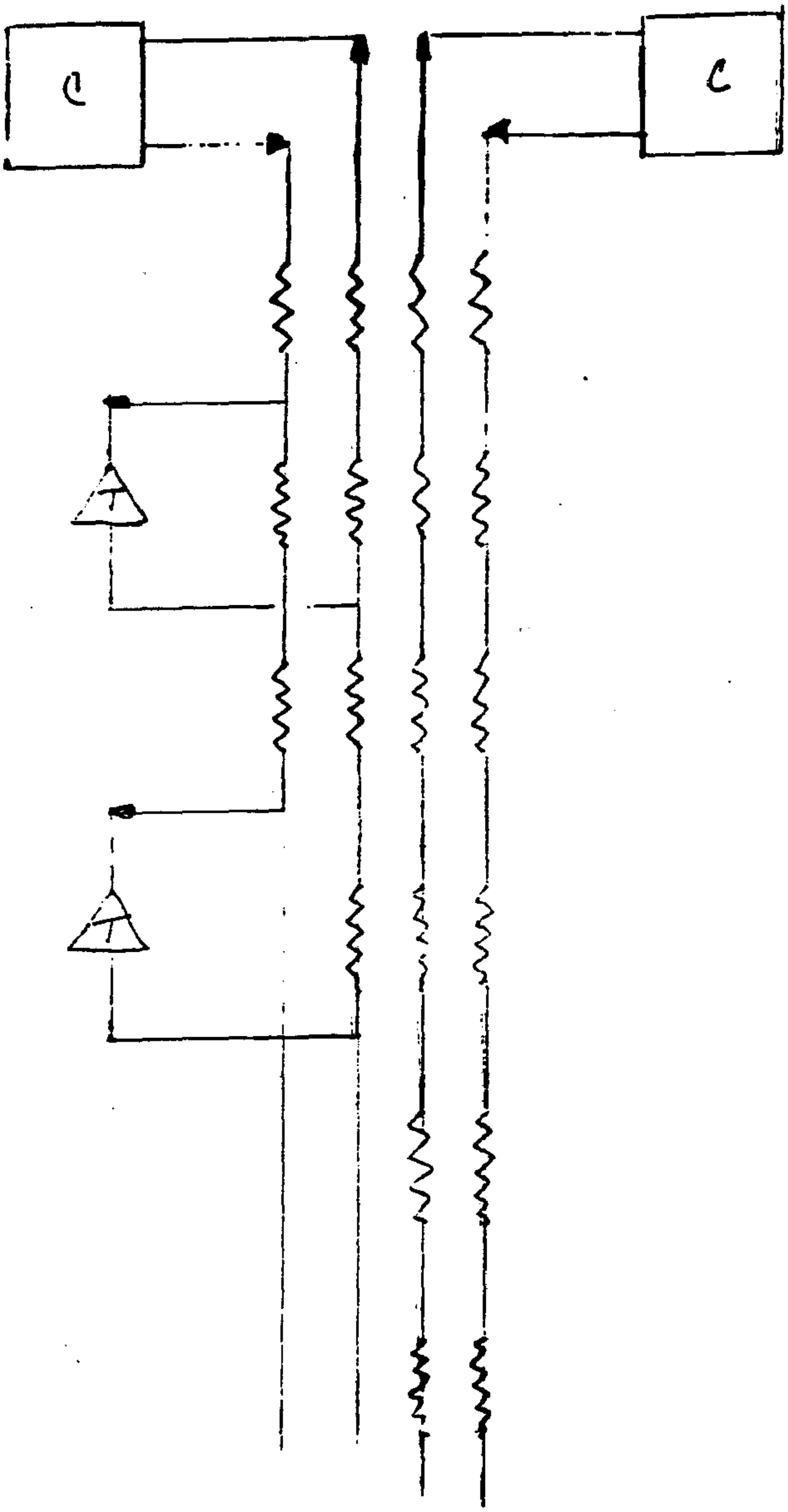
a) Liquid N_2 spill needs to be handled by reducing rate of evaporation

b) He spill will generate inert atmosphere in top of tunnel

Sizing of refrigerator.

1) General agreement that 50%
extra capacity is required

2) Efficient operation at ⅔
of full capacity may be
provided by a separate
turbine loop


C
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Cryogenic system agreements

1) Use of shield between 80°K and 4.5°K

2) Return of quench fluid through cold pipes within cryostat

3) Removal of synchrotron heat by conduction through coil

4) Steady state refrigeration cycle for magnet cooling

5) Use of liquid helium circ. pumps

6) Use of liquid helium storage

Cryogenic system parameters to be determined

1) Pressure of 1Φ Liquid He in magnets
2) "15°K" shield temperature
3) (15°K) Shield cooling fluid
4) Number of cold pipes in cryostat
5) Handling of transients
6) Size of refrigerators
7) Redundancy - reliability of the overall cryogenic system.

Problem areas

1) Thermal contraction
2) Bowing during cooldown/warm ups
3) Time constants in system control
4) Computer control-system characteristics
5) Inventory management for helium and nitrogen
6) Valves
7) Sloping collider
8) Replacement of a magnet

Desirable experimental work

1) Determination of heat leaks
2) ~~[illegible]~~ Simulation of cryogenic effects of a quench
3) Magnet support system
4) Liquid helium pumps
5) Cryogenic valves

Projected Heatleaks *

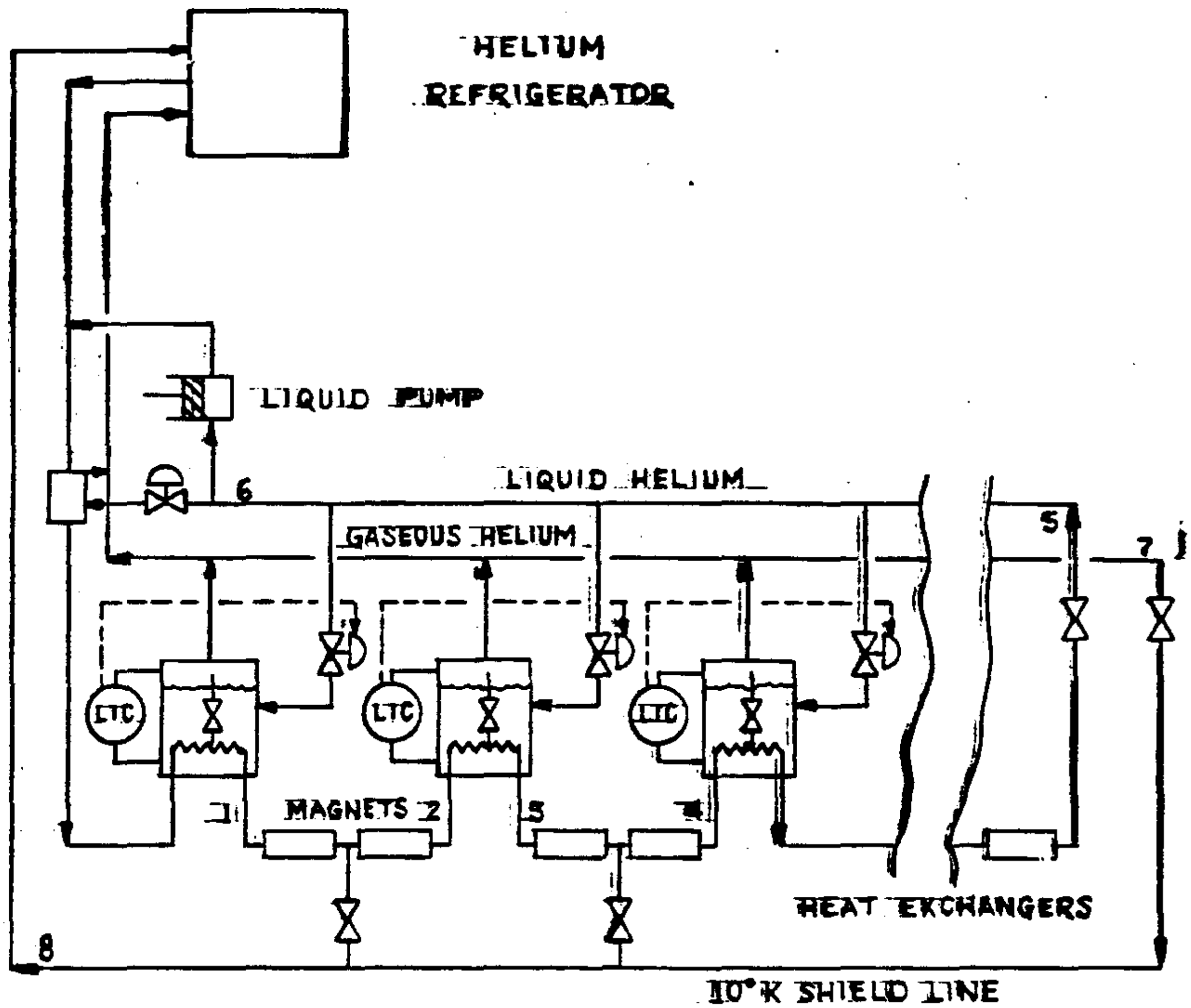
Magnet	6.5 T	5.0 T **	3.0 T
Surface area (ft^2)			
4.5°K	1.34×10^6	1.55×10^6	1.97×10^6
80°K	1.66×10^6	2.30×10^6	1.86×10^6
Minimum heatleak (W)			
4.5°K	12.1×10^3	14.0×10^3	19.7×10^3
80°K	1.66×10^5	2.30×10^5	1.86×10^5
Projected Heat leak (W)			
4.5°K	26.5×10^3	10.8×10^3	5.7×10^3
80°K	1.96×10^5	2.8×10^5	2.77×10^5

* Not included: synchrotron rad., splices, valves, refrig. piping

** Numbers are for 2 complete rings.

ATTAINABLE HEAT LOADS

	4.5°K W/FT.²	80°K W/FT.²
LIQUID HELIUM TRANSPORT DEWARS (41,000 LITERS)	.009	.096
TEVATRON LIQ.He TRANSFER LINE	.0246	.175
NMR DEWARS	.0015	?
TEVATRON DIPOLES	.382-.509	1.43
FNAL MEASUREMENT	.0012-.002	—



SCHEMATIC OF THE HELIUM REFRIGERATION CIRCUIT FOR THE 3T SUPERFERRIC MAGNETS (TAC)

FIGURE 18

INDEX

INDEX

Tuesday Morning 15 Jan 1985

NEWS REPORTS

SSC C&O Workshop
Cryogenics "News Report"
Tue 15 Jan 85
W. Fowler

Cryo Talks
11 AM to Noon

Tues C. Rode
SSC MAGNET CRYOGENIC COMPARISONS
Design A, B, C & D
Impact of common failures

Wed J. Van Sloan
Commercial Plants
Start-up and Operational Problems

Thur D. Brown
Lower temperature operations

1/11/85

Cryo Group Work List

1. Review heat leaks, weights etc.

2. Cool Down

3. Magnet Replacement

4. flow areas — flow rates

   Conduction cooling and/or porosity of coil package

5. Quench recovery

6. Magnet Shields, Type (air, LN, He) flow and area required.

7. Mobil Refrigerators for cool-down of magnet replacement.

CRYOGENIC AND MAGNET SYSTEM INTERFACES

1. MAGNET OPERATING TEMPERATURE
   ALLOWABLE ΔT for multipole
2. HEAT LOAD
   A. SUPPORT HEAT STATIONING
   B. HEAT SHIELDS
      - HIGH TEMPERATURE (80°K)
      - LOW TEMPERATURE
        - IN OR OUT?
        - MEAN OPERATING TEMPERATURE?
        - PIPING SPACE?
   C. INSULATION SYSTEM
3. PRESSURE DROP IN MAGNETS - ALL OPERATING CONDITIONS
4. PIPING - NUMBER AND SIZE OF PIPES REQUIRED
   A. OPERATING FLEXIBILITY VS. COST AND SPACE
   B. PRESSURE DROP VS. OPERATING TEMPERATURE
   C. PRESSURE DROP VS. OPERATING EFFICIENCY (COST)
5. HELIUM VOLUME IN MAGNET SYSTEM
6. COOLDOWN MASS OF MAGNET SYSTEM
7. SPACE REQUIRED FOR RECOOLERS, ETC.,
8. WARM UP
9. DESIGN PRESSURE

D.P. BROWN
9 JAN 85

Cryogenic Questions

- **Large Scale Cooldowns**
  Time, cost, how often?

- **Magnet Replacement**
  Time required, beam valves, how is it done, how often?

- **Steady State Operation**
  Removing heat from synchrotron radiation and ramping.

- **Two Phase Flow**
  Is it stable?

- **One Phase Flow**
  What do the recoolers look like?

- **Quench Recovery**
  Two-in-one implications.

- **Separate Cryogenics**
  Should one-in-one magnets have separate cryostats?

WORKSHOP ON COMMISSIONING AND OPERATION OF THE SSC

II. RESULT OF WORKSHOP SHOULD BE:

- TO DETERMINE THE IMPORTANCE OF VARIOUS MAGNET FEATURES TO THE EFFICIENT OPERATION AND/OR COMMISSIONING OF THE MACHINE. GRADED FROM 0 TO 10, SUCH THAT:

  0 = IRRELEVANT
  5 = IMPORTANT
  10 = CRUCIAL

- TO DETERMINE HOW WELL A MACHINE BUILT WITH A PARTICULAR MAGNET TYPE ACCOMMODATES THOSE FEATURES. GRADED FROM 0 TO 10, SUCH THAT:

  0 = NOT AT ALL
  5 = POSSIBLE
  10 = EXCEPTIONALLY WELL

- TO ASSIGN AND SCHEDULE COMPLETION OF THE WORK BY APRIL 1, 1985.

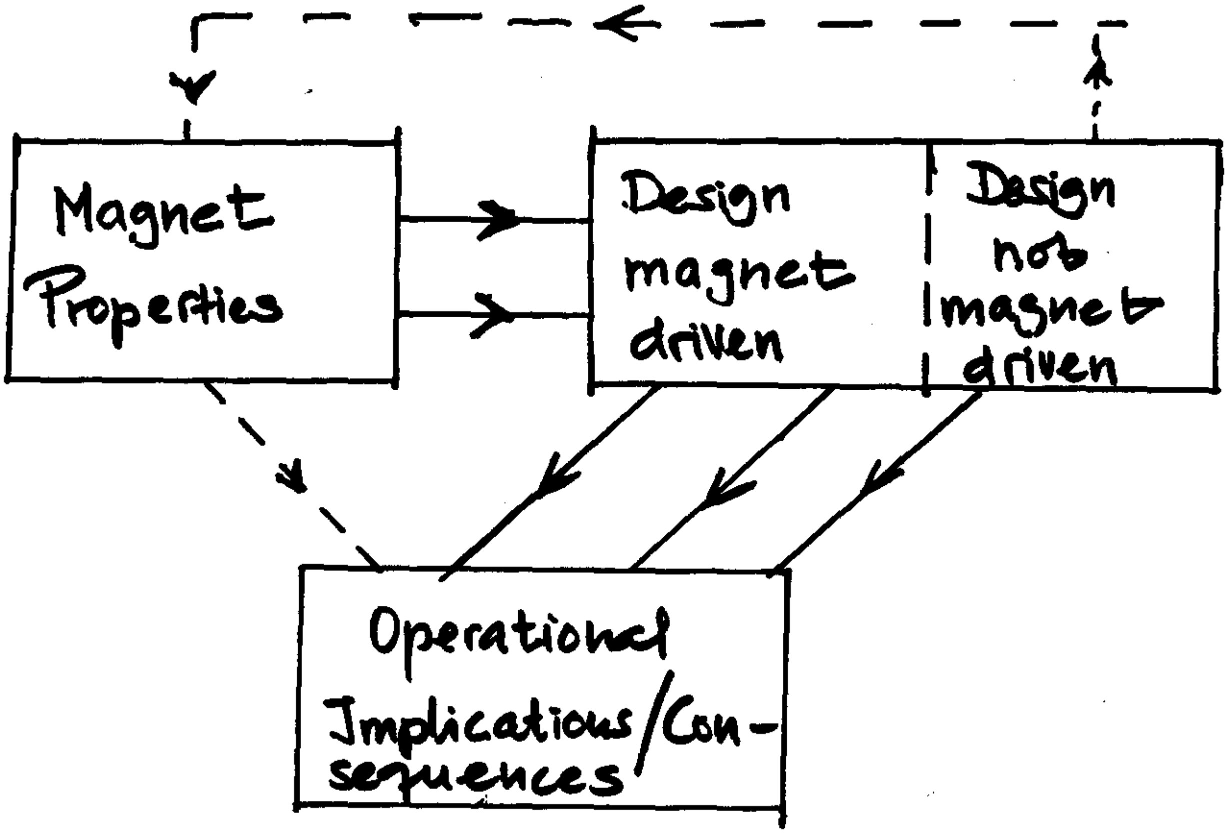
SSC C80 Workshop
The "News Reports"
Design - Christof Leemann

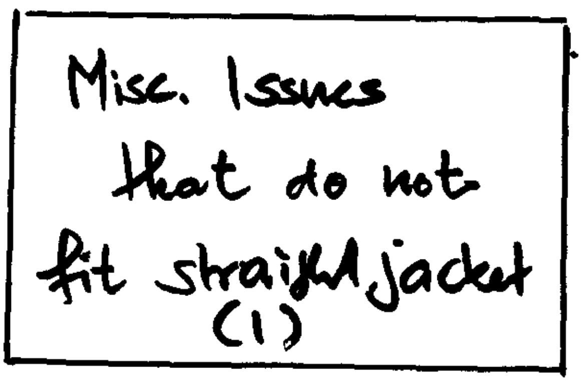
Schedule for Jan 15, '85

930 to ~1000 Meet in Rm 347 for brief further discussion, clarification of objectives and assignments

2:45 to 3:45 Meeting in Rm 308 for progress review, discussion of direction; scheduling of talks

"Design Group"; a Proposed Structure to Organize Thoughts





1. Magnet Description

1.1 "Gross" features/properties

1.1.1 Field level
1.1.2 Superferric vs. conductor dominated
1.1.3 Geometry: aperture, length, 2in1, 1in1 etc
1.1.4 stored energy; other electrical properties

1.2 Field Quality Related {DAF statement ?}

1.2.1 systematic multipoles
1.2.2 persistent current effects
1.2.3 random errors
1.2.4 Filament size, other conductor properties
1.2.5 Description of in situ correctors

1.3 Fabrication/Installation Related

1.3.1 % cold tested
1.3.2 magnet selection & placement
1.3.3 Alignment/tolerances

We have to establish (within the proposed framework:

- Lists:
  - Magnet properties that are relevant
  - Design features
  - Specific operational issues

- Functional relationships
  - will facilitate obtaining a clear picture, quantitative ranking/grading

2. Design

2.1 Magnet Type Driven

2.1.1 Consequences of field [illegible]

2.1.2 Correction strategies: types, placement, excitation etc of correctors

2.1.3 Impact on IR design / collision maintenance

2.1.4 Coupling between rings: concise description, rel. importance of magnet type

2.1.4 Any other magnet derived optics constraints

2.2 Not (or only weakly) Magnet Driven

2.2.1 Chromaticity correction scheme

2.2.2 PS- regulation / arrangement requirements

2.2.3 Lattice periodicity / symmetry / clustering of IR's, injection / abort / rf

3. Operational Implications

3.1 Impact on commissioning:

3.1.1 1st turn
3.1.2 initial c.o.
3.1.3 final c.o.
3.1.4 accel 1 to 20 TeV

3.2 Impact on Availability

3.2.1 general redundancy considerations
3.2.2 analyze typical cycle / exp. time vs. total cycle time

3.3 Analyze importance of Field Quality in present context

3.4 Independent Manipulations of Beams

3.4.1 Importance / Merits
3.4.2 Design Requirements

Some preliminary results / committments

o Magnets
- enumeration of key, gross features near trivial
- detailed discussion of importance of field quality, aspects of magnet selection postponed → DAE
- discussion of persistent current effects, cold vs. warm testing, approaches to correction → EF

o Design / Acc. Physics Issues
- consequences of B level → CL, EC
- correction strategies → EF, SP

- "Coupling" [2 in 1 magnets, IR design, bb ξ, optics limitations] → SP, EF, EC, CL, JP

o Remaining Issues unaddressed yet

SSC C&O Workshop
The "News Reports" 01/15/85
Systems - Don Hartill

Systems

People:

Dixon	Bogert	FNAL
Richard	Cassel	SLAC
Karl	Koepke	FNAL
Gerry	Tool	FNAL
John	Zeigler	TAC

Announcement:

Today (Tues.) 4:00 pm.

Karl Koepke will speak on

"Quench Detection and Protection of SC Magnet Systems"

A short list includes

i. Quench Detection + Protection KK, GT, JZ

ii. Magnet Power Supplies + Regulation RC, JZ

iii. Correction Elements RC, JZ

iv. Vacuum System DH

v. RF DH

vi. Beam Stabilization DH

vii. Beam Position and Loss Monitoring DB

viii. Failure Modes DB, JF

ix. Controls DB, DH

⋮

Activities

1. John Ziegler described present thinking on TAC Magnet Design including PS and QP system

2. Quench Protection

   i. Passive

      a. cold vs warm diodes

      b. response time

   ii. Active

      a. cold vs. warm diodes

      b. response time

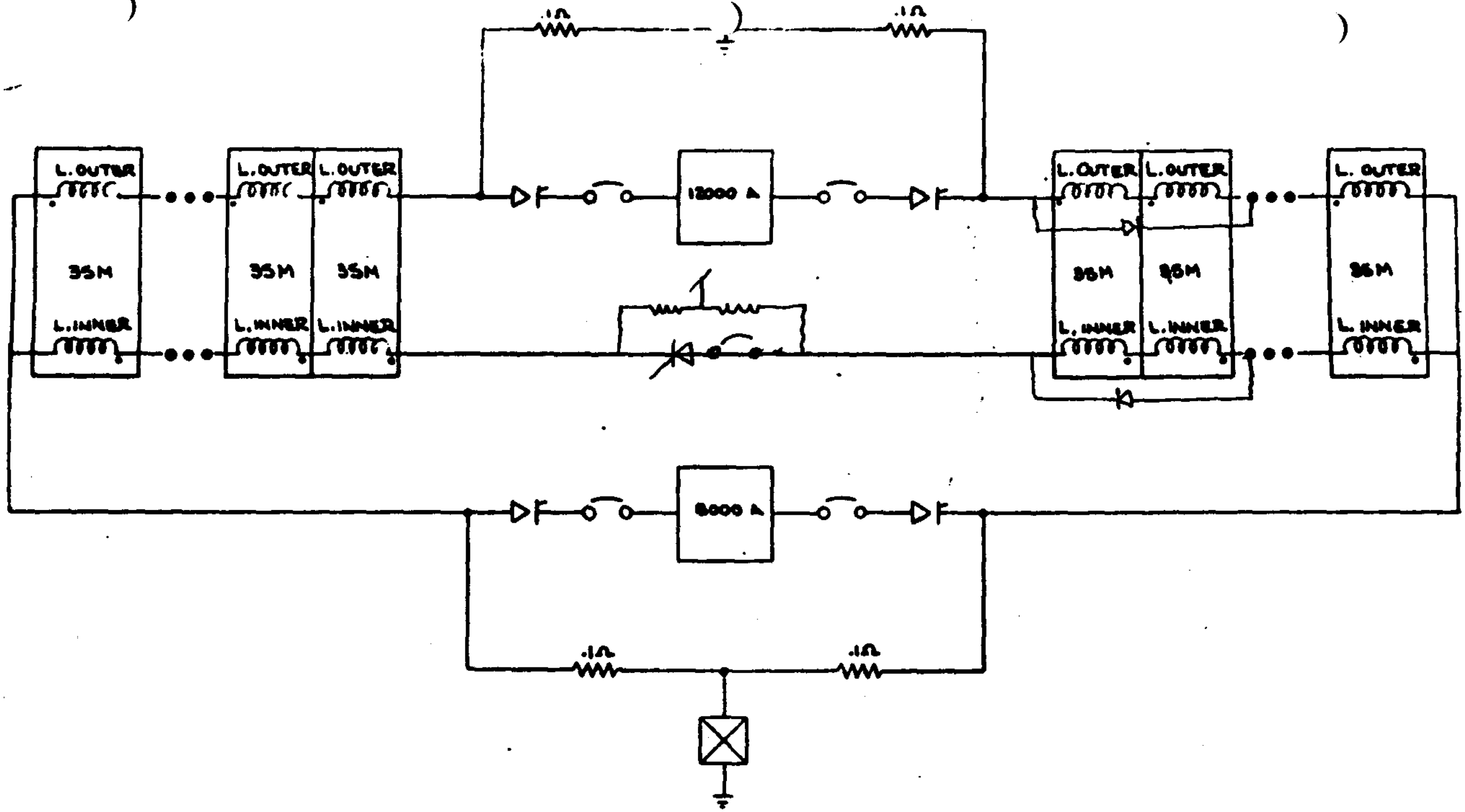
      c. failure modes and frequency

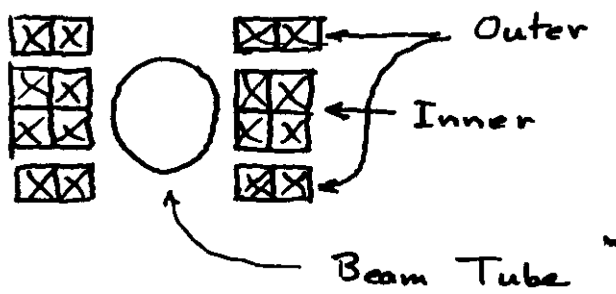
   iii. Safety leads

      a. ≃ 1 watt to 4.5°K / lead

Question:

1. Do cold diodes survive radiation level ?





@ $B_0 = 3T$

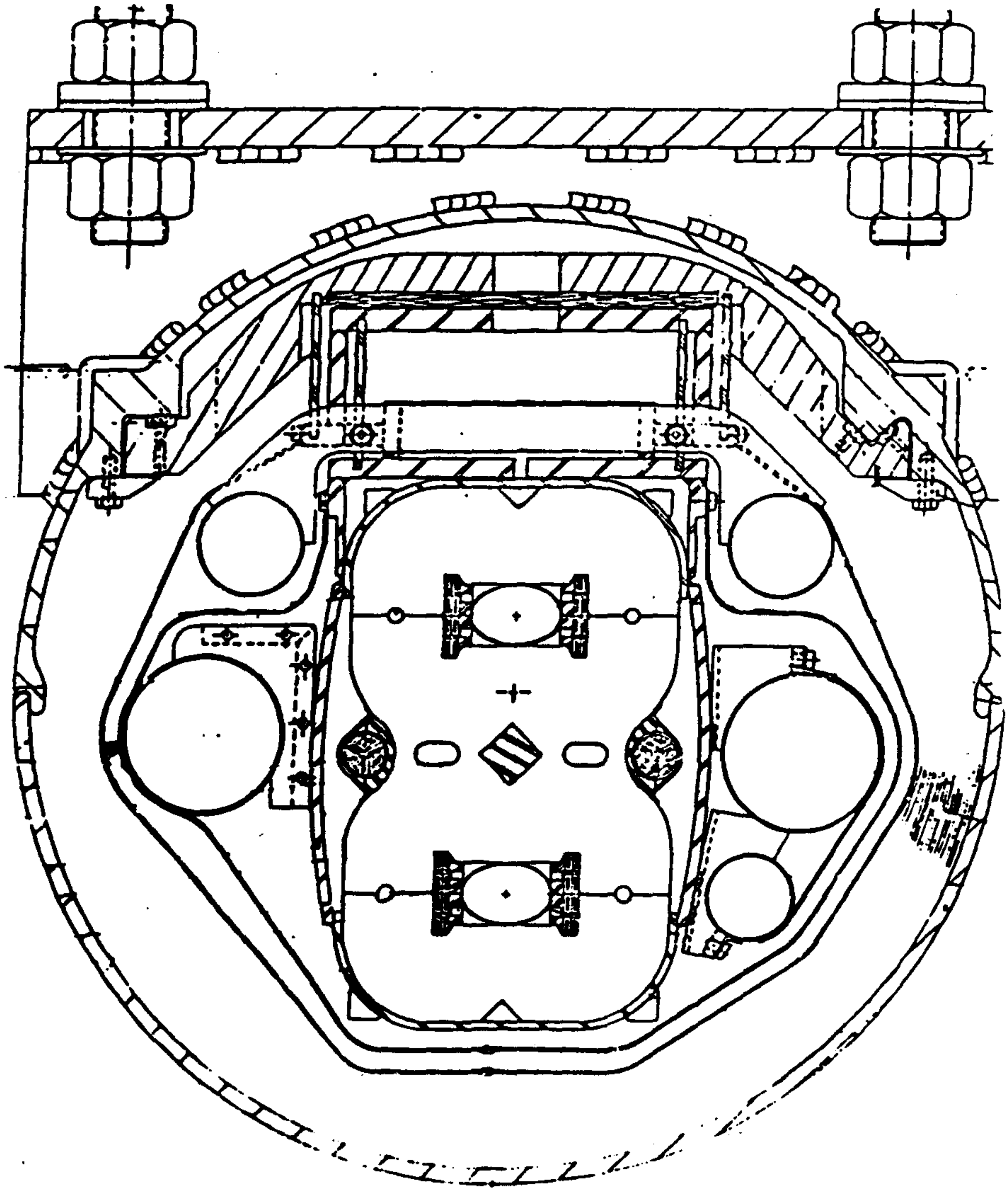
$I_{inner} = I_{outer} \approx 10 kA$

$L_{inner} = 3.3834 \times 10^{-5}$ H/m

$L_{outer} = 3.1164 \times 10^{-5}$ H/m

$M = 2.822 \times 10^{-5}$ H/m

$k = 0.869$

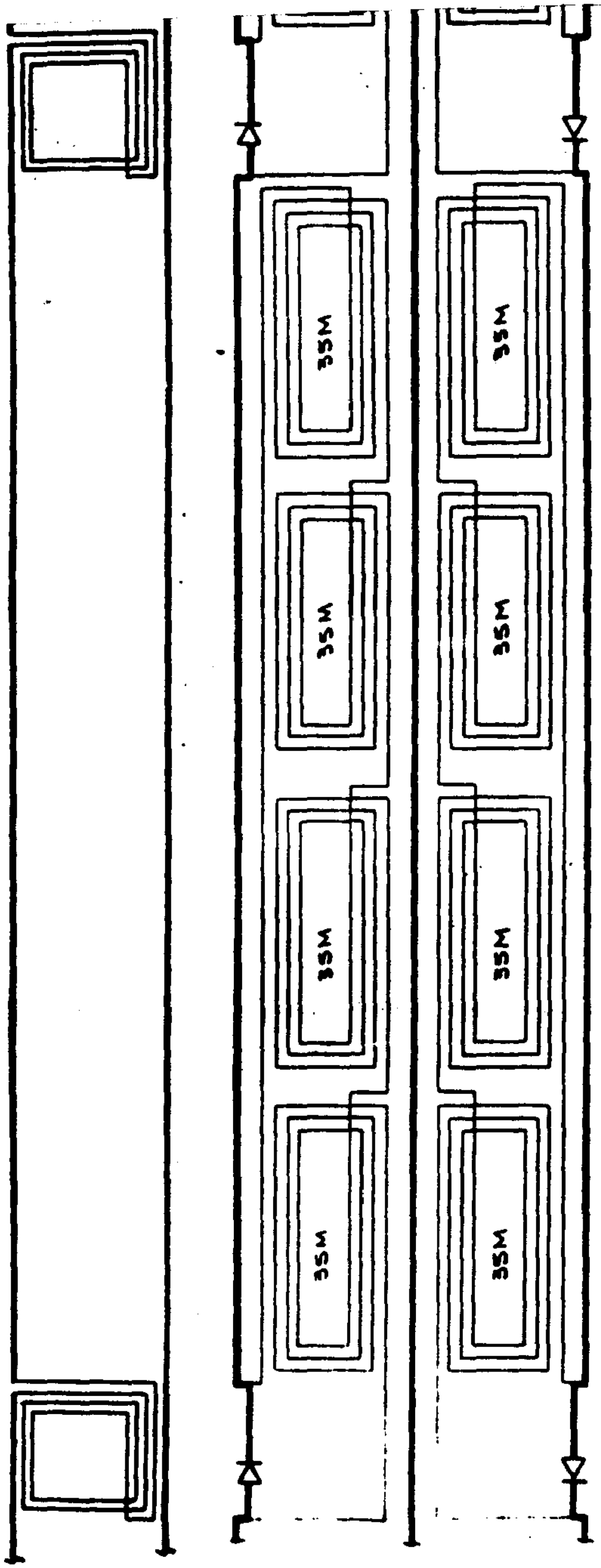


3. Power Supplies

i. Initial discussion

Question:

2. How well do the Quad and Dipole Power Supplies have to track to satisfy the tune spread limit?


35M
35M
35M
35M
35M
35M
35M
35M

Scheduled Reports - Tue 15 Jan. 1985

1. **Cryogenics:** 11:00 a.m.

   Claus Rode: "SSC Magnet Cryogenic Comparison (Design A, B, C, & D) Impact of Common Failures".

2. **Operations:** 1:30 p.m.

   Bob Mau: "Commissioning the FNAL Energy Doubler".
   John Poole [redacted] "SSC Warm Start Time Estimate"
   Phil Bryant: "Magnetic Coupling Effects at the ISR".

3. **Design:** 2:45 p.m.

   Meeting for progress review, discussion of direction, scheduling of talks.

4. **Systems:** 4:00 p.m.

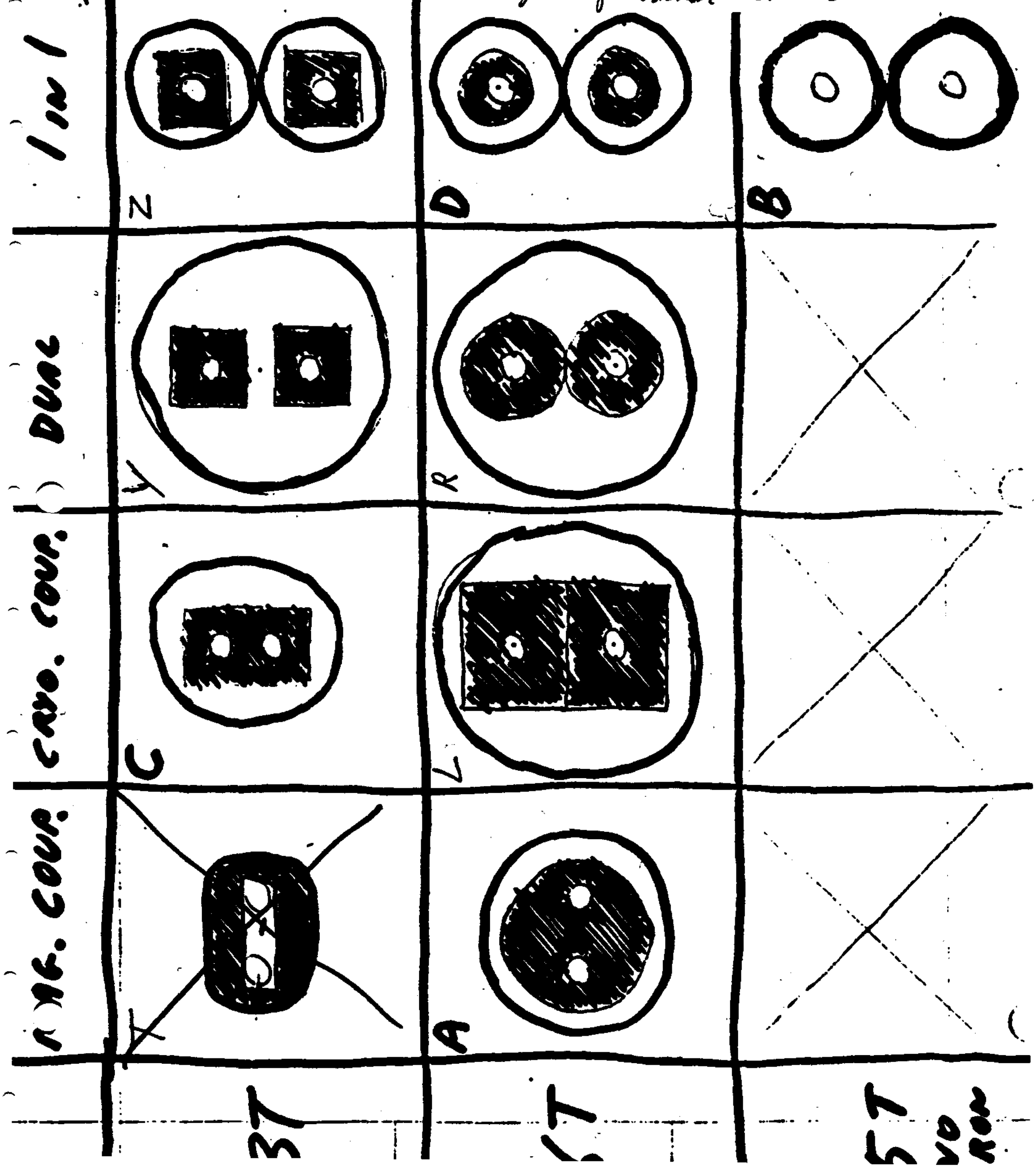
   Karl Koepke: "Quench Detection and Protection of SSC Magnet Systems".

Coming Attractions:

Cryogenics: Wednesday a.m.: John VanSloan, "Commercial Plants: Start-up and Operational Problems".

Cryogenics: Thursday a.m.: Don Brown "Lower Temperature Operations".

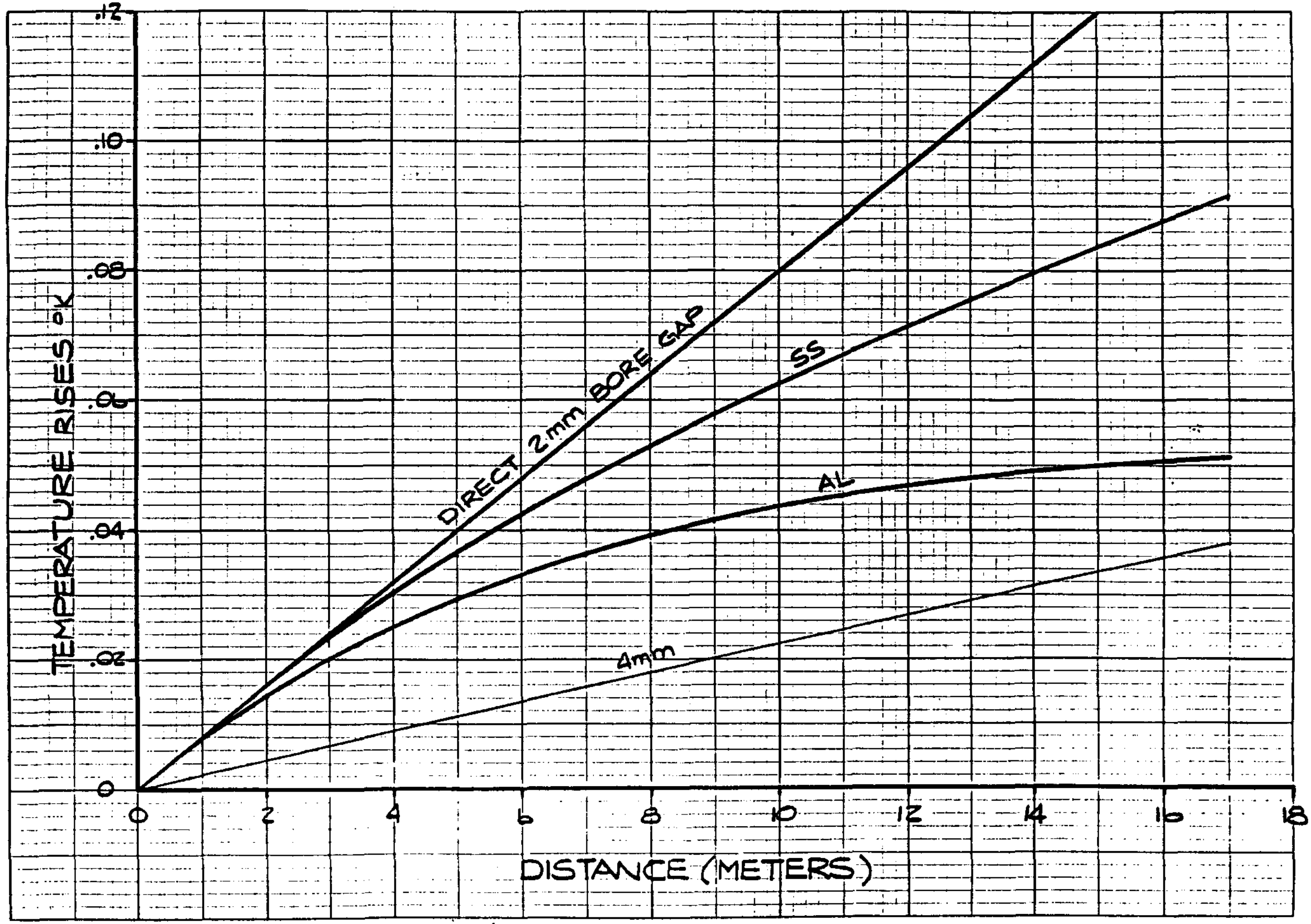
SSC C&O Workshop
Claus Rode 01/15/85
"SSC Magnet Cryogenic Comparison -
Impact of Common Failures

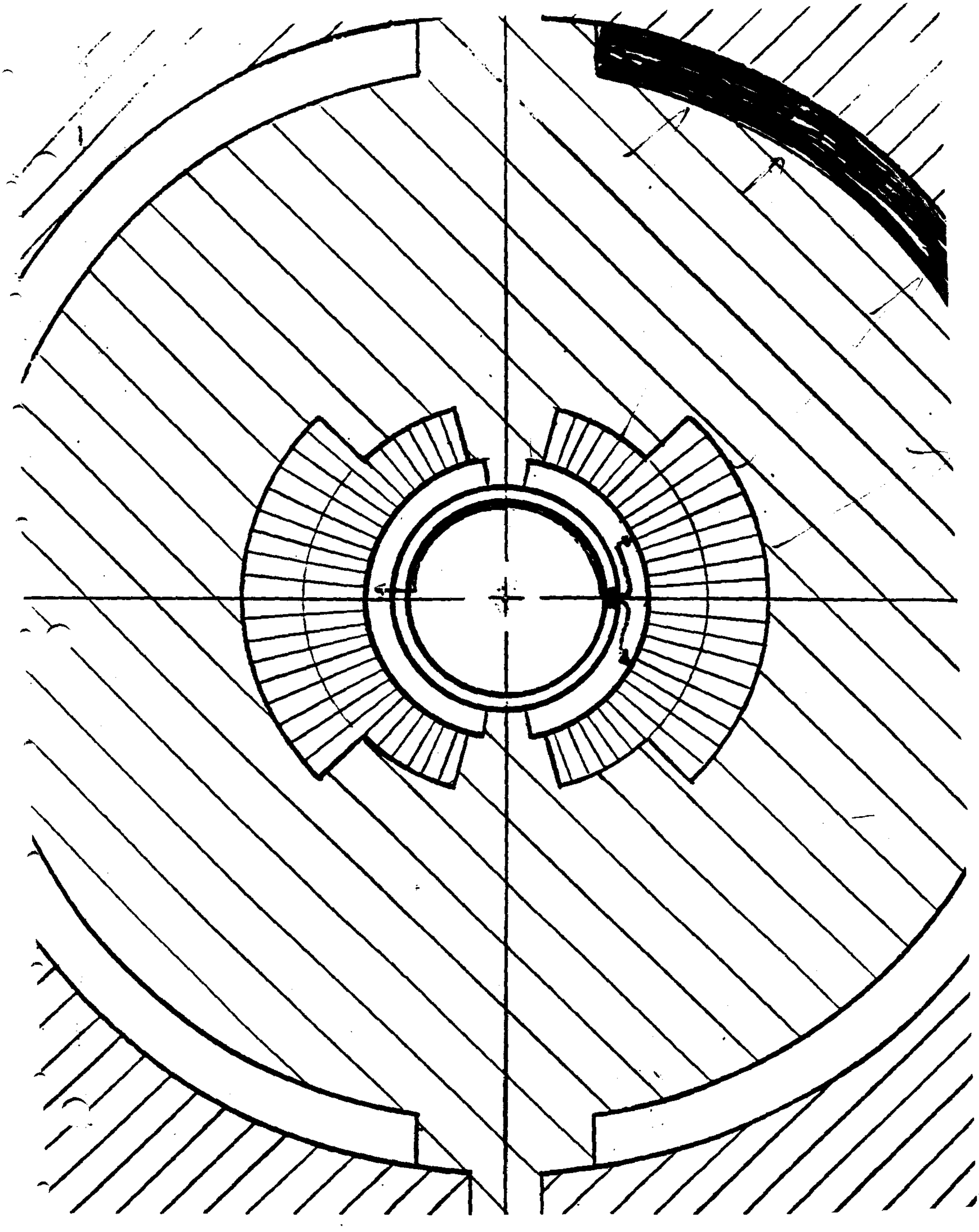


MAGNET COMPARISON

		A	D	B	C
MAGNET					
Field	(T)	6 1/2	6	5	3
Cold Mass	(MJ)	5.10^6	6.10^6	$2.4\ 10^6$	$3.3\ 10^6$
Cold Mass/Ref	(MJ)	420.10^3	500.10^3	200.10^3	140.10^3
Cold Mass/Section	(MJ)	35.10^3	20.10^3	12.10^3	33.10^3
Section	(M)	600	600	1070	150.
Section/Ref		12	24	16	42
MAGNET COOLING					
Type		Orifice Flow	Direct + Cond.	Direct	Conduction
Main Flow		Two 2" holes	? Ring Between iron & collar	Bore + 8 wedges	Two 4" high D's
Pressure	(atm)	4	4	4	2
Flow	(g/sec)	2 x 140	? 4 x 100	4 x 50	2 x 56
Temp. Gradient	(^{0}K)	~ .05	.04 alum/.07 SS	.03	.07
Subcooler Spacing	(M)	200	200	107	300
Subcooler		Dewar	Dewar	20 exch.	Dewar
Shields		80^0	80^0+10^0	80^0+10^0	80^0+10^0

CONDUCTION COOLING





ALTERNATE MAGNET He FLOW SCHEMATIC - 4 PIPE
CHR 11- 8 -84

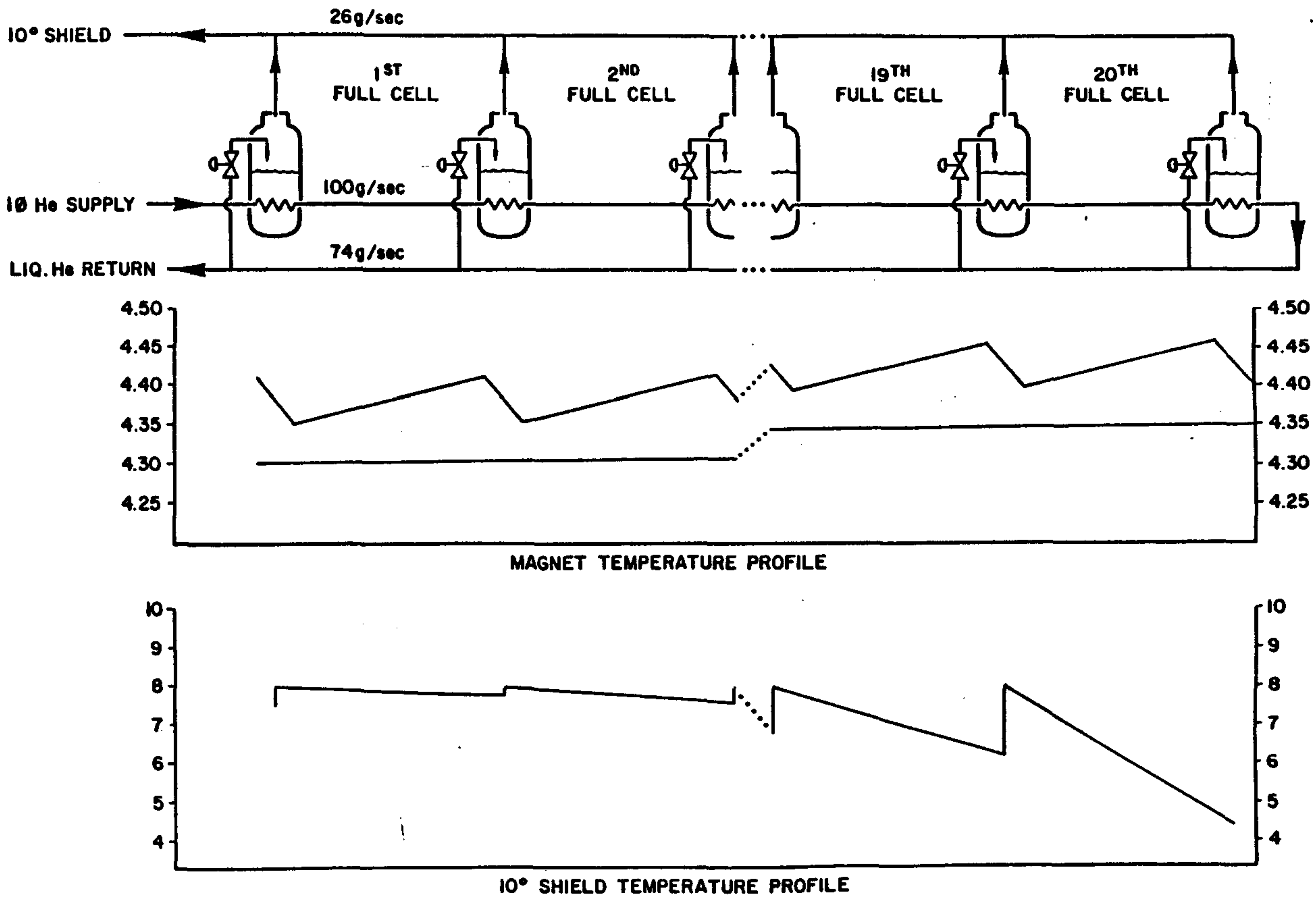


FIG. 4

ALTERNATE
5T SSC MAGNET PARAMETERS

NORMAL OPERATION

STRING LENGTH	4.27 KM		Flow 100.		g/sec	
1Ø Magnet	Input	4.0	atm	4.3[9]°K	Liq.	
	Output	3.7	atm	4.46°K	Liq.	
Liq. Return	Input	3.7	atm	4.40°K	Liq.	
	Output	3.4	atm	4.42°K	Liq.	74. g/sec
10° Shield	Input	1.123	atm	4.35°K	Gas	
	Output	1.113	atm	8. °K	Gas	26. g/sec
80° Shield	Input	5.0	atm	74. °K	Liq.	
	Output	4.0	atm	89. °K	Liq.	

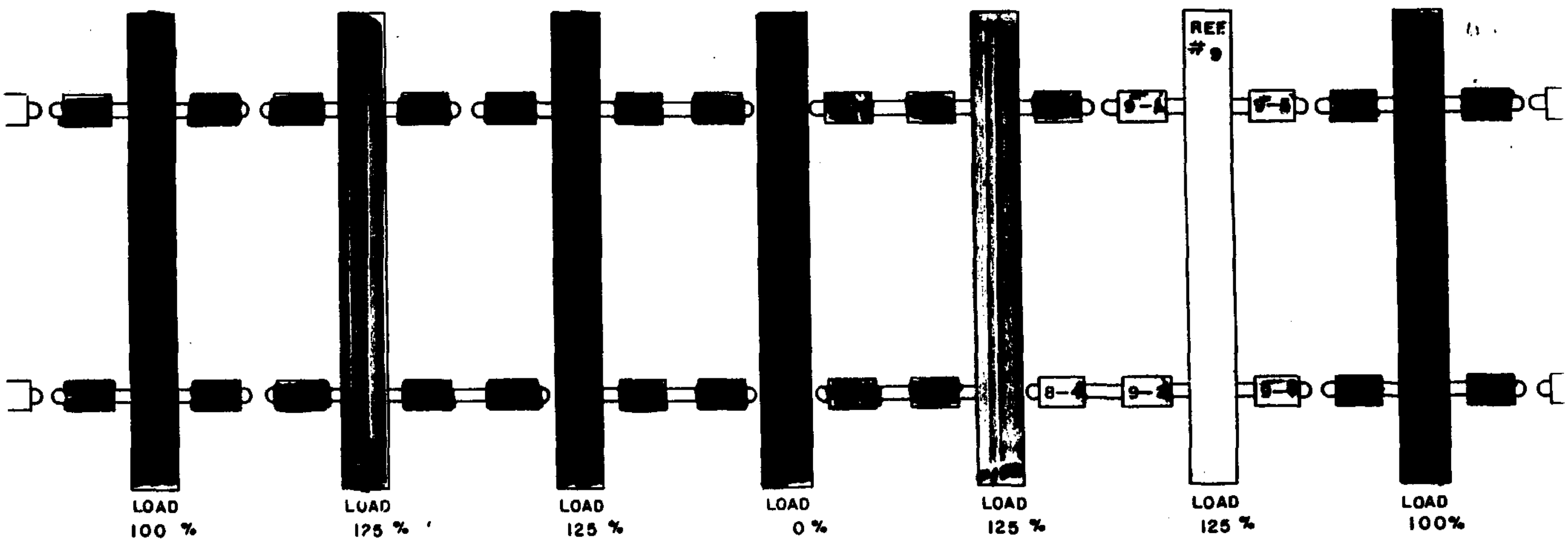
ONE He REFRIGERATOR COMPLETELY OFF

LONGEST STRING	8.53 KM		Flow 100.		g/sec	
1Ø Magnet	Input	4.0	atm	4.3[2]°K	Liq.	
	Output	3.4	atm	4.46°K	Liq.	
Liq. Return	Input	3.4	atm	4.40°K	Liq.	
	Output	2.9	atm	4.42°K	Liq.	48. g/sec
10° Shield	Input	1.123	atm	4.35°K	Gas	
	Output	1.043	atm	8. °K	Gas	52. g/sec
80° Shield	No Changes					

Table I

H_e REFRIGERATOR CONFIGURATION

REFRIGERATOR # 7 COMPLETELY DOWN FOR REPAIR



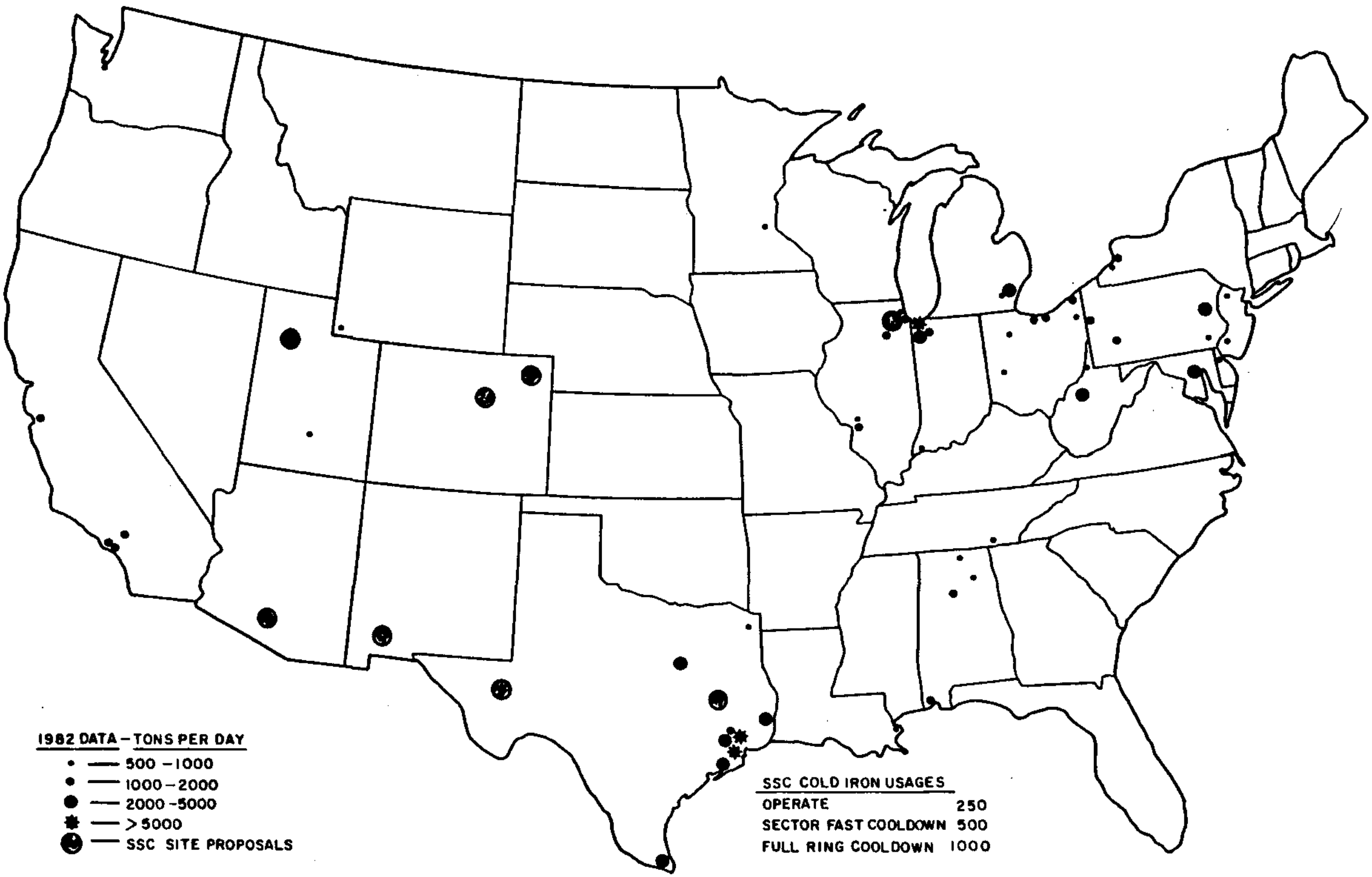
OPTION: IF NEEDED REF. #4 & #10 CAN SUPPLY EXCESS LIQUID

MAGNET OPERATIONAL IMPACTS

	A	D	B	C
INITIAL COOLDOWN:				
N_2	Buy 13,000 tons	Buy 16,000 tons	--	--
Temp	80,20,5	?	<20,5	80,20,5
Tunnel "MTF" TESTING:				
N_2	Buy 300 ton/day	Buy ?	--	Pre test all
REPAIR SEQUENCE:				
Time (days)	~5	5	3	4-5
Repair Isolation	Valves on some lines He & N_2 purges		U-tubes	Purge with He
Bore Isolation	Purge with He		Valves	Purge3.3 km with He
Warm Up Using	Gas		Electric Heaters	Gas
Warm Up Location	1 cell to 300^{0}K 2 cells to 80^{0}K + drift 14 cells drifting		1 Section	1 magnet + 2 enc

	A	D	C
N_2 STORAGE TON	1200	500	2000
N_2 PLANT TON/DAY	0	350	240
QUENCH IN ONE RING HIGH FIELD	OTHER QUENCHS	B&"D" ??? DEACCELERATE TO .5 TEV OR 1 TEV	DUMP; LOW ENERGY QUENCH
INJECTION	??	—	—

AIR SEPARATION CAPACITY



BNL - FINAL CRYOGENIC AGREEMENTS 1-10-85

USE CONDUCTION COOLING

USE TWO SHIELDS: $80^{\circ}K$ PLUS 10 to $20^{\circ}K$

ALL CRYOGENIC CIRCUITS 20 ATM MAWP

VACUUM SHELL 5 ATM MAWP IS USEFUL

AREAS FOR FURTHER DISCUSSION WITH MAGNET DESIGNERS

BORE TUBE FOR 4 CM MAGNET	29MM / 33.4MM ID
HOLES IN IRON/SLOT BETWEEN COLLAR AND IRON (TWO HOLES BETTER THAN ~~ONE~~ FOUR) (MEASURE CONDUCTIVITY OF IRON)	{ MAGNET IMPACT CRYOGENIC IMPACT
WARM-UP BY ELECTRIC HEATERS	IMPACT
COST VS ADVANTAGES OF ADDITIONAL PIPES	$30M a
COLLAR MATERIAL	AL / SS

COMMON TRIPS & PROBLEMS

PROBLEM	SOLUTION
SUBCOOLER VALVE FAILS: CLOSED	ΔT INCREASE .06°K
OPEN	SPILL LIQUID INTO SHIELD
MAIN COMPRESSOR	NEED STANDBY UNIT; SPINNING OR AUTO STAR. INDEPENDENT
TURBINE DRY	USE LIQUID
WET	USE JT VALVE PLUS LIQUID
COLD COMPRESSOR	1) DEACCELERATE TO 18 TEV 2) OPERATE SUB ATM. ~ 4 HR 3) START STAND BY UNIT
LIQUID He PUMP	REF. TO FULL FLOW
LIQUID N_2 CIR. PUMP	REPAIR ON ~8 HR TIME SCALE
N_2 VACUUM COMPRESSOR	START SPARE
CONTAMINATION SHIFTS	DECOUPLE REF & MAG
RAMP TRIP TEMP. OSC. (SYNC.)	DESIGN MAGNET FOR LOW ΔT DESIGN SYSTEM FOR TRANSIENTS
POWER FAILURE LOCAL	SWITCH TO ADJACENT REF
SITE	CRYOSTAT DESIGNED FOR 20 ATM

REFRIGERATER PERMIT

DUAL LEVEL: 1) OK TO INJECT
2) OK TO ACCELERATE ABOVE 10 TEV
OTHERWISE ONLY ALARM

MAGNET CRYOGENIC DESIGN GOAL

LOW HEAT LEAK

Dipole N_2 1.25 w/m

Dipole He .15 w/m

MINIMUM NUMBER OF PIPES: 4 EACH MAGNET

80^oK Shield

10^oK Shield (Quench Header)

Return Header (2Ø or Liquid Return)

Supply Header (1Ø Coils)

NOTE: Two additional in tunnel { 4in He 2 atm lead flow; 3in N_2 20 atm return }

NON FRAGILE

20 atm all circuits

?? 5 atm vacuum shell

He circuit 300^oK step

N_2 circuit 200^oK step (Liq. ???)

VAC. LOSS

SYSTEM DOWNTIMES

FROM: 0000 1/ 4
TO: 1721 1/ 4

DOWN	UP	SYSTEM	DESCRIPTION OF TROUBLE	HOURS	EFR#
0215	0302	TVAC	E3 UPSTREAM BEAM VALVE WON'T OPEN	.78	0
0300	0400	TOPM	HFU A4 UNIT B3 BUILDING C3 REQUIRED REPLACEMENT	1.00	0
0300	0404	MRPS	REPLACING THE BATTERY BOX FOR E3.	1.07	0
0502	0812	TCRYO	LEAD FLOW BAD AT F1	3.17	0
0505	1155	MRPS	THE D1 BYPASS TRIM SUPPLY IS TRIPPING OFF.	6.83	0
0528	0545	PACC	H- ARC CURRENT TOO HIGH AND IT WON'T COME DOWN	.28	0
0530	0953	TUNING	TRYING TO GET BEAM AROUND MAIN RING	4.38	0
0726	0800	MRPS	A0 QUAD REGULATOR DEAD	.57	0
0851	1021	TPS	A3 DUMP DOOR OPEN.	1.50	0
1245	1623	MRREG	MULTIPLE D0 REGULATION ABORTS	3.63	0
1430	1445	MRRF	ANODE PGM TO HIGH	.25	0
1600	1605	CMISC	ACNET DEAD ALL BEAM DOWN.	.08	0
1646	1700	MRPS	WORKING ON D0 OV PASS SUPPLY	.23	0
1706	1713	MRPS	D0 OV PASS TRIPPED	.12	0
1713	1717	TCOR	F1 BULK SUPPLY TRIPPED ON WATER FLOW	.07	0
1721	1724	MRPS	D0 TRIM SUPPLY TRIPPED	.05	0

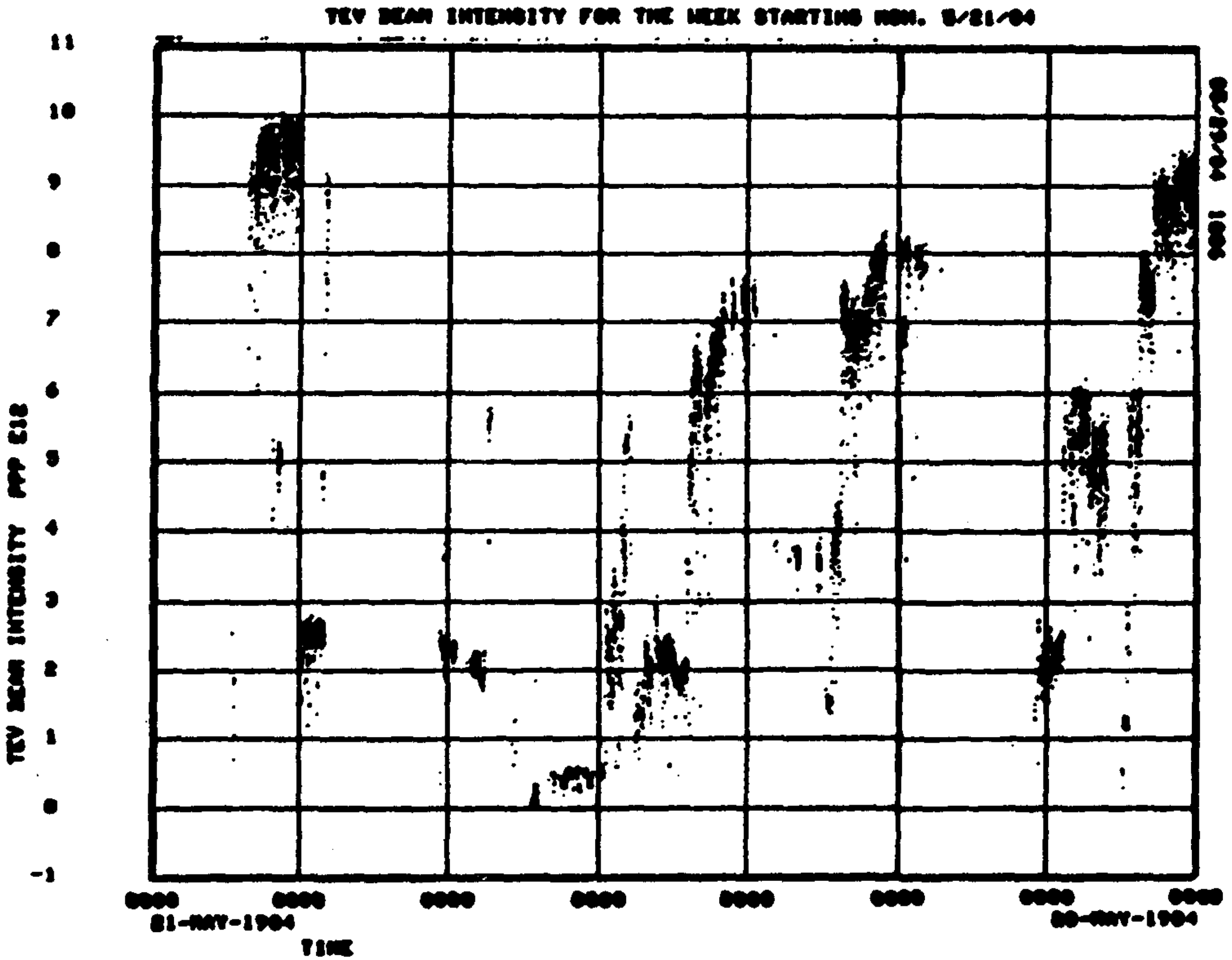
SSC C&O Workshop
Bob Mau - "Commissioning the FNAL Energy Doubler"
01/15/85

WEEK NO. 31

QUENCH ET

	DATE/TIME	TIME IN CYCLE	LOCATION	BEST GUESS FOR CAUSE	IF QUENCH RECOVERY TOOK LONGER THAN AVERAGE EXPLAIN
	5/23/84 0436	41.6	D36 D	Fast extraction was just set to 25%	
	5/23/84 0655	41.6	F48	Fast extraction studies pushing intensity.	
AUTO RECOVERY	5/23/84 2332	17.543	B48	WE HAD A DI BIM ABORT AND WHEN THE BEAM ABORTED IT HIT B48.	
Auto Recovery	5/24/84 0824	56.382 90 GEV	D1 Full House	Bad VFC channel D19U.	ONCE AGAIN THE CONTROLS SYSTEM DIED DURING RECOVERY.
	5/24 2355	18.905	A11 + B48	ABORT KICKER MISFIRE	
	5/25 0108	26	D3	HEATER FIRED BEFORE QUENCH	AUTO RECOVERY CLOSED THE CENTRAL VALVE TO 40% HALF WAY THRU RECOVERY
Auto	5/25 1144	35	A11	extraction beam loss magnet of ET we don't understand it	
	5/25 2156	43.542	A32 L	APPARENTLY THE FSM FLAG 16 WAS DISABLED SO THE FRIG DIDN'T TRIP [illegible]	THE A32 [redacted] KAUTZKY VALVE STUCK OPEN.
	5/26 0850 hrs	55.412	A32 L	Noisy VFC VFC card changed	
	5/2_ 0930	43.5	A32 L	Noisy VFC OPIN to Tom called changed	
	5/26 [illegible]	43.5	A32 L	Noisy VFC Global World called in	

1030
1300 [illegible]


TEV BEAM INTENSITY FOR THE WEEK STARTING MON. 5/21/84
TEV BEAM INTENSITY PPP E12
11
10
9
8
7
6
5
4
3
2
1
0
-1
0000
21-MAY-1984
TIME
28-MAY-1984

OPERATIONS SUMMARY

Period of Time Covered: WEEK #21

'ates: 5/21/84, 0000 hrs. through 5/27/84, 2400 hours.

Energy: 800 GeV Flattop 20 Seconds

Mode of Extraction: SLOW

Total No. of TeV Protons Accelerated:	.281	$\times 10^{17}$
Total No. of MR Protons Accelerated:	.219	$\times 10^{17}$
Total No. of Main-Ring Ramps:	10072	
Total No. of TeV Protons Injected:	UNK	$\times 10^{17}$
Total on TH Loss Monitor:	UNK	$\times 10^{15}$
Total to Meson Area:	.010	$\times 10^{17}$
Total to Neutrino Area:	.012	$\times 10^{17}$
Total to Proton Area:		$\times 10^{17}$
Average/Pulse:	2.79	$\times 10^{12}$
Average/Pulse: For HEP	7.87	$\times 10^{12}$
.verage Injection Efficiency:	UNK	%
Average Extraction Loss:	UNK	%
MR Aborts:	UNK	
TeV Aborts:	UNK	
MR Charge Aborted:	UNK	$\times 10^{16}$
TeV Charge Aborted:	UNK	

	Scheduled Hours	Actual Hours	
High-Energy Physics	112.0	67.45	Efficiency: 60.2 %
Accelerated Studies	29.0	19.38	Efficiency: 66.8 %
Startup:	16.0		
Tuning:		1.86	
Accelerator Failure:		68.31	
Operation Hours:	157.0	157.00	
Scheduled Shutdown:	11.0	11.00	
d Hoc Shutdown:			
Total Hours:	168.0	168.00	

week #21

SYSTEM DOWNTIMES 1984
05/21 0000 TO 05/27 2400

SYSTEM	HOURS	%TOTAL	%HEP	ENTRIES	SYSTEM	HOURS	%TOTAL	%HEP	ENTRIES
PACC	.15	.171	0	2	LVAC	.1	.114	0	1
LRF	.92	1.05	0	11	LQUAD	0	0	0	0
LMISC	0	0	0	0	2VAC	0	0	0	0
2PS	0	0	0	0	2MAG	0	0	0	0
2MISC	0	0	0	0	3VAC	.03	.034	0	1
BCOR	0	0	0	0	3MAG	0	0	0	0
BLLRF	0	0	0	0	BRF	.42	.48	0	4
BMISC	.12	.137	0	1	B3MPS	0	0	0	0
BVAC	0	0	0	0	BPS	0	0	0	0
BMAG	0	0	0	0	BMISC	0	0	0	0
MRVAC	.6	.685	0	1	MRPS	.73	.833	0	1
MRMAG	0	0	0	0	MRCOM	0	0	0	0
MRWATR	0	0	0	0	MRRF	.89	1.01	0	14
MRMISC	0	0	0	0	MRRES	.08	.091	0	1
MRCAP	0	0	0	0	SYVAC	0	0	0	0
SYPS	3.39	3.87	0	12	SYMAG	0	0	0	0
SYLOS	0	0	0	0	SYMISC	.23	.263	0	1
SYCRYO	0	0	0	0	SYOJEN	3.02	3.44	0	1
SYOPM	0	0	0	0	LCON	0	0	0	0
BCON	0	0	0	0	MRCON	1.5	1.71	0	3
SYCON	.12	.137	0	2	CMISC	1.61	1.83	0	13
TCON	5.47	6.24	0	26	JPOWER	0	0	0	0
UWATER	0	0	0	0	JMISC	0	0	0	0
UCHL	.52	.593	0	1	SAFETY	0	0	0	0
HUMERR	0	0	0	0	EXPAR	1.42	1.62	0	1
NTF	0	0	0	0	ENSAV	0	0	0	0
MISC	1.47	1.67	0	3	TUNING	3.2	3.65	0	4
COOL	0	0	0	0	PBAR	0	0	0	0
TVAC	0	0	0	0	TPS	9.4	10.7	0	9
TMAG	.73	.833	0	3	TCOR	17.46	19.9	0	16
TCRYO	13.02	14.8	0	23	TOPM	3.85	4.39	0	11
TRF	0	0	0	0	TINJ	.12	.137	0	7
TMISC	.24	.274	0	3	TOJEN	19.94	22.7	0	14

SCHEDULED HEP 0 TOTAL DOWNTIME 87.55 TOTAL ENTRIES 192

Ref. 010

Tunnel Location	Magnet Removed	Magnet Replacement	Date
C-11-5	2092	2382	MARCH 28,

Inspector of upstream & downstream magnets M. ALBERTUS

Replacement Status [X] OK [ ] Low Field [ ] Incorrect Series

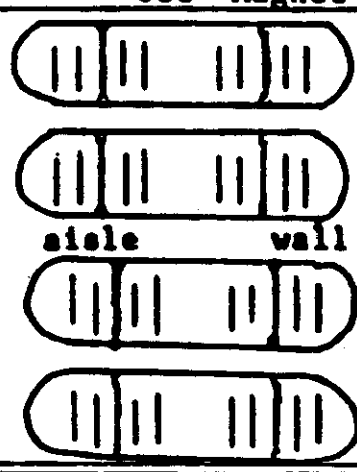
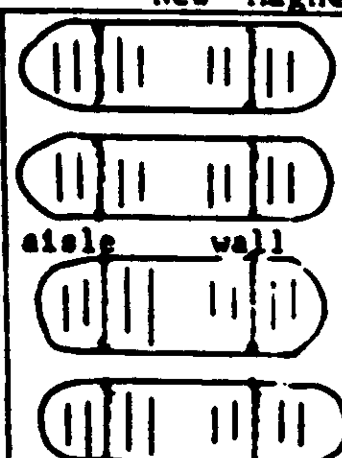
If magnet removed is a quad, was it surveyed prior to removal? [ ] Yes [ ] No

REASON FOR REPLACEMENT

1. [X] Short: failed under power BLACK Listed Date MARCH, 19
2. [ ] Hi-pot Milliamps ______ V to Grnd ______ Date ______
3. [ ] Convenience

BENDING MAGNET LEVELING DATA

(Fill in appropriate bubble location)

	"Old" Magnet	Level Location	"New" Magnet	
UPSTREAM END		Aisle		1st Measurement
		Wall		2nd Measurement
DOWNSTREAM END		Aisle		1st Measurement
		Wall		2nd Measurement

REMARKS

2092 BlACK Listed TWICE 5 MR

Distribution: H. Edwards/342, R. Gerig/306, S. Hickey/314, R. Mau/306, C. Moore/306, R. Orr/306, & D. Plant/306

Week #	40-43	44-52	1-6	7	8-10	11-13	14-21	22-28
Dates	10-3/11-6	11-7/1-1	1-2/2-12	2-13/2-19	2-20/3-11	3-12/4-1	4-2/5-27	5-28/now
Modes	SY tune up EAD tune up	HEP	HEP	Accel. studies	M & D	Start up	800 GeV	800 GeV
Problems that affected HEP	Spool piece failures E-14 E-21 E-25 E-27 E-29	Nitrogen delivery problems	Site-wide power outage			Ground Fault F13-2 F13-3 F13-4 Bad Splice at B0	Left Bend Vacuum Problems Feeder 46 dug up	F36-4 failed C13-2 failed E27-4 failed B34-4 failed CHL [illegible] 19 conductor cable out
Successes	Beam delivered on 10-3-84 scheduled to PW and PC 10 second spill	15 second spill set up HEP	HEP	800 GeV beam 825 GeV ramp 200 GeV stored			20 Second flat top	Spill quality >95% 0-1kHz Flying wires 1 meter squeeze Fast extraction intensity >2.5 E12
Scheduled HEP	529	1019	799				1020	792
Actual HEP	101	529	503				577.3	461.5
Act/Sched.	19%	52%	63%				56.6%	58.3%

VERY GENERAL OV) VIEW OF STUDIES VS HEP

1. WE ATTEMPED TO BREAK THE RUNNING WEEK UP AS FOLLOWS:

    7 STUDY SHIFTS (ALSO INCLUDED M&D)
    14 HEP SHIFTS

2. STUDIES HAD 3 MAJOR PURPOSES

    A. TO ENHANCE THE PRESENT RUN
    EXAMPLES ARE TEV QUENCH RECOVERY, SPILL QUALITY STUDIES, SY APERTURE STUDIES

    B. TO LEARN HOW TO RUN PARASITIC ACCELERATOR STUDIES DURING HEP
    FLYING WIRE STUDIES.

    C. TO PREPARE FOR FUTURE HEP MODES AND FUTURE ACCELERATOR OPERATING MODES
    EXAMPLES ARE FAST EXTRACTION STUDIES, BO LOW BETA STUDIES, MRRF PARAPHASING & LOW FREQUENCY CAVITY WORK.

3. IN GENERAL PARASITIC STUDIES DURING THIS YEARS RUN WERE PARASITIC AND DID NOT INTERFER WITH HEP.

STUDIES STATISTICS

						TOTAL
WEEK #	40-43	44-52	1-6	14-21	22-28	846
SCHEDULED STUDIES HRS.	106	272	107	212	149	452
ACTUAL STUDIES HRS.	46.6	168	71.6	131.9	34	53%
STUDIES/SCHEDULED	44%	61.8%	66.9%	62.2%	22.8%	
SCHEDULED HEP HRS.	529	1019	799	1020	792	4159
SCHEDULED STUDIES HRS.	106	272	107	212	149	846
STUDIES/HEP	20%	26%	13.4%	20%	18.8%	20%
ACTUAL HEP HRS.	101	529	503	577.3	461.5	2197
ACTUAL STUDIES HRS.	46.6	168	71.6	131.9	34.0	452
ACT. STUDIES/ACT. HEP	46%	31.7%	14.2%	22%	7.3%	20%

DOWN TIME

ENERGY	400	400	400	800	800
WEEK #	40-43	44-52	1-6	14-21	22-28
LINAC	3.9	5.5	4.8	2.7	4.3
BOOSTER	.7	1.2	4	1.4	4.3
MR	22.7	6.0	3.6	5.1	5.2
TEV	233.0	56.0	32.7	48.0	70.8
SY	41.9	5.5	3.6	12.3	2.9
UTILITIES	39.8	2.5	4.6	4.8	1.2
TUNING	4.3	6.3	6.4	7.0	7.2
CONTROLS	7.6	4.5	2.6	6.3	1.0
TOTAL	353.9	87.5	49.9	66.3	100.1

THIS DATA IS

$$\frac{\text{DOWNTIME} \times 100}{\text{ACTUAL HEP+ACTUAL STUDIES+TUNING}} = \% \frac{\text{DOWNTIME}}{\text{UPTIME}}$$

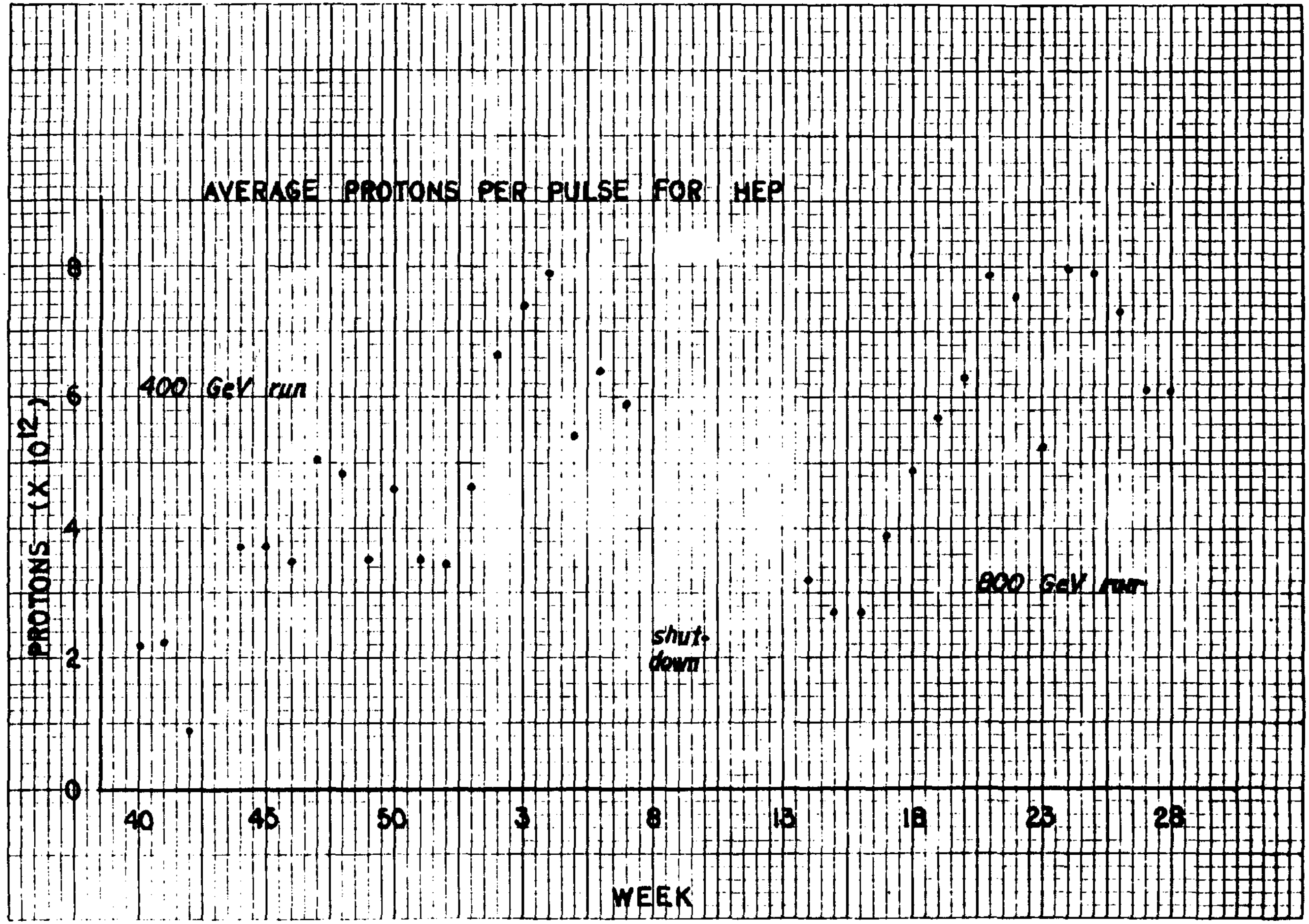
TEV DOWNTIME

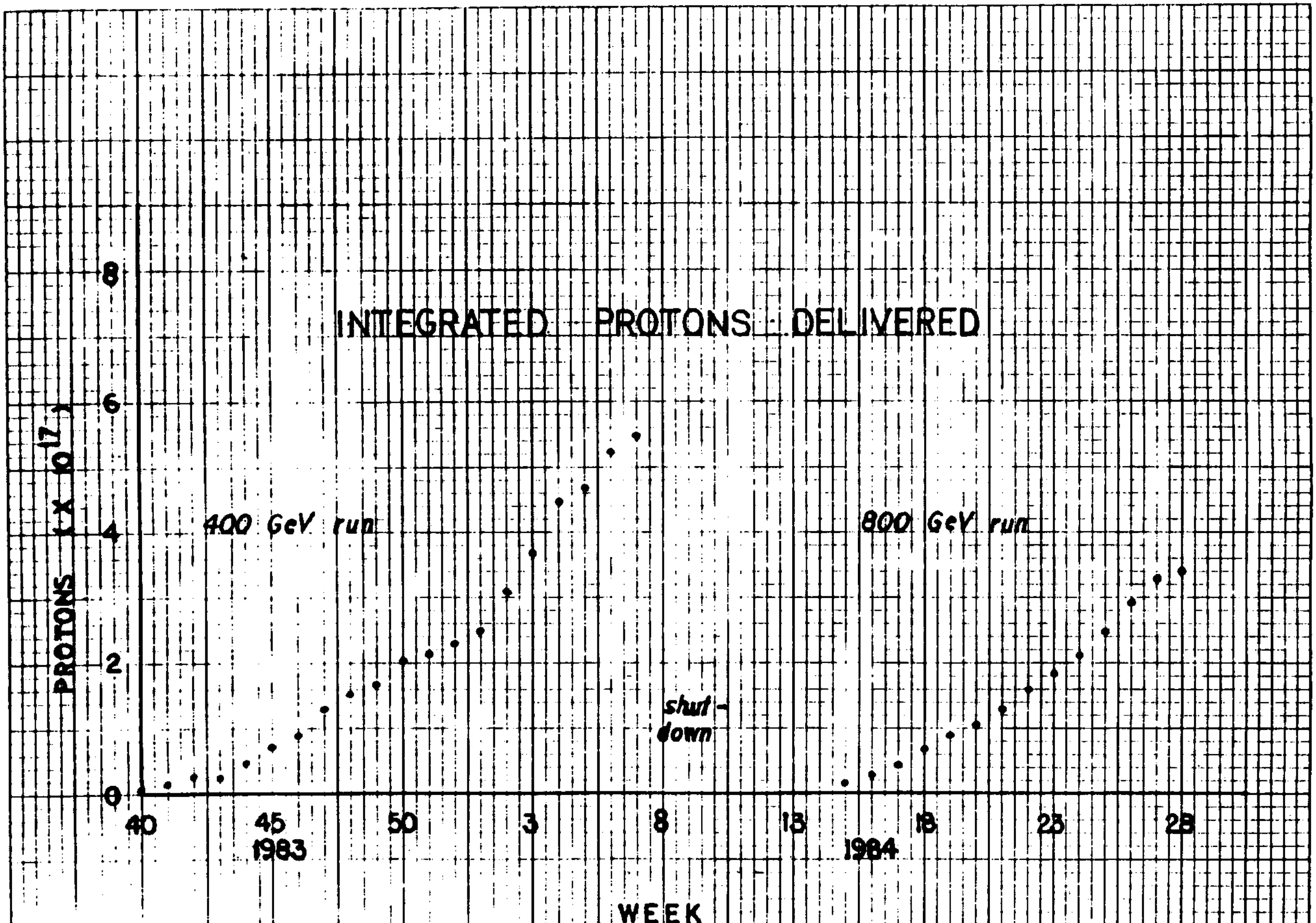
ENERGY	400	400	400	400	400
WEEK #	40-43	44-52	1-6	14-21	21-28
CRYO CHL	19.5	14.3	16.7	16.4	31.4
P.S. GPM	54	12.8	7.99	8.8	6.2
CONTROLS	7.6	4.5	2.9	1.8	2.2
TEV INJ.	0	2.3	1.7	.8	.7
TEV RF	25	3.3	1.2	.91	.8
TEV VAC	0	1	.4	1.9	.3
TEV CORR	1.5	1.2	.4	4.4	.6
TEV MISC	7	11.77	1.4	1.4	3.4
TEV MAG	141	4.4	0	.78	38.1
T QUENCH	5.2	8.2	5.3	9	4.7
TOTAL	260.8	63.8	38	46.2	70.4

THIS DATA IS $\frac{\text{DOWNTIME} \times 100}{\text{ACTUAL HEP+ACTUAL STUDIES+TUNING}} = \% \frac{\text{DOWNTIME}}{\text{UPTIME}}$

QUENCHES

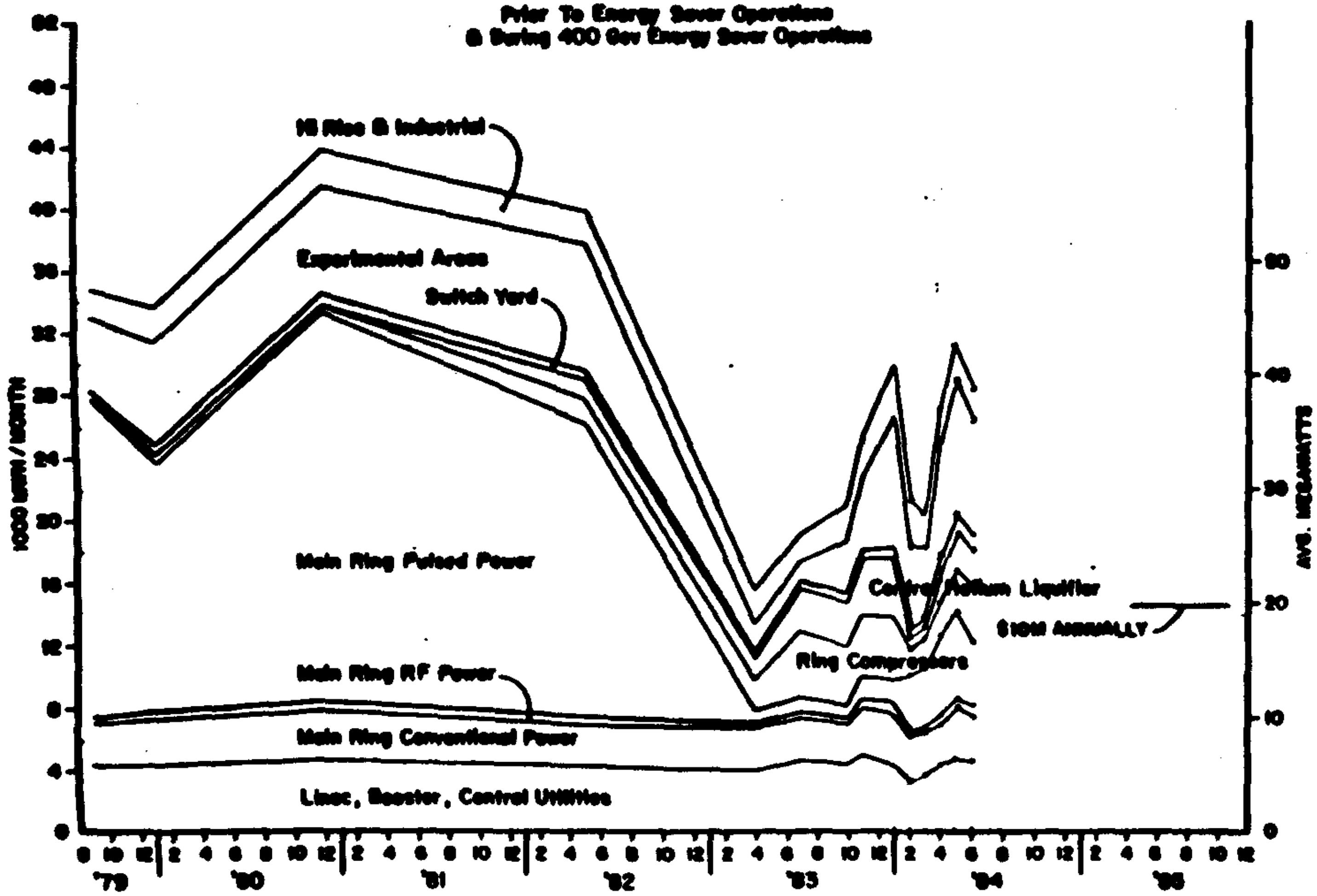
	1983		1984		
ENERGY	400	400	400	800	800
WEEK	40-43	44-52	1-6	14-21	22-28
#WEEKS	4	9	6	8	7
SAVER QUENCH TOTAL	28	197	68	69	39
QUENCH/#WEEKS	7	21.9	11.3	8.6	5.6
SY LB	6	0	1	10	0
RB	12	9	8	5	4
TOTAL	18	9	9	15	4
SY QUENCH/# WEEKS	4.5	1	1.5	1.9	.6


AVERAGE PROTONS PER PULSE FOR HEP
400 GeV run
800 GeV run
shut-down
PROTONS (X 10^12)
0
2
4
6
8
40
45
50
3
8
13
18
23
28
WEEK


INTEGRATED PROTONS DELIVERED
PROTONS (X 10^17)
0
2
4
6
8
400 GeV run
800 GeV run
shut-down
40
45
1983
50
3
8
13
1984
18
23
28
WEEK

POWER USAGE AT SAMPLE TIMES

Prior To Energy Saver Operations
& During 400 Gev Energy Saver Operations



RECOVERY TIME FOR EACH TYPE

BEAM QUENCHES

INJECTION QUENCHES	.33 HRS.
ACCELERATION QUENCHES	.42 HRS.
FLAT TOP QUENCHES	.76 HRS.
FLAT TOP QUENCHES	.85

OTHER QUENCHES

FULL HOUSE	4.26 HRS.
QPM FAILURES	.78
P.S. FAILURES	4.08

SSC C & O Workshop
John Poole 01/15/84

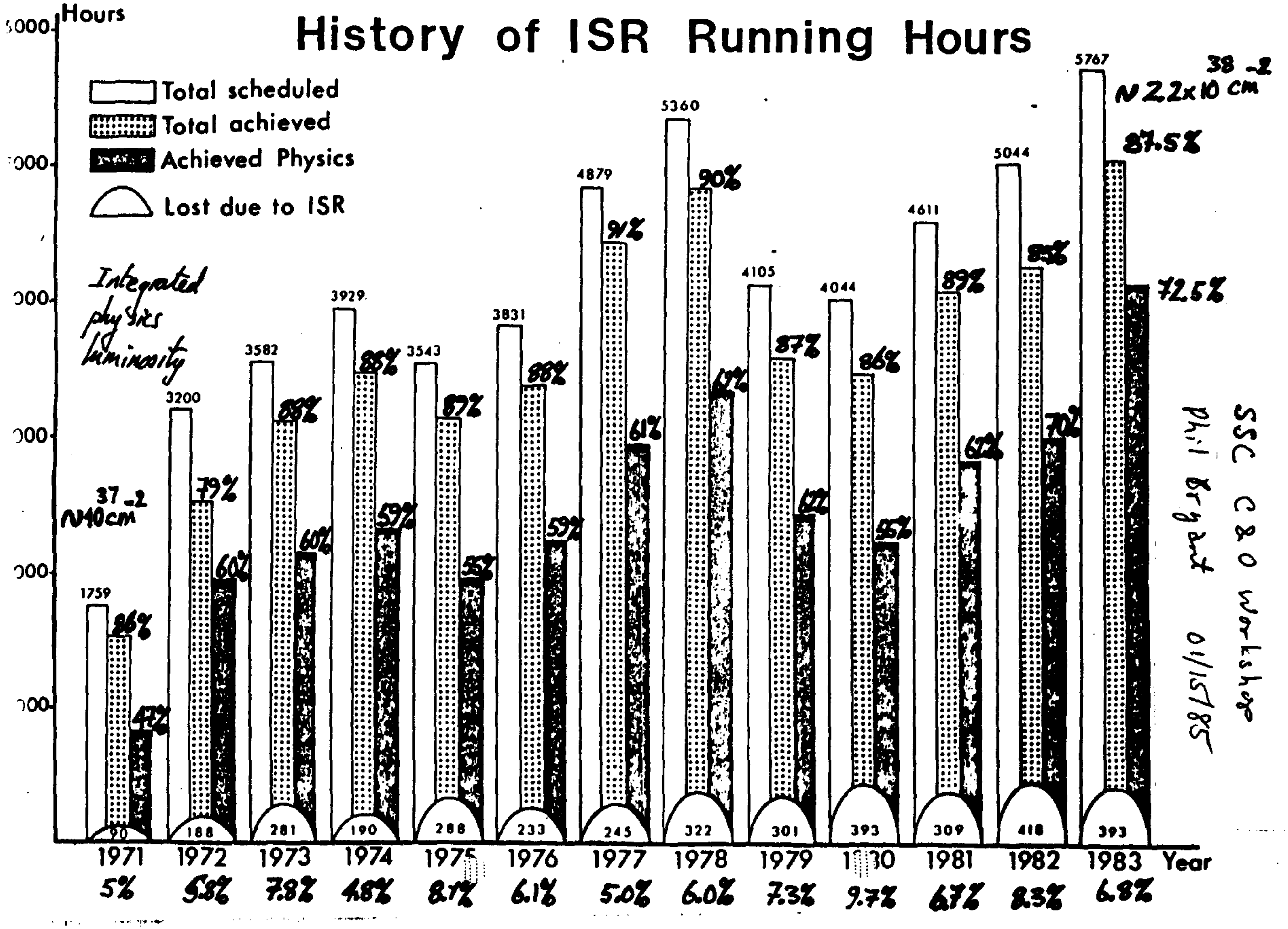
SSC REGULAR REFILL – WARM START

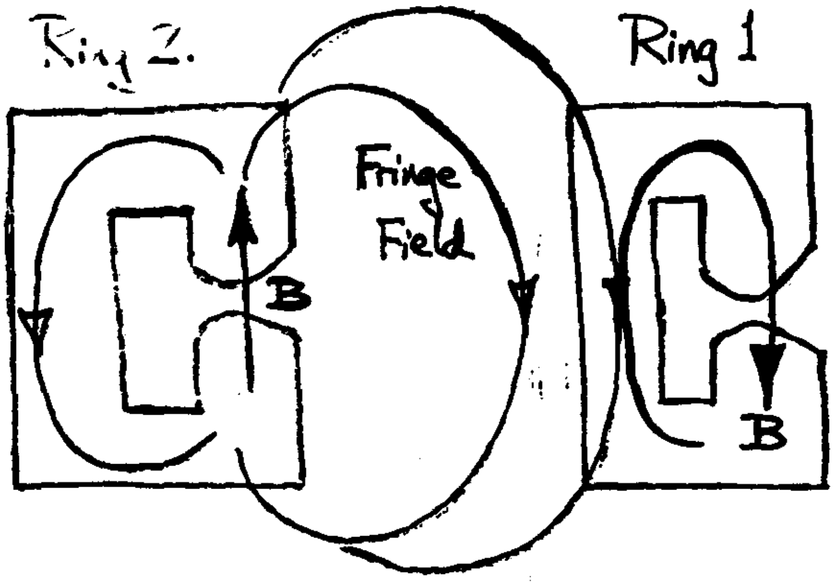
CYCLING AND SETUP	1 hr.
SET-UP AND CHECK INJECTIONS	15 m
SEPARATE SMALL BEAMS	15 m
FILL BEAMS	45 m
ACCELERATE	15 m
LOW βETAS (EACH ONE)	15 m
LUMINOSITY (EACH ONE)	15 m
ADJUST TUNES, COUPLING + COLLIMATION	30 m
	3 h 30 m
SCREW UP CONTINGENCY	30 m
	4 h 0 m

IF LOW βETAS + LUMINOSITY HAVE TO BE SERIAL ADD 2½ hrs FOR THE LAST ONE TO BE READY

TYPICAL DAY

PHYSICIST ACCESS	3 hrs
SET UP, FILL	3 hr 30 m
EXPERIMENTAL MAGNETS AND THEIR COMPENSATIONS	15 m each
	6 h 45 m
PHYSICS	17 h in 24


History of ISR Running Hours
Hours
Total scheduled
Total achieved
Achieved Physics
Lost due to ISR
Integrated physics luminosity
$\sim 40 cm^{37 -2}$
$\sim 2.2 \times 10^{38} cm^{-2}$
1759
86%
47%
90
3200
79%
60%
188
3582
88%
60%
281
3929
85%
59%
190
3543
87%
55%
288
3831
88%
59%
233
4879
91%
61%
245
5360
90%
67%
322
4105
87%
62%
301
4044
86%
55%
393
4611
89%
62%
309
5044
85%
70%
418
5767
87.5%
72.5%
393
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
Year
5%
5.8%
7.8%
4.8%
8.1%
6.1%
5.0%
6.0%
7.3%
9.7%
6.7%
8.3%
6.8%
SSC C&O Workshop
Phil Bryant 01/15/85



— Fringe field effect in second block.

- Near max. field iron is saturating and μ varies rapidly with field!
- Stray field changes μ of return yoke
- Acting as a magnetic amplifier, this changes reluctance of the circuit and changes field

— Seen in ISR at maximum field with the sensitive optics of the S.C. low-β which opens up a wide stopband at $Q=9$. Orbits at top of stack can move over 10mm.

Brief History of the 7th Antiproton Physics Run. (April 1982)

A Record Run with the Complications of Acceleration to 31 GeV/c and the Terwilliger Scheme.

3rd April Saturday – 4th Sunday – 5th Monday: AA stacks 1.05×10^{11} antiprotons.

Note transfer from PS can only be set by antiprotons. Total set-up 4 pulses.

Record current and efficienc[y]

5th Monday

- 06.00h Close ISR tunnel.
- 12.50h Transfer lines from PS and ISR set ups with 4 $\bar{p}$ pulses
- 17.35h Pulses 5 to 21 stacked. 3.834 mA (7.68×10^{10} giving 73% efficiency). Peak stacking efficiency 94%.
- 19.15h $\bar{p}$ beam accelerated to 31.4 GeV/c now 3.582 mA
- 19.30h Terwilliger scheme applied now 3.486 mA

6th Tuesday

- 00.15h 14.1A of protons stacked in other ring.
- 02.25h Proton beam accelerated and Terwilliger scheme applied.
- 06.00h Beams steered, Roman Pots in, STABLE BEAMS luminosity 0.98×10^{27} cm^{-2} s^{-1} (3.486mA × 12.6A)
- 20.00h Cooling on both beams. Protons have small transverse blowups but antiprotons are cooled at 8.1% per hour. Peak luminosity of 1.2×10^{27} cm^{-2} s^{-1} reached.

7th Wednesday

8th Thursday

108 hours of physics for total cross-section measurement at 31.4 × 31.4 GeV/c^2

9th Friday

10th [Fr]iday

ISR-BOM/PJB/
Philip BRYANT

3/11/82

The Interdependence of the Two Rings and its Effect on MD Scheduling.

1./ Interdependence of the Rings.

(a) Fringe Field. Recently brought to notice by the combination of sensitive machine optics (SL and DL) and acceleration to 31 GeV/c

(b) Overlap Knockout. A bunched beam on coasting beam effect which became of importance during acceleration to 31 GeV/c.

(c) Beam-Beam Resonance Excitation. Principal reason for the exclusion of resonances below 8th order in the stack and the abandonment of the '5C' line.

(d) Beam-Beam Tune Shift. One factor in working line correction and indicator for the beam-beam limit.

(e) Common Equipment. Common magnets such as SFM, Solenoid and OAFM couple rings as well as use of common diagnostic equipment and common control computer.

(f) Quiet Experiments. Certain sensitive experiments "see" the other ring in many ways. For example, particle loss measurements, noise injection onto the mains, poor vacuum or cleaning in an intersection etc.

2.1 Effects on MD Scheduling

This is a rather complex question. For example vacuum limit tests were originally very short and easily performed (see MD 278, revised schedule, 7-8/3/1973 – 2h for vacuum limit test), but in recent years they have become very long, needing almost 100% of the available beam and computer time and once the beam is stacked it is so intense (~60A) that beam-beam effects virtually exclude work in the other ring (see MD 1280, 7/7/1982 – 15h for vacuum limit test). In general, it is true to say that as intensities have increased and measurements have become more refined, it has become more difficult to find compatible experiments to run in the two rings.

In order to get some feeling for the scheduling problems, a fairly simple analysis has been made of three groups of 10 consecutive schedules.

Group 1. Early ISR, 1973 10 consecutive schedules.
Group 2. Middle ISR, 1977 10 consecutive schedules.
Group 3. Late ISR, 1982 10 consecutive schedules.

(A schedule contains 1 to 3 MD runs of typically 20h.)

The allocation of time in the above groups of schedules has been broken down into 3 categories.

which is still equally restrictive, may be scheduled with a particularly quiet or undemanding experiment in the other ring. The time then falls in category A.

- When an experiment is marked "P" i.e. parasitic or the other ring is marked "priority" the time is put in category C, but this is not always a question of incompatibility. Sometimes priority is given to ensure an important experiment is finished if say time is lost due to a PS breakdown.

- Some supposedly independent experiments certainly got poor results due to clashes over available computer time or beam time or by simply not realising that beam-beam effects were present.

- Some of the joint scheduling of both rings must conceal cases where the intention is to keep the second ring quiet to prevent interference.

- Joint scheduling of the two rings should be for experiments such as "luminosity optimisation", but in many cases the work in the two rings could be done independently.

- The exclusive use of ring 2 over several days in Group 3 for $\bar{p}$ MD at 3.5 GeV/c for the gas jet target is somewhat exceptional.

T.J. Bryant.

Category A. (indicated in blue)
Independent experiments in the two rings

Category B. (indicated in yellow)
Joint use of the two rings.

Category C. (indicated in red)
Exclusion of use of other ring or priority over other ring (note "P" on schedules indicates "parasitic")

Allocation of MD Time [h]

Group \ Category	A (Independent)	B (Joint)	C (Full or Partial Exclusion)	Total Hours
1 (1973)	113.5	118.0	56.5	288.0
2 (1977)	172.5	94.5	58.0	325.0
3 (1982)	76.0	153.0	122.0*	351.0

* Contains $\bar{p}$ MD time at 3.5GeV/c for gas jet target using ring 2 only.

The above results should be approached with some caution. The main points are;—

- A given experiment may have "Quiet" or "Reserved" marked against the other ring and hence those hours fall into category C. On another occasion the same experiment,

Systems Group

Dixon Bogert
Dick Carnel
Don Hartill
Karl Koepke
Gerry Tool
John Zeigler *

SSC C & O Workshop
Karl Koepke - "Quench Detection And Protection of SSC Magnet Systems"
01/15/85

Quench Protection

1. Commissioning
2. Operations - reliability, operating ease

} function of magnet type

Two natural subgroups: Superferric 3T
High Field - all others

Consider* quench protection per sector, per aperture ⇒
no obvious distinction among 2 in 1,
1 in 1,
dual,
cold iron, warm iron

* Define quench coupling as cryogenic or operations problem

Tried to avoid active / passive protection controversy - will be decided by common T_{max} standard $500 \le T_{max} \le 800$ K and/or reliability/operability considerations

<u>Superferric cable</u>

 $\Rightarrow$ Low-Beta cable + Cu (RRR 200)

MIITS ($B=0$, $T_M = 500$ K) $\approx$ 45

$I \approx 10$ kA

$I^2 t = 44 \; 10^6 \Rightarrow t = .44$ sec

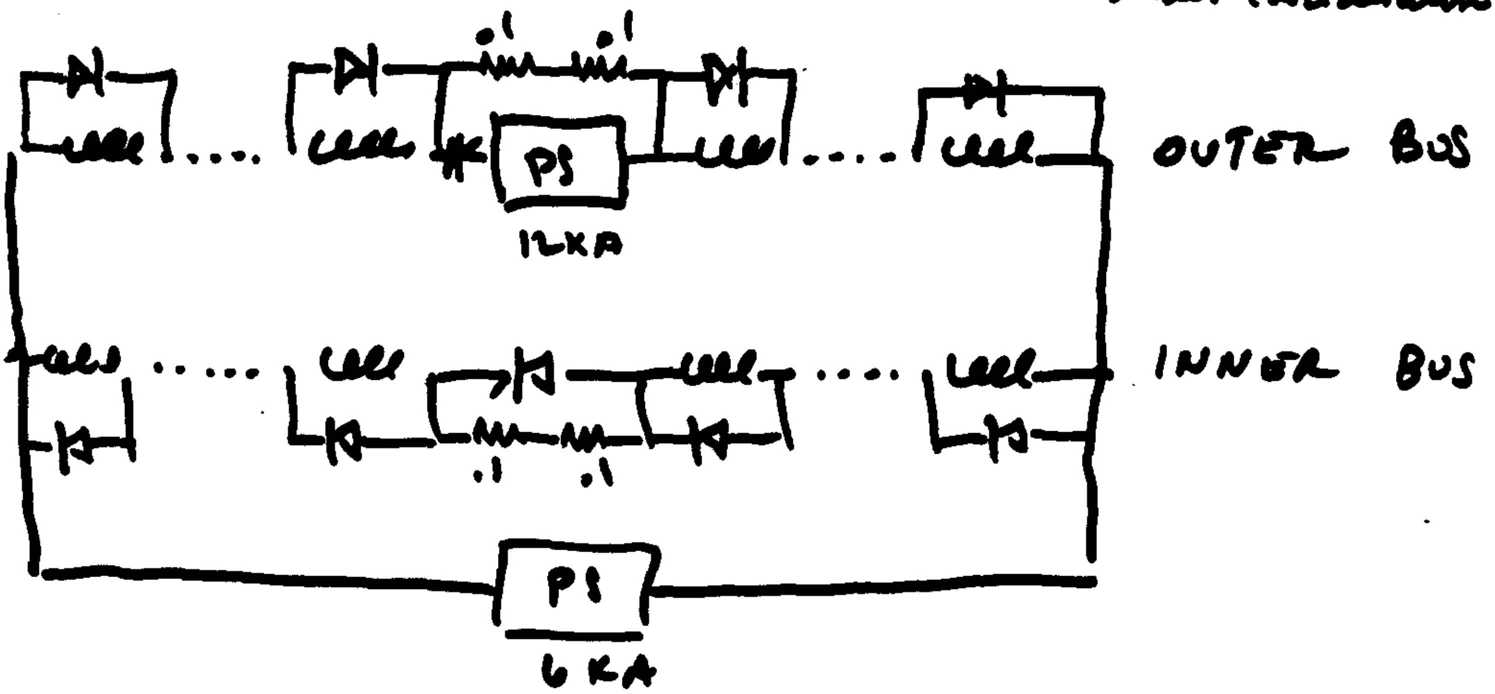
Inductance / meter = 0.1 mH/m

If 12 sectors + 4 dumps/sector

$M = I^2 \frac{\tau}{2} \approx 62$ MIITS

20% more Cu and/or RRR > 200 $\Rightarrow$ eliminate diodes

3T Dipole Power Circuit (6/12 sectors under consideration)



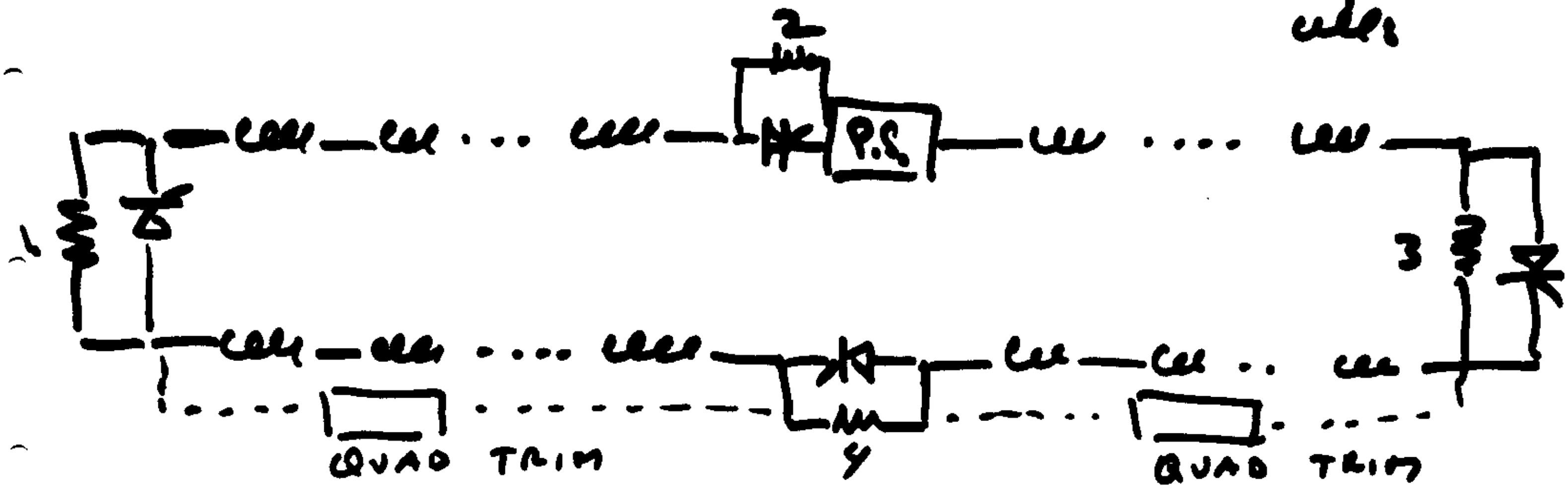
2 cold (warm) diodes per half cell independent of magnet length
≈ 80 dipoles (140 m) per sector if 12 sectors

Separate Quad Power circuit ≈ 3 kA

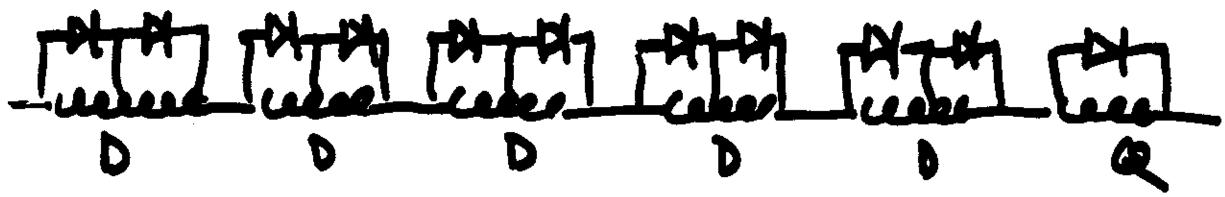
80 quads per sector if 12 sectors

High Field Magnets

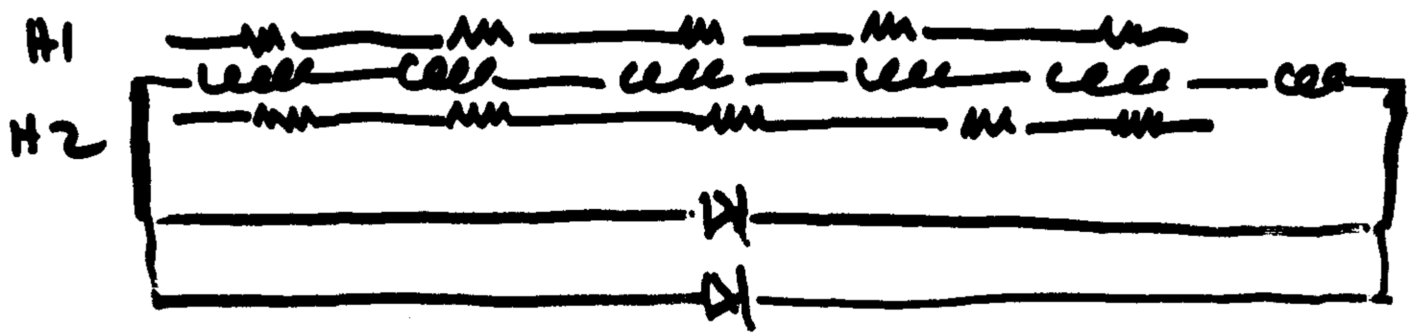
12 sectors, 200 m magnet cells



PASSIVE HALF CELL



ACTIVE HALF CELL



diodes or SCR's

Comparisons per sector per aperture

	10 KA 160 m 3T	6 KA 11 m 5T	5.4 KA 16.6 m 6.5T
P.S.	3 (1½)	1	1 (2?)
DUMPS	2	4	4
DIODES	240 (80×3)	1360 (640×2 + 80) Factor 6	700 (320×2 + 60) Factor 3

CAVEAT: 2 diodes/magnet $T_{max} > 500K$
may need 4 diodes/magnet

ACTIVE OPTION

		160	120
Heater P.S.		160	120
SCRS (DIODES)			

Quench Detection

Passive System — V Det. ~ .5V

RESPONCE TIME NOT CRITICAL

ALTERNATE (SIMPLER)

SCHEMES POSSIBLE, i.e.,

Compensation, current

transformer

ACTIVE SYSTEM — VDET ≤ 10V

Responce time critical

- ORDER OF LINE CYCLE

CONCLUSIONS

3T easy to protect - passive only option

T35 A. passive will probably work } present
B. active guaranteed to work } information

ACTIVE / PASSIVE RELIABILITY
OPERABILITY

PASSIVE - EASY TO OPERATE
DIODE QUESTIONS 1. cold cycles
2. radiation

ACTIVE - MORE MAINTENANCE
& FALSE QUENCHES

Wednesday Morning 16 Jan 1985

NEWS REPORTS

Cryogenics News Report
Bill Fowler Wed 16 Jan 85

Cryogenic Questions

L-1 • **Large Scale Cooldowns**
Time, cost, how often?

L-2 • **Magnet Replacement**
Time required, beam valves, how is it done, how often?

L-3 • **Steady State Operation**
Removing heat from synchrotron radiation and ramping.

L-4 • **Two Phase Flow**
Is it stable?

L-5 • **One Phase Flow**
What do the recoolers look like?

L-6 • **Quench Recovery**
Two-in-one implications.

L-7 • **Separate Cryogenics**
Should one-in-one magnets have separate cryostats?

1/11/85

Cryo Group Work List

F 1. Review heat leaks, weights etc.

F 2. Cool Down

F 3. Magnet Replacement

F 4. flow areas — flow rates

Conduction cooling and/or porosity of coil package

F 5. Quench recovery

F 6. Magnet Shields* Type (air, LN, He) flow and area required.

F 7. Mobil Refrigerators for cool-down

CRYOGENIC AND MAGNET SYSTEM INTERFACES

1. MAGNET OPERATING TEMPERATURE
2. HEAT LOAD
   - A. SUPPORT HEAT STATIONING
   - B. HEAT SHIELDS
     - HIGH TEMPERATURE (80°K)
     - LOW TEMPERATURE
       - IN OR OUT?
       - MEAN OPERATING TEMPERATURE?
       - PIPING SPACE?
   - C. INSULATION SYSTEM
3. PRESSURE DROP IN MAGNETS - ALL OPERATING CONDITIONS
4. PIPING - NUMBER AND SIZE OF PIPES REQUIRED
   - A. OPERATING FLEXIBILITY VS. COST AND SPACE
   - B. PRESSURE DROP VS. OPERATING TEMPERATURE
   - C. PRESSURE DROP VS. OPERATING EFFICIENCY (COST)
5. HELIUM VOLUME IN MAGNET SYSTEM
6. COOLDOWN MASS OF MAGNET SYSTEM
7. SPACE REQUIRED FOR RECOOLERS, ETC.,
8. WARM UP

D.P. BROWN
9 JAN 85

1/16/85

Cryo Group Work List

Item	Subject	Responsible Person	Due
L1 & F4	Review heat leaks, weights etc flo areas - flo rates	WBF	end of workshop
L1/F2	Large Scale Cooldown	CR	MAR 1
L1a	Large Industrial Plants	J Van S	MAR 1
L2/F3	Magnet Replacement	PV and A	Apr 1
L2	Steady State Operation	PV and A	1st Draft Complete Review & 2nd Draft MAR 1
L4	Discarded		
L5	Recoolers	DB	MAR 15
L6/F5	Quench Recovery	CR	MAR 15
L7	Separate Cryogenics	DB+DW	MAR 1
F6	MAGNET Shields	DB	MAR 1
F7	Mobil Refrigerators	R.B	Mar 1

Design News Report – C. Leemann
Wed 16 Jan 1985

Summary of Tuesday's Discussion

[A.C., E.C., E.F., C.L., S.P., J.P.]

Main topic: coupling between beams
"What design features / operations procedures are required to abort/refill one beam while keeping the other "alive"? "

Possible answers:

(a) Decel to 1 TeV
(b) Decel to 5 TeV (e.g.), refill at 1 TeV
(c) Stay at 20 TeV, refill at 1 TeV

Concerns / Considerations / Comments etc:

(a) & (b) :
- rf implications
- might just simply not be possible with any magnet: hysteresis effects, rapid response of correction elements required
- (a) only: no particular & in l constraint
- clarification about magnetic cycle required
- no (extra) constraint for IR design

options (b) & (c):

- require IR capable of accommodating unequal energy beams
- existence proof of this required probably involves SC septum magnet
  [need input: (i) acceptable? 0° photon target?
  (ii) design possibilities/limitations of septa]
- incompatible with 2 in 1 magnets

Important (open) question

- What investment of time does one beam constitute? (15 min vs 8 hours)

A tentative conclusion:

- If gains are modest (~30 min) forget this feature unless it turns out to be moderately easy!

Noted during discussion

- long range bb-forces/effects still not transparent!
- Injection scenario not in hand (with respect to the above!)
- would prefer no/regularly spaced gaps

Discussion Topics for Today

- o Implications of Magnet Style for lattice Design (with A. Garren)

  - 2 in 1: optics constraints, focusing sequence
    IR design
  - 1 in 1: IR design, over/under vs side by side
    impact of large beam separation
    "non coupling" IR design

- o Relevance of Field Quality for the Present Discussion

  - F.Q. as an operational consideration
  - F.Q./magnet type correlations
  - consequences of magnet selection, "shuffling", particular correction methods

Systems news report - D. Hartill
wed 16 Jan 1985

Systems

Talk: 4:00 p.m. Dick Cassel will speak on

"Power Supply Considerations for the SSC"

Today's Discussion:

Power Supplies and Beam Diagnostics

Activities

1. Quench Protection
   i. Karl's talk
   ii. Conclusion 3T is easier
   iii. 2 in 1 may induce artificial quenches in non-quenching bore thru transformer action into sensing circuits at ends of magnet string

2. Vacuum System
   i. physical plant comparison
   ii. Synch. Rad.

      power/meter $\propto BE^3$

$\mathcal{U} = \frac{1}{r} E^4$

   iii. 2 in 1 vs 1 in 1 vs. Dual

$u = \frac{1}{r^2} E^4$ just usual maintenance considerations (# protons $\propto r$)

$u_T = u \times N$ beam tube size & length for instabilities

3. Listened to TeV and ISR operations talks

Scheduled Reports - Wed. 16 Jan 1985

1. <u>Cryogenics</u>: 11:00 AM

   John Van Sloan: "Commissioning a Large LHe Plant"

   Don Brown: "Cryogenic System Performance Assumptions"

2. <u>Operations</u>: 1:30 PM

   Russ Huson: "Status of TAC"

   Derek Lowenstein: "Operations Cost Subgroup Report"

   Rich Orr: "Magnet Change Time Estimates"

   John Poole: "2-in-1 vs 1-in-1 Commissioning and Operation Considerations"

3. <u>Design</u>: 2:45 PM

   No reports scheduled.

4. <u>Systems</u>: 4:00 PM

   Richard Cassel: "Power Supply Regulation"

SSC C&O Workshop
John Van Sloan 16 Jan 85

GENERAL PLANT INFORMATION

- PURIFIER
  1. HELIUM ENRICHMENT EQUIPMENT
  2. N_2 RECYCLE EQUIPMENT

- LIQUEFIER
  1. LIN LEVEL REFRIGERATION
  2. 2 LEVELS OF TURBO EXPANDER REFRIGERATION
  3. 1 LEVEL OF RECIP EXPANDER REFRIGERATION

- UTILITIES
  1. COOLING H_2O
  2. BOILER
  3. FIRE H_2O SYSTEM
  4. INSTRUMENT & UTILITY AIR

TOTAL PLANT EQUIPMENT

- 12 RECIPROCATING COMPRESSORS
- 2 TURBO EXPANDERS
- 1 COMPANDER
- 4 RECIPROCATING EXPANDERS

STAFFING

1 PLANT MANAGER

1 ASSISTAN PLANT MANAGER

9 OPERATORS

2 MECHANICS

1 INSTRUMENT/ELECTRICAL

START UP SCHEDULE

- PRE COMMISSIONING (2-15-82 TO 4-30-82)
  1. UTILITY COMMISSIONING
  2. COMPRESSOR RUN IN
  3. VACUUM SYSTEMS CHECK OUT

- START-UP (4-30-82 TO 6-6-82)
  1. DERIME LIQ.
  2. CONVERSION TO HELIUM
  3. COOL DOWN OF LIQUEFIER
  4. PURIFIER START UP
  5. LOADING SYSTEMS COMPLETE

- SSC START-UP
  1. FIRST PLANT 1 MONTH
  2. BY THIRD PLANT START-UP TRIMMED TO 1 WEEK

START-UP PROBLEMS

- INSTRUMENTATION FAILURES
- MECHANICAL FAILURES
- DERIME PROBLEMS
    1. HEAT IN CHARCOAL BEDS
    2. HEAT TO LIQUEFIER
- LEAK PREVENTION

OPERATING PROBLEMS

1– CONTAMINATION OF LIQUEFIER

1. NEON CONTAMINATION
2. LIQUID TRAILER CONTAMINATION
3. PLANT UPSET (ERRORS)

– VACUUM MAINTENANCE

– HELIUM MOLECULE RECOVERY
(CURRENTLY 98%)

– ON STREAM TIME

1. MAJORITY OF PROBLEMS EARLY WERE MECHANICAL FAILURES ~ 80%
2. CURRENT ON STREAM TIME
   - 92% OF TOTAL PLANT CAPACITY
   - 96% PRODUCT IS PRODUCED

Cur

GOALS 95% + 98% RESPECTIVELY

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CRYOGENIC SYSTEM PERFORMANCE ASSUMPTIONS

- 4.5°K MAX. MAGNET OPER. TEMP.
- CRYOGENIC LOOP ΔT = 0.2°K MAX.
- 2 WEEK COOLDOWN IS O.K.
- 5 DAY NOM. MAGNET REPLACE. TIME IS O.K. - SHORTER IS BETTER
- 10 "EVENTS" PER YEAR → 75 $\frac{\text{DAYS DOWN}}{\text{YEAR}}$
- SCHEDULED MAINTENANCE = 10%, CAN OVERLAP WITH OTHER ACCEL. MAINTENANCE
- COOLDOWN MASS $(1\cdot \overset{D}{\text{IN}}\cdot 1)/(2\cdot \overset{A}{\text{IN}}\cdot 1) = 1.3$

DPB
1/16/85

LOWER TEMPERATURE OPERATION

- ROOM TEMP. COMPRESSOR OPERATES SUB-ATMOSPHERIC
  - INLEAKAGE OF AIR
  - LARGER HX AND COMPR.
  -
- EJECTOR

  - SIMPLE, BUT INFLEXIBLE
  - INEFFICIENT, BUT CHEAP
  - TECHNOLOGY "WEAK", TRIAL AND ERROR
  - PRESS. RATIO CAN BE HIGH
  - "WET" EXPANDER NOT ALLOWED
- COLD COMPRESSOR
  - RECIP. OR CENTRIF.
  - RELATIVELY HIGH EFFIC.
  - FLEXIBLE (ESPEC. RECIP.)
  - "HIGH TECH"
  - PRESS. RATIO CAN BE HIGH

DPB
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SSC C&O Workshop
Russ Huson 01/16/85

TEXAS ACCELERATOR CENTER at HARC
ORGANIZATION CHART

PROGRAM MANAGEMENT GROUP

Chairman: R. Tribble, Texas A&M

R. Boom, Univ. of Wis.
R. Diebold, ANL
A. Gleeson, Univ. of Tx.
P. Livdahl, FNAL
G. Phillips, Rice Univ.
D. Gottlieb, HARC
P. Reardon, BNL
R. Weinstein, U. of H.
W. Wenzel, LBL

ORGANIZATION

Project Manager: F.R. Huson
Project Spokesperson: P. McIntyre
HARC Contracts Officer: A. Sherman
Business Manager: B. Huguelet
Administrative Assistant: E. Gommermann

Business Department:
- Head: B. Huguelet
- Invoices & Payment: R. Lane
- Accounting & Budget: R. Schmidt
- Purchasing: D. Stanko
- Sec'y/Rec'p't: G. Jahn
- Secretary: L. Angele
- Secretary: M. Dau

Cryogenics:
- Head: J. Colvin
- Techs: W. McCafferty, T. Cross, J. Stockton

Physicists:
- D. Neuffer
- A. Dragt
- H. Bingham
- D. Swenson
- G. Lopez
- S. Pissanetzky
- S. Heifets
- W. MacKay
- T. Tominaka
- M. Kobayashi
- K. Lau

Eng's/Designers/Computing:
- H. Hinterberger
- R. Wolgast
- W. Tuzel
- B. Uy
- J. Briske
- J. Greenough
- W. Schmidt
- R. Rocha
- M. Davidson
- R. Jones

Shop:
- R. Stegman, Head
- L. Crowe
- J. Eaker
- T. Welch
- G. Shotzman

Electrical:
- J. Zeigler, Head
- J. Hunter, Tech.
- B. Birdwell, Tech.

FUNDING

<u>HARC</u>
DOE
Mitchell

<u>Texas A&M</u>
Physics Dept.
DOE/HARC-Res. Fnd

<u>Univ. of Houston</u>
Physics Dept.
College of Science

<u>Rice</u>
Physics Dept.

<u>The Univ. of Texas</u>
College of Science

<u>Univ. of Wis.</u>
Nuclear Engineering Dept.
High Energy Physics

<u>BNL</u>
Accelerator Div.

<u>Fermilab</u>
Magnet Division

<u>LBL</u>
Physics Division

<u>ANL</u>
Physics Division

STATUS

II. FACILITY

1. FULL MACHINE AND WELD SHOP.
2. FULL CRYOGENIC EQUIPMENT

   25 LITER/HR HELIUM LIQUIFIER BNL

   75 LITER/HR HELIUM LIQUIFIER HARC
3. ELECTRONICS SHOP
4. COMPUTERS

VAX 730	
VAX 780	UNIVERSITY OF HOUSTON
VAX 782	TEXAS A&M UNIVERSITY
CYBER 205	COLORADO STATE (UNIVERSITY OF HOUSTON)
CRAY X-MP	LIVERMORE (DOE)

Operations Cost Subgroup

SSC C&O Workshop
Derek Lowenstein
Wed 01-16-85

R. Huson
D. Lowenstein
R. Mau
R. Orr
E. Paterson
L. Vos

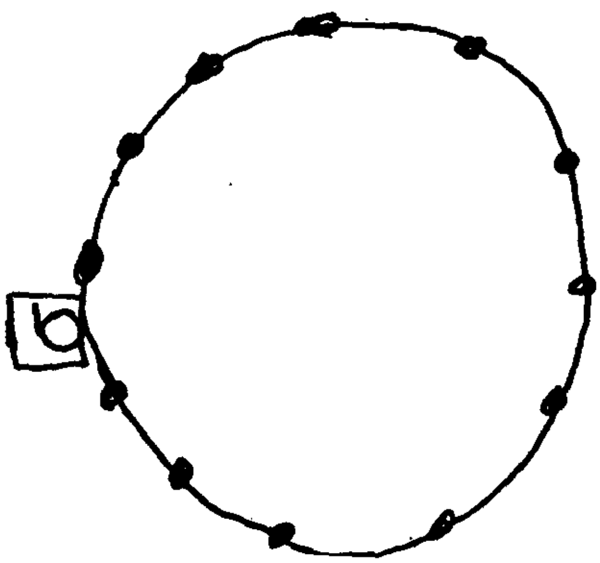
Cost

- Baseline (Collider Independent)
- Collider Costs
  - Scaling with size
  - Non Scaling

→ Effort to compare large vs. very large

Assumes 1 in 1. No effort yet to consider 2 in 1, dual.

Assumed that many ring functions would be clustered at regular intervals around ring (8 km).



TEV: R≈1 km B≈4.45T C≈2π km

D_{REF} ≈ 6 km

SSC: R≈15 km B=6.0T C≈30π km

B≈3.0T C≈60π km

D_{REF} ≈ 8 km

Operating Costs

1/15/85

* Numbers in parenthesis are for 3T case.
Numbers not in parenthesis are for 6T case.

Items that scale per unit length (=8 km)

Collider Item	MPWE / Shift	Shifts	MPWE	M&S/Power Purchases ($M)	Bus Total MPWE	Bus Total M&S/Power Purchases
Cryogenic						
Cryo Field Operator	2/3 (2/3)	5	3⅓ (3⅓)		40 (80)	
Maintenance Mechanics	1 (1)	1	1 (1)		12 (24)	
Maintenance Electronics	½ (½)	1	½ (½)		6 (12)	
Maintenance Supervisor/Asst.	7/12 (7/24)	5	[illegible]		10 (10)	
				Helium .1 (.1)		1.2 (2.4)
				Power 1.5 (.75)		18.0 (18.0
				Misc. .2 (.1)		2.4 (2.4
General Operations & Maintenance (Power Supplies, Controls, Instr., Air Cond., Water Systems . . .)						
Electronics Tech	1/6 (1/6)	5	5/6 (5/6)		10 (20)	
Electronics Shop	1 (1)	1	1 (1)		12 (24)	
Mechanical Shop	1 (1)	1	1 (1)		12 (24)	
Mechanical Tech (use cryo group)						
Emergency Response & Security (covered by trained field operators)						
Satellite Field Oper. Supv.	1/12 (1/24)	1	1/12 (1/24)		1 (1)	
				Misc. + Burr .1 (.2)		1.2 (2.4
			8.6 (8.1)	1.9 (1.1)	103 (195)	22.8 (25.

DJL

NON SCALING ITEMS

1/15/85

COLLIDER CENTRAL GROUP COSTS

				$ MMS
SSC CRYOGENIC SUPPORT STAFF	12	1	12	12 (12)
SSC CRYOGENIC OPERATORS	1	5	1	5 (5)
SSC TUNNEL MAINTENANCE				135 (189) ← 81.4 PDC DESIGN
SSC OPERATIONS SUPPORT (RF, VACUUM, CONTROLS ......)				120 (120)
INJECTOR OPERATIONS SUPPORT				120 (120)
INJECTOR CRYO SUPPORT				20 (20)
MACHINE OPERATORS	6	5	6	30 (30)
				442 (496)

INTERSECTION REGIONS (PHYSICS PROC. SUPPORT)	500
CENTRAL SHOPS	100

NOTE: MSTC, POWER ETC. YET TO BE ESTIMATED
ACCELERATOR R&D AREA (KA03-01/02) NOT YET ESTIMAT.
& FACILITIES

1/15/85

Operating Costs
Summary (Interim)

Item	MPWR	Salary (@43K)	Mat'e Etc.
Injector Systems (02-01)	140	6.0	?
Collider Cryogenic (02-01)	85 (143)	3.6 (6.1)	21.6+? (22.8+?)
Collider Other Areas (02-01)	320* (408)* [illegible]	13.8 (17.6)	1.2+? (2.4+?)
Intersection Region Support (02-02)	500	21.5	?
Central Shops	100	4.3	?
Accelerator R&D (03-01)	?	?	?
Facilities R&D (03-02)	?	?	?
Physics Research (01-01)	?	?	?
Direct	1145 (1291)+?	49.2 (55.5)+?	
G&A (40%) except for power	458 (516)+?	19.7 (22.2)+?	
	1603 (1807)+?	68.9 (77.7)+?	

(Purchasing, Personnel, Plant Eng., Buildings & Grounds, S&EP, CSCF, Stores, etc.)

? = Haven't yet estimated this entry

SSE CDO Workshop
Rich Orr
1/16/85

Magnet Change Times

Format only — Needs detailed scenario

— Assume two vehicles

Days

Steps	1 in 1: 3T	1 in 1: 6T	1 in 1: 6T ([illegible])	2 in 1 or Dual: 3T	2 in 1 or Dual: 6T
Diagnose Problem	2/3	2/3	2/3	2/3	2/3
Warm-up	1.5	1.5	1	2	2
Stage spare	(1/3)	(1/3)	(1/3)	(1/3)	(1/3)
Transport	(1/3)	(1/3)	(1/3)	(1/3)	(1/3)
Cool spare	(1/2)	0	0	(1)	0
Remove bad magnet	1/3	1/3	1/3	1/3	1/3
Move spare to location	(1/3)	(1/3)	(1/3)	(1/3)	(1/3)
[illegible]	1/3	1/3	1/3	1/3	1/3
Connect	1/6	1/6	1/6	1/3	1/3
Pumpdown Leak check	2	1.5	1.5	2	1.5
Cooldown	1	2	1	2	3
Hi-Pot	1/3	1/3	1/3	1/3	1/3

Note: 1. For 6 IRs, 6 separate insertion ports are required for 100 m magnet.

2. A monorail would be nice

3. Rail system must be designed for 100 m magnet.

SSC C&O workshop
John Poole wed 16 Jan '85

GENERAL

1 A PROBLEM AFTER THE START OF ACCELERATION MEANS THAT BOTH BEAMS WILL HAVE TO BE RE-STARTED.

2 DECELERATION WILL NOT BE USEFUL BECAUSE OF THE REQUIREMENT TO GO BELOW INJECTION ENERGY

3. ANY PROBLEM IN 1 RING STOPS WORK IN THE OTHER

4. HORIZONTAL AND VERTICAL OPTIMISATION OF LUMINOSITY IS REQUIRED FOR SMALL CROSSING ANGLES

COMMISSIONING

1. WITH 2-IN-1 ONE CAN ONLY DO THE SAME TYPE OF THINGS IN BOTH RINGS. FAILURES (FREQUENT DURING COMMISSIONING) IN ONE RING WILL STOP WORK IN THE OTHER RING

2. ANY INTERACTION OF ONE RING ON THE OTHER WILL COMPLICATE CONTROL MODELS WHICH WILL THEREFORE TAKE LONGER TO COMMISSION.

AT BEAM LOSS FROM RING 1 THE BEAM IN RING 2 WILL GET A KICK WHICH WILL PROBABLY BLOW IT UP.

TO KEEP THIS BEAM AND INJECT ANOTHER IMPLIES A COMPLEX SERIES OF DELICATE OPERATIONS viz.

- FIX TUNE
- TAKE OUT EXPERIMENTAL MAGNETS
- RUN DOWN LOW BETAS
- DECELERATE BEAM

SSC REGULAR REFILL

	FILL	"RE-FILL"
CYCLE AND SET UP	.45	.30
SET UP INJECTION	.15	10
SEPARATE BEAMS	.15	-
FILL	.45	25
ACCELERATE	.15	.15
LOW BETAS	.15	.30
EXPERIMENTAL MAGNETS etc.	.15	.30
LUMINOSITY STEERING	.15	.15
ADJUSTMENTS	30	15
	3h 30m	2h 50m

CONTINGENCY	30m
	4h 00m

R Cassel 01-16-84

Power Supply Regulation

Bends 0.1 mm rot. $\Rightarrow \frac{\Delta I}{I} = 10^{-4}$

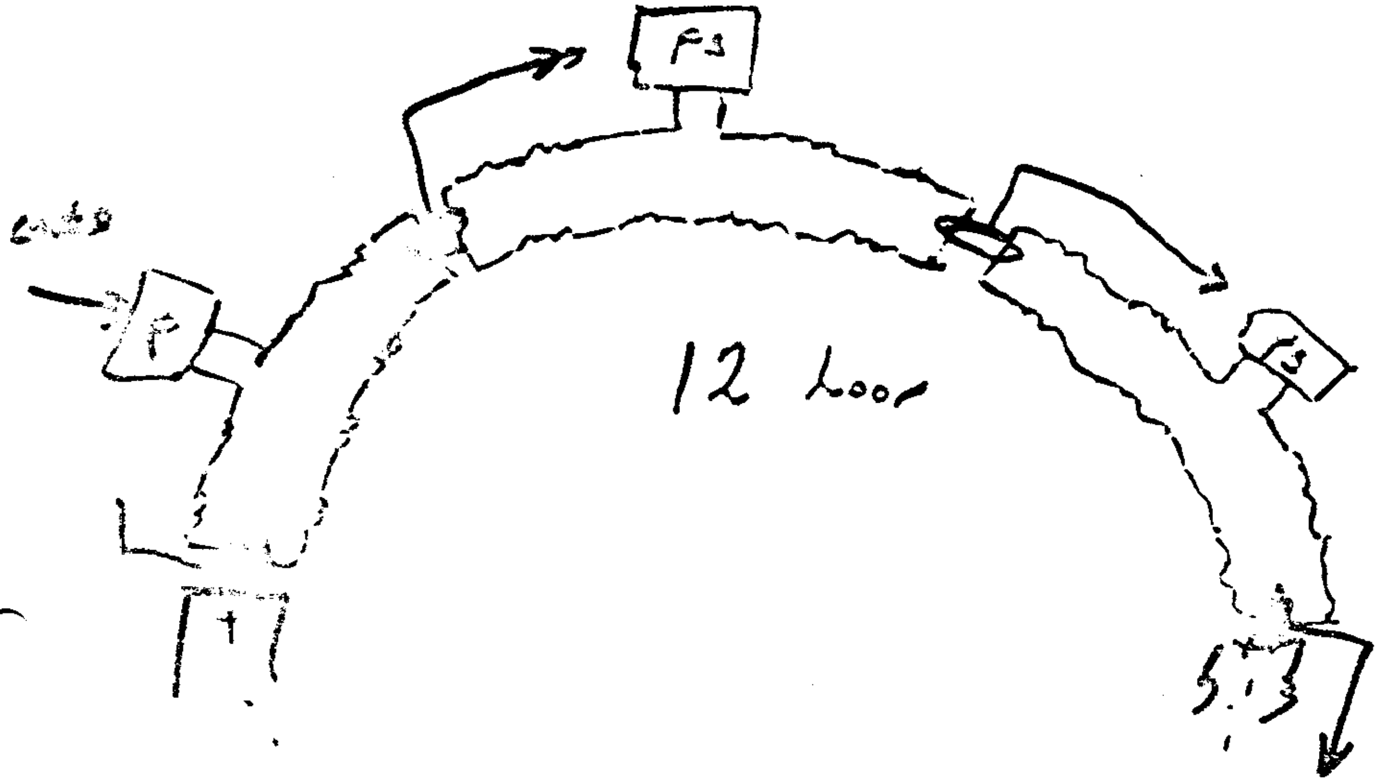
Quads Acc $\Delta\nu = 0.02 \Rightarrow \frac{\Delta I}{I} \simeq 2 \times 10^{-4}$

Col. $\Delta\nu = 0.002 \Rightarrow \frac{\Delta I}{I} \simeq 2 \times 10^{-5}$

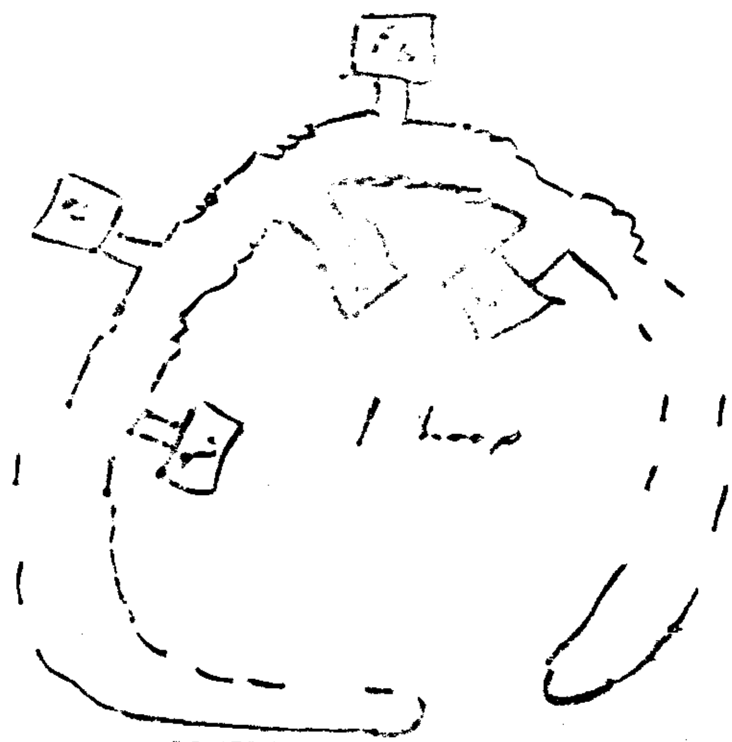
MAGNET TYPE relate to REGULATION

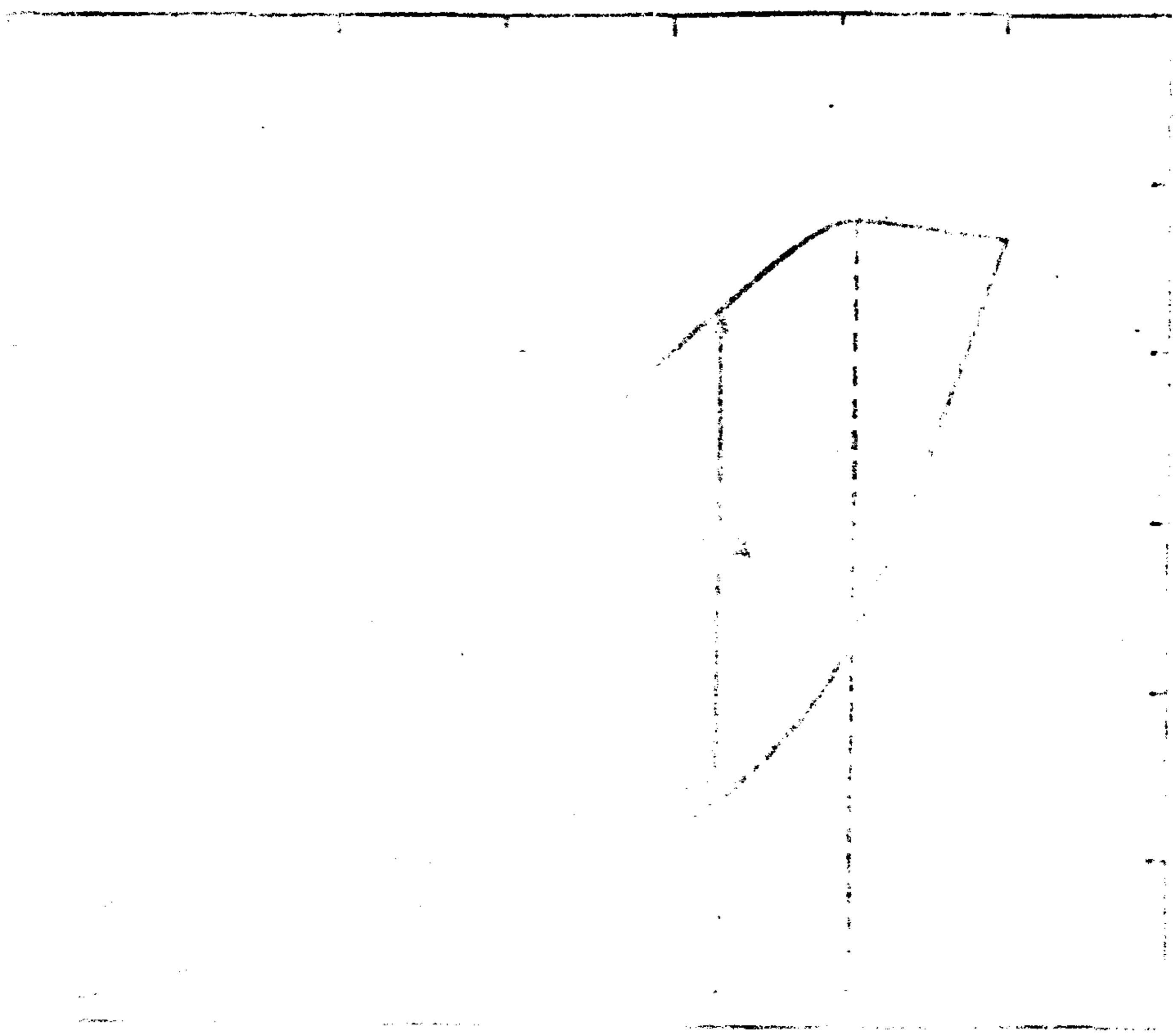
POWER SUPPLY configuration

one regulation loop Vs 12



Vs





12 Loop System $\Delta I / I = 1 \times 10^{-4}$

DIFFERENCE TRANSDUCTORS
MEASUREMENT OR

OPERATION Of EACH LOOP FROM [illegible] TRANSDUCTOR with the 12The
O[illegible]N

P[illegible] WORLD WORK
[illegible] STUDY

TRANSMISSION LINE EFFECTS

OPERATION [illegible] STUDY

12 Loop LOW Field MAG.

R[illegible]ATE ON [illegible] SUM OF INNER/OUTER
CURRENT USING SAME [illegible]
AS HIGH Field

SAME PROBLEMS AS HIGH FIELD
M[illegible] (NEED STUDY)

I[illegible] TO OUTER CURRENT
TR[illegible] NOT CRITICAL $\frac{\delta I}{I} = 10^{-3}$

[illegible] FIELD VS
SUM CURRENT NEEDS STUDY

[illegible] OF FIELD VS
INNER + OUTER CURRENT
NEEDS STUDY

QUAD REGULATION

HIGH FIELD

AIR CORE

QUADS IN SERIES WITH DIPOLES

NO PROBLEM

HIGH FIELD

IRON

QUADS IN SERIES WITH DIPOLES

TRIMS ON QUADS PER SECTOR

AT 1/10 OF RATED CURRENT

SHOULD NEED REGULATION OF

2×10^{-4} to 1×10^{-3}

CAN BE DONE

LOW FIELD

SEPARATE QUADS

QUADS TRACK BEND CURRENT + PROGRAM

REGULATION 2×10^{-5} to 6×10^{-5}

DIFFICULT

IRON MAG VS AIR

RESIDUAL FIELD. EFFECT OF QUENCH IN ONE SECTOR OR LOSS OF REGULATION. ?

SSC C & O Workshop

Scheduled Reports - Thu 17 Jan 1985

1. <u>Cryogenics:</u> 11:00 a.m.

   No talks scheduled.

2. <u>Operations:</u> 1:30 p.m.

   No talks scheduled.

3. <u>Design:</u> 2:45 p.m.

   Lyn Evans: "The SppS".
   Ernest Courant: "Consequences of 3 Tesla versus 6 Tesla".

4. <u>Systems:</u> 4:00 p.m.

   No talks scheduled.

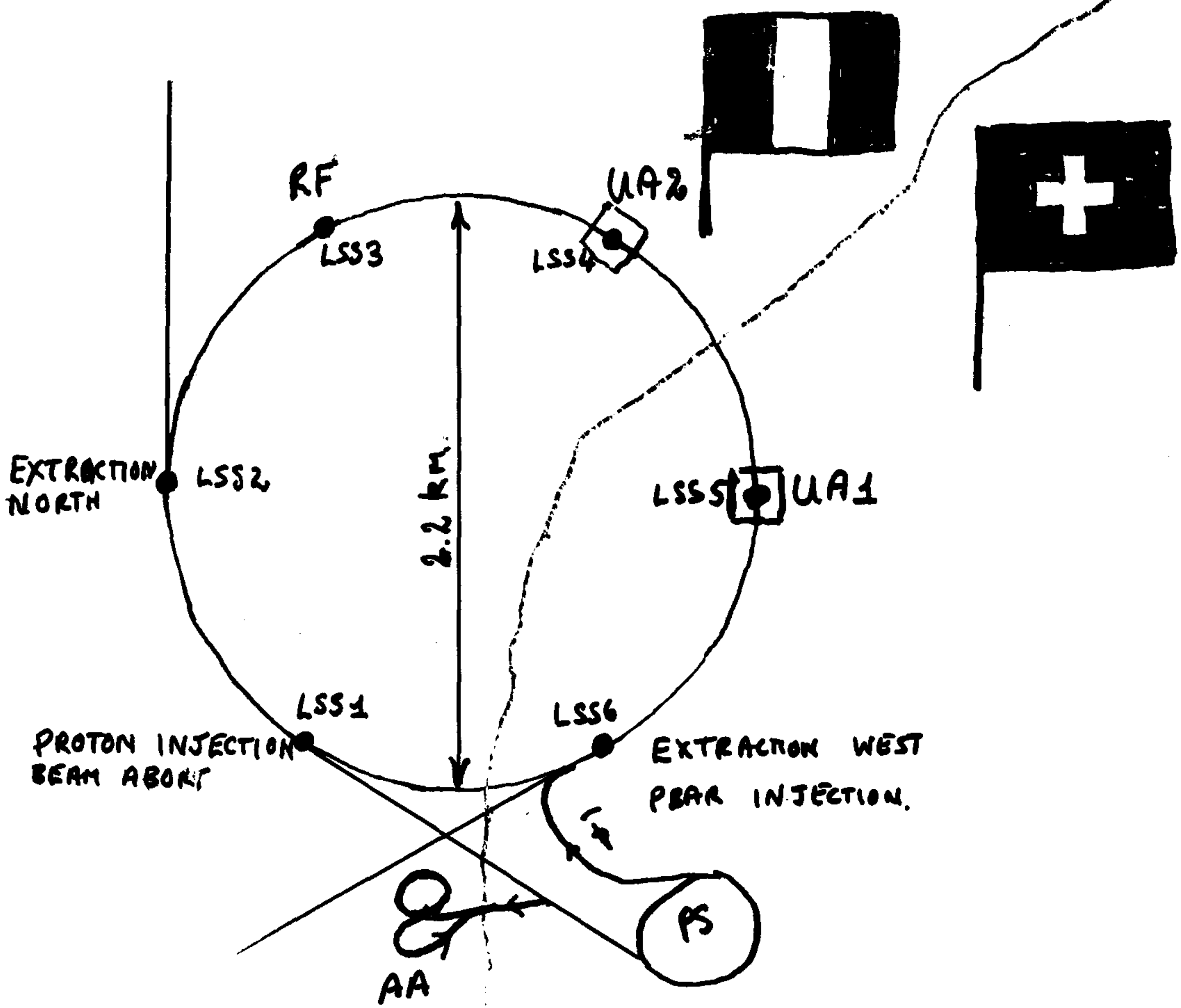
<u>Coming Attractions:</u>

1. Thu 17 Jan 1985: 5:00 p.m. (Lounge 375 LeConte) STEERING COMMITTEE MEETING.
2. Tue - Wed 26-27 February 1985: (Fermilab) STEERING COMMITTEE MEETING.
3. Tue - Wed 26-27 March 1985: (place to be announced) STEERING COMMITTEE MEETING.
4. Mon 1 April 1985: FINAL GROUP REPORTS ARRIVE AT LBL.
5. About 15 April 1985: REPORT OF C & O STUDY GROUP APPEARS.

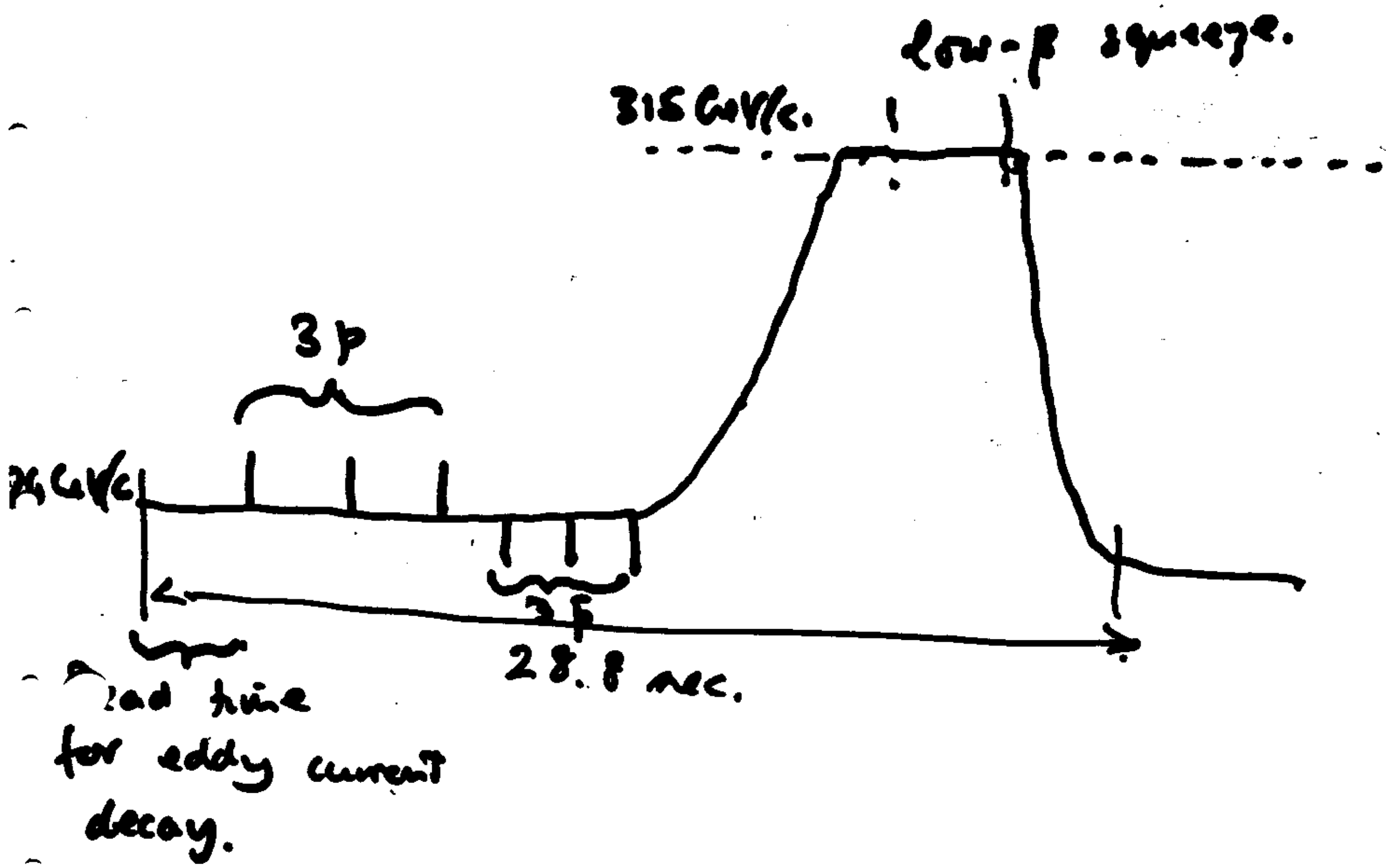
SSC C&O workshop
Lyn Evans, Thu 17 Jan 85

CONTENTS.

- Choreography
- Machine performance.
- Limitations
- Machine reliability
- Power supply stability requirements
- Beam separation


RF
LSS3
UA2
LSS4
EXTRACTION NORTH
LSS2
2.2 km
LSS5
UA1
LSS1
PROTON INJECTION
BEAM ABORT
LSS6
EXTRACTION WEST
PBAR INJECTION.
PS
AA

SPS cycle.

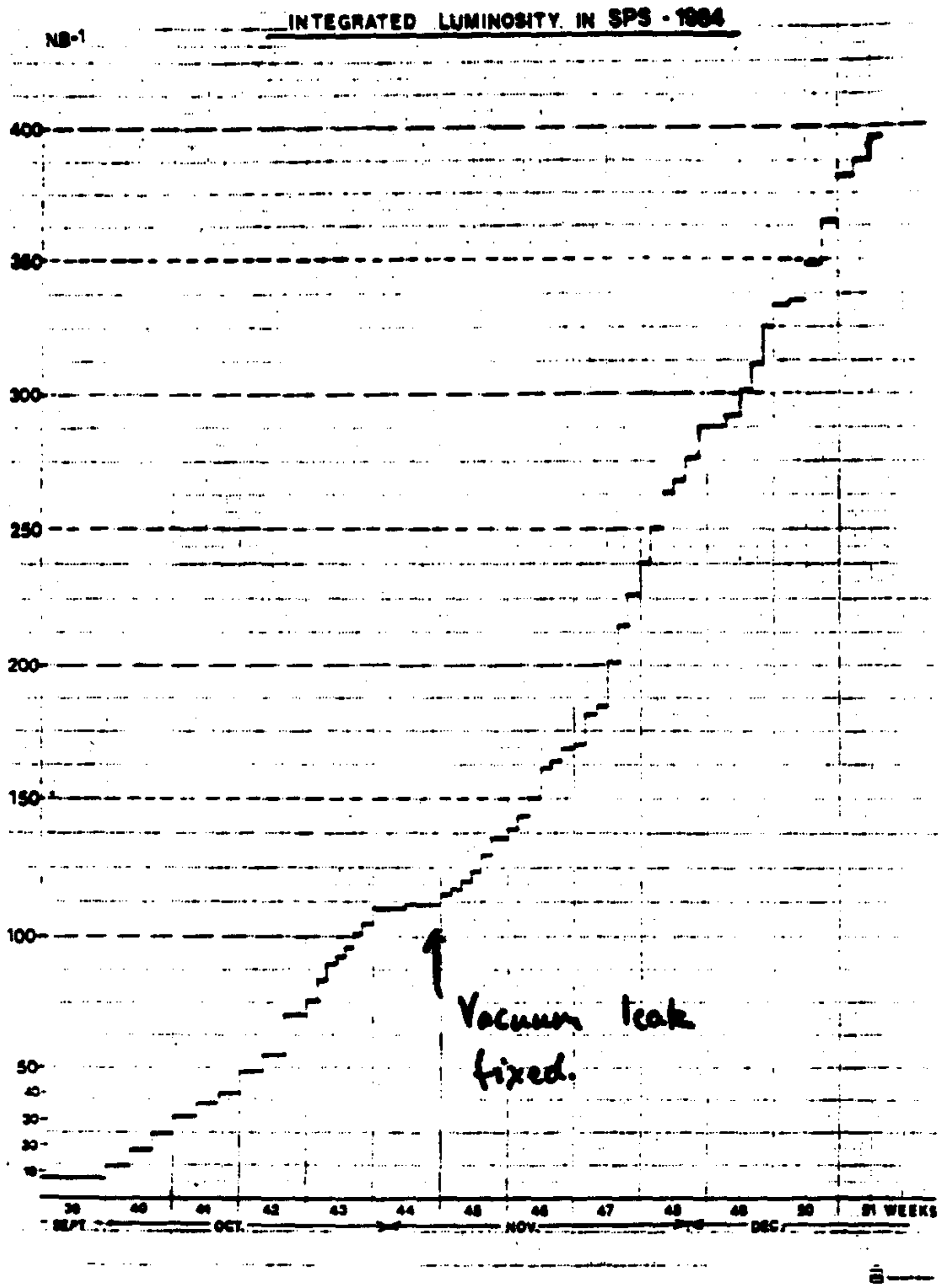


low-β squeeze.
315 GeV/c.
3 p
26 GeV/c
3 p̄
28.8 sec.
dead time
for eddy current
decay.

COLLIDER PERFORMANCE

	Design	Achieved	
AA stacking rate (10^9 h^{-1})	25	6.6	
$\bar{p}$ transfer efficiency	100%	75%	
N° of bunches/beam	6×6	3×3	
p intensity/bunch (10^{11})	1	1.4	1.6
$\bar{p}$ intensity/bunch (10^{11})	1	0.15	0.22
Normalized emittances ($\beta\gamma\pi\, 10^{-6}$ m)			
ε_H	24	18	
ε_V	12	18	
Beam-beam parameter ξ	.003	.004	
$\beta_H^* \times \beta_V^*$	2×1	1.3×.65 (1×0.5)	1×0.5
Peak luminosity (10^{29} cm^{-2}s^{-1})	10	1.6	3.6
Luminosity lifetime (h)	—	16	32

$$\frac{1}{\tau_L} = \underbrace{\frac{1}{\tau_p} + \frac{1}{\tau_{\bar{p}}}}_{\text{intensity decay}} + \underbrace{\frac{1}{\tau_{\varepsilon p}} + \frac{1}{\tau_{\varepsilon \bar{p}}}}_{\text{emittance growth}}$$



AA stack dropped 4 times
in 13 weeks

Shot 1491 analysis after 9 µF condensers added to MPS.

```
SPS COLLIDER Shot No.1491                      17 DEC 84  3:[illegible]
AA stack intensity 27.[illegible]E10.  Stored time [illegible] ( 7[illegible]
C   P+  FIRST   NOW    LIFE    | FIRST   NOW    LIFE  P-
U       E10     E10    Hrs     | E10     E10    Hrs
R   A   15.31 10.6422  75.2    | 1.96  1.6149 115.2  Z
R   B   14.99 10.1095  69.7    | 1.82  1.4059    0   Y
E   C   15.77 10.3268  68.5    | 1.83  1.4786 112.2  X
N   Tot 46.36 31.3651 123.2    | 5.62  4.5735    0   Tot
[illegible]
      [illegible] SCAN( 3:57)  pi.mm.mrad.  SYNCH LIGHT         0
E HOR 32.6 32.2 53.5  29.6 34   34.8   46.0  28.3  26.6886
E VER 38.9 30.4 38.8  25.4 22   25.4   46.2  20.5  27.6825
  E29  [illegible] [illegible] Hrs Crossing Magnet  P+Gas  P-P  P-Gas
  UA1 2.66   .9[illegible] 25.7 AZ BY CX   9997      73  3326    10
  UA4 2.53   .[illegible] 35.9 AX BZ CY      2      67  2337     8
  Mean 2.60  .910 32.8       UA6   2500  JET  11%
Integrated Luminosity(nb-1)This Year 365.470 This Shot 16.320
Comments:  ----------------------  STABLE BEAMS  ----------------
  19:10h    WE PLAN TO KEEP THIS STACK UNTIL 04:00 MONDAY
            AND REFILL WITH NEXT DENSE ABOUT 07:00 MONDAY
            THERE WILL BE NO ACCESS GIVEN IN THE INTERVAL
EA 14:30h   OPERATEUR  CRM   13 - 4191
```

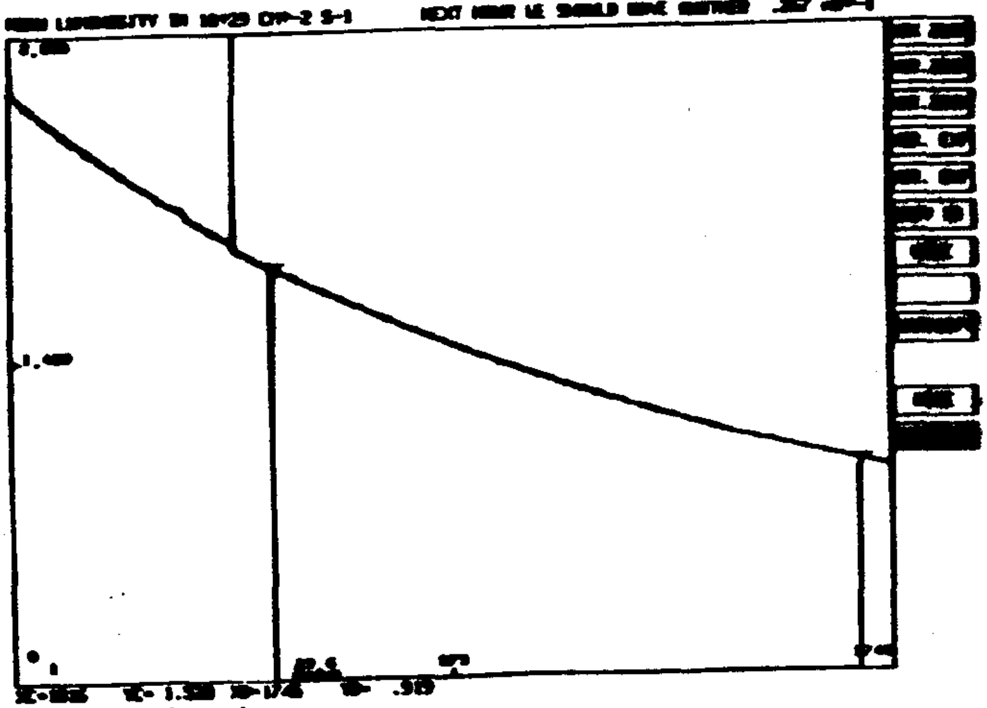
MEAN LUMINOSITY SHOT 1491

INITIAL LUMINOSITY 2.392 10**29 CM**-2 S-1

INTEGRATED LUMINOSITY 16.511 nB**-1

NEXT HOUR WE SHOULD HAVE ANOTHER .387 nB**-1

MEAN LUMINOSITY IN 10**29 CM**-2 S-1



Time in min. into count

Reliability

~ 50% of stacks killed by hand
(compare with ISR)
Mean length of store ≈ 15 hours.

- 380 kV glitches
- water
- main power supplies
- sextupole "
- low - β "
- security guards
- Fire
- Experimental magnet
- Thunderstorms
- RF - some redundancy
- Unknown.

[redacted] elements

[redacted], QD, Bend, 4 sextupoles, 30 low-β,
16 [redacted], RF, 2 spectrometer magnets,
2 [redacted] poles.

Main Power supply requirements

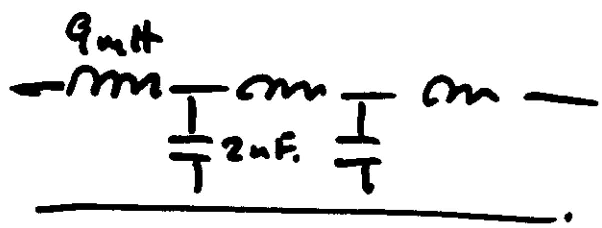
- Quadrupole ripple very bad for beam lifetime. (resonance trapping)
- $\Delta Q \simeq 0.001$ easy to see on Schottky signal
- $\frac{\Delta I}{I} < 3 \times 10^{-5}$

- Transmission line effects seem to be important.

$$f_\beta = (n - \nu)\, f_{rev}$$

First β-tron line at 13 kHz in SPS

⇒ 1 kHz in SSC.

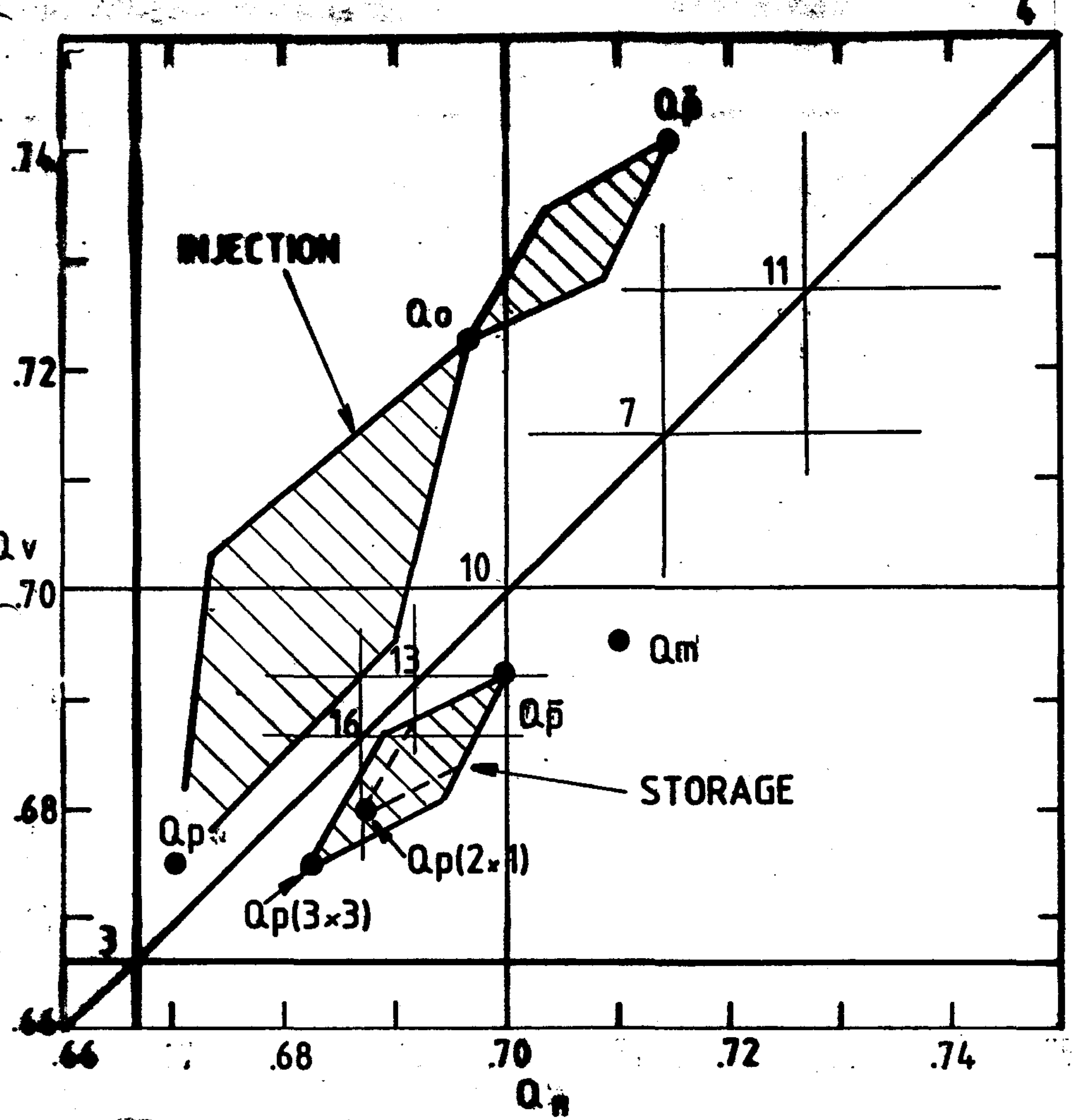


SPS cutoff ≈ 50 kHz.

Fast spikes can propagate.

Performance limitations

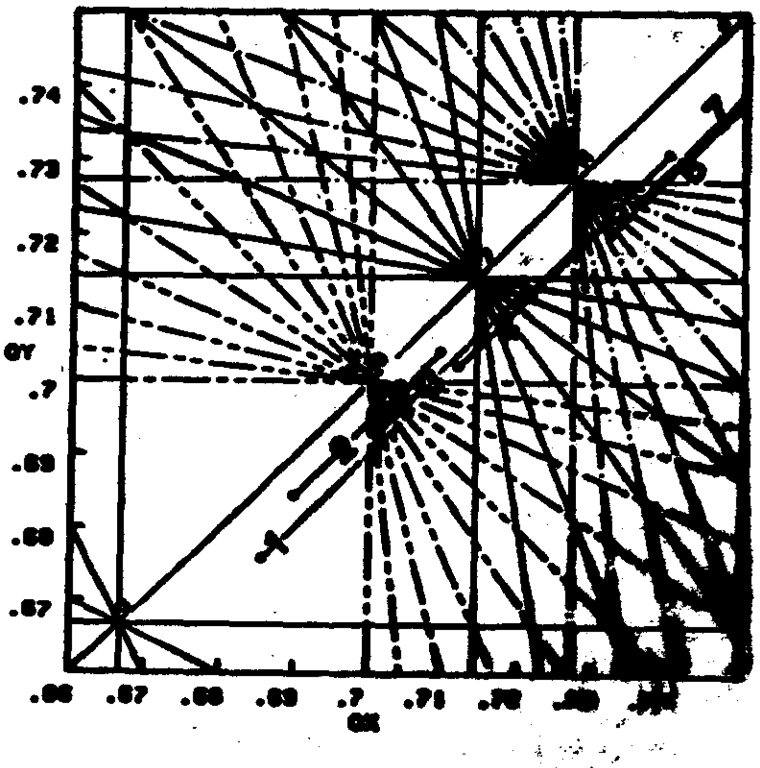
- Antiproton production.
- Beam-beam interaction
- Intrabeam scattering.



Incoherent, coherent and beam-beam tune shifts.

SPS.

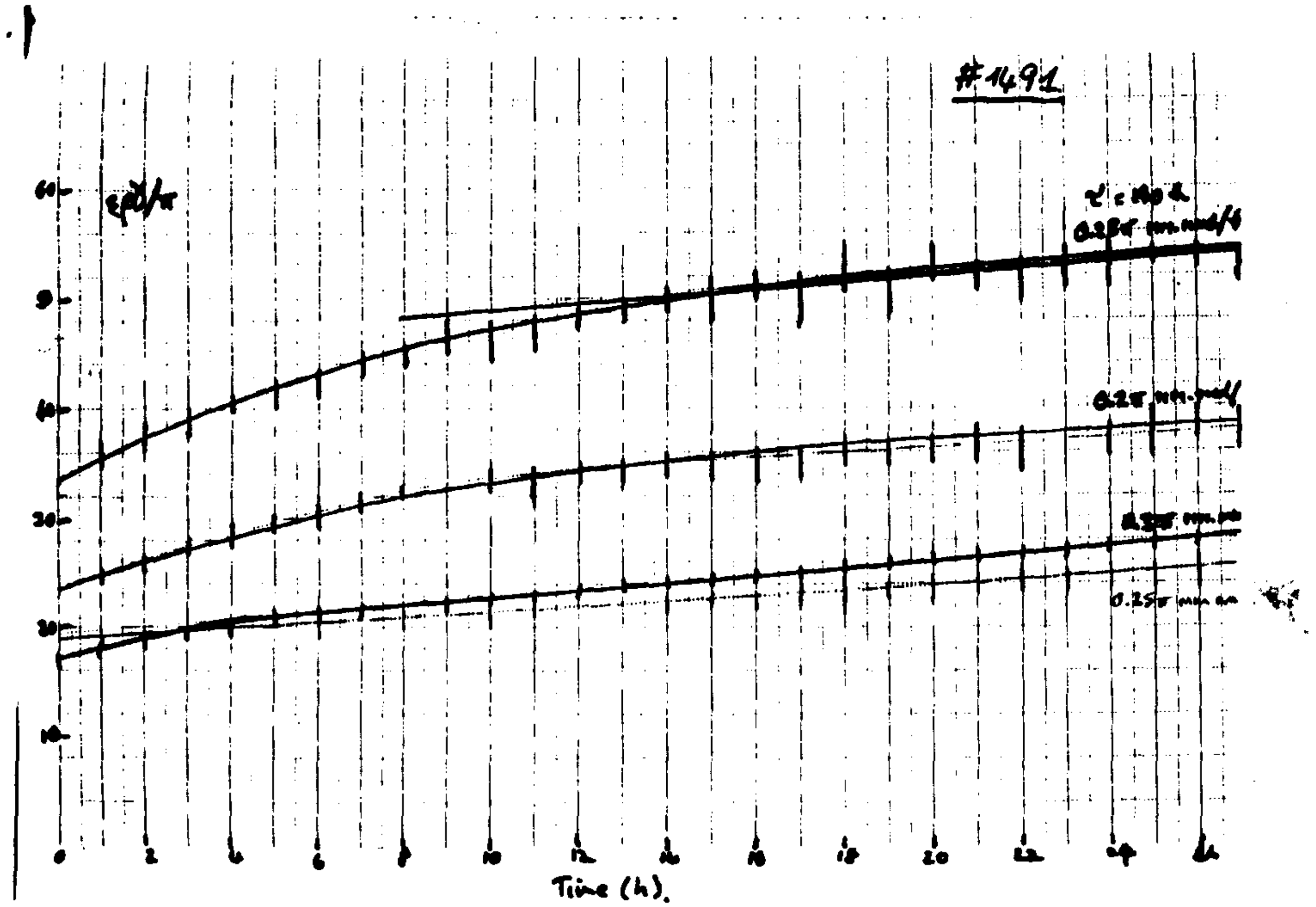
a)



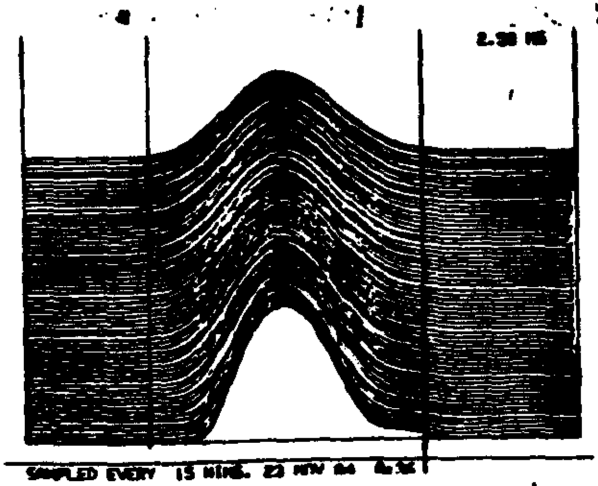
b)

Fig. [illegible]
Scan of the working diagram [illegible] the third and fourth order resonances in the SPS [illegible]

3 p vs 1 p̄ f = [illegible] per cros[illegible]

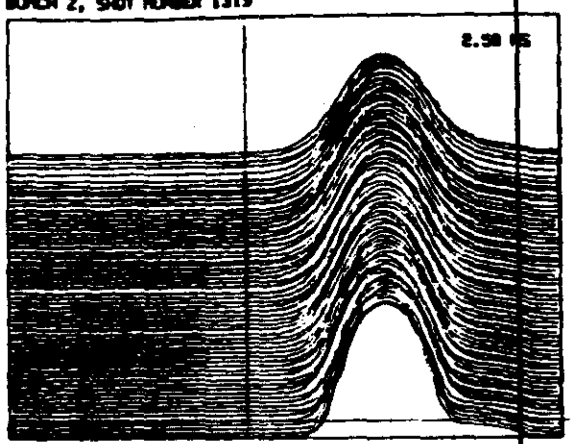


#1491
0.25 mm
0.25 mm an
Time (h).
0
2
4
6
8
10
12
14
16
18
20
22
24
26
10
20
30
40
50
60



SAMPLED EVERY 15 MINS. 23 NOV 84 8:56

BUNCH 2, SHOT NUMBER 1319



SAMPLED EVERY 15 MINS. 23 NOV 84 8:37

SPS COLLIDER Shot No.1319 23 NOV 84 8:27:19

AA stack intensity 34.040*E10. Stored time 3[illegible]h 11m (7790)

C	P+	FIRST	NOW	LIFE	FIRST	NOW	LIFE	P-	C
U		E10	E10	Hrs	E10	E10	Hrs		U
R	A	15.32	5.[illegible]	7.6	1.73	1.2140	37.5	Z	R
R	B	16.19	5.[illegible]	7.7	1.85	1.2769	37.2	Y	R
E	C	15.[illegible]	5.7[illegible]	7.3	1.91	1.2566	35.9	X	E
N	Tot	47.3[illegible]	17.[illegible]	7.7	5.50	3.7485	36.9	Tot	N
T	BCT	5[illegible]	24.[illegible]	5.4					T

WIRE SCAN [illegible] 2(16) [illegible] SYNCH LIGHT [illegible]

E HOR 50.3 50.1 49.7 29.3 30.3 29.9 26.7194

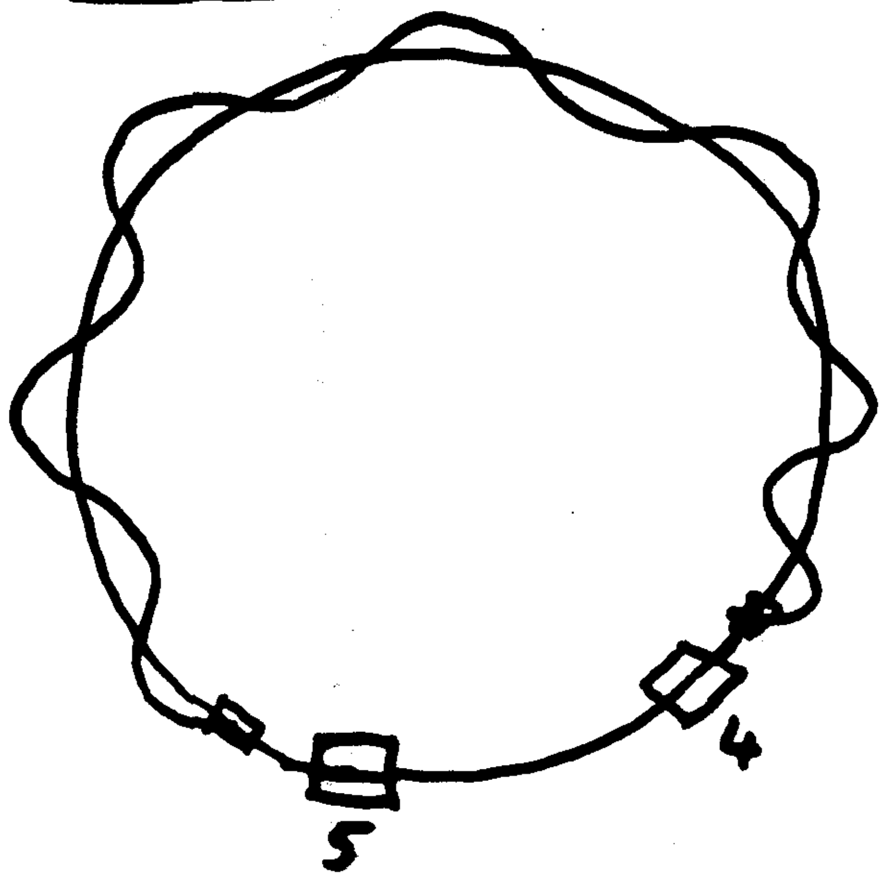
E VER 35.6 35.3 [illegible] 21.9 21.4 21.5 27.6[illegible]

[illegible]E29	[illegible]	[illegible]	Hrs	Crossing	Magnet	P+Gas	P-P	P-Gas
[illegible]UA1	3.[illegible]	.[illegible]2	1.5	AZ BY CX	9997	3231	2144	20
[illegible]UA4	3.[illegible]	.5[illegible]	3.1	AX BZ CY	-6000	79[illegible]	1453	97
[illegible]an	3.3[illegible]	.5[illegible]	2.3	UA6	1	JET	O[illegible]	

Integrated Luminosity(nb-1)This Year [illegible] This Shot17.2[illegible]

Comments

Beam Separation.



- reduce total beam-beam tune spread by separating at unwanted collision points.

ELECTROSTATIC SEPARATORS			1984-11-03-00:07:04
HORIZONTAL DEFLECTION IN BA4		HORIZONTAL DEFLECTION IN BA5	
414	416(turned)	520	522(+)
Motors status:			
dmd: 20.0 20.0	25 25	25 25	17.4 17.4
hdw: 19.9 19.9	24.9 24.9	25 24.9	17.4 17.4
Gap..: 39.9 MM	49.9 MM	50.0 MM	34.9 MM
~~Amplitude and … in I4 I5 (in sygma)~~			
Field:44.39 KV/CM	17.30 KV/CM	11.63 KV/CM	23.72 KV/CM
dmd:-20.0 -20.0	-25 -25	-25.0 -25.0	-17.4 -17.4
hdw:-20.0 -20.0	-25 -25	-25.0 -25.0	-17.5 -17.5
ZD1 HV PS	ZD2 HV PS	ZD1 HV PS	ZD2 HV PS
MAINS ON	MAINS: ON	MAINS: ON	MAINS: ON
STATUS: OK	STATUS: OK	STATUS: OK	STATUS: OK
sparks: 0	sparks 0	sparks 0	spark 0
DMD.HV:176.9KV	DMD.HV: 86.3KV	DMD.HV: 58.5KV	DMD.HV: 83.3KV
HDW.HV:177.5KV	HDW.HV: 86.3KV	HDW.HV: 58.2KV	HDW.HV: 82.9KV

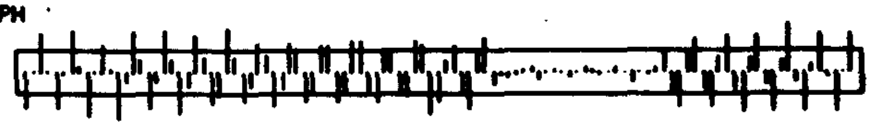
Hardware setup.

9+4 12.6V

40 414 25.5kV
50 416 26.5
50 520 25.3
55 522 26.0

FILE(290)CO:FIL 1984-11-03-00:35:02 BP010
(189)XAV0-(189)XAV9

BPH

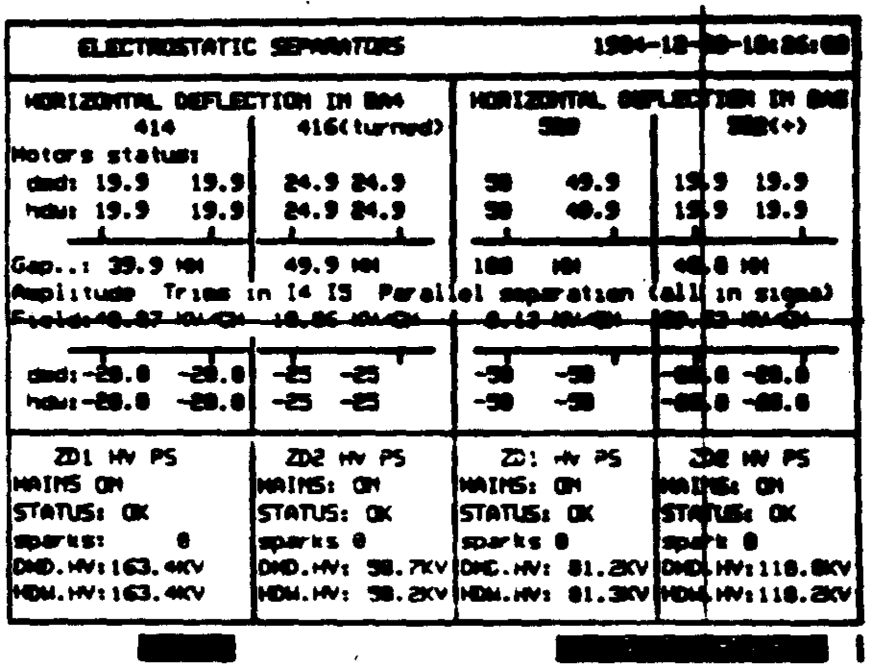


H.DIP

MEAN	SIGMA	MAX	MIN	P/US	TIME	GEV	Q
-.08	2.25	4.75	-4.22	100	-1	26.12	26.71

± 2.6 ... ...

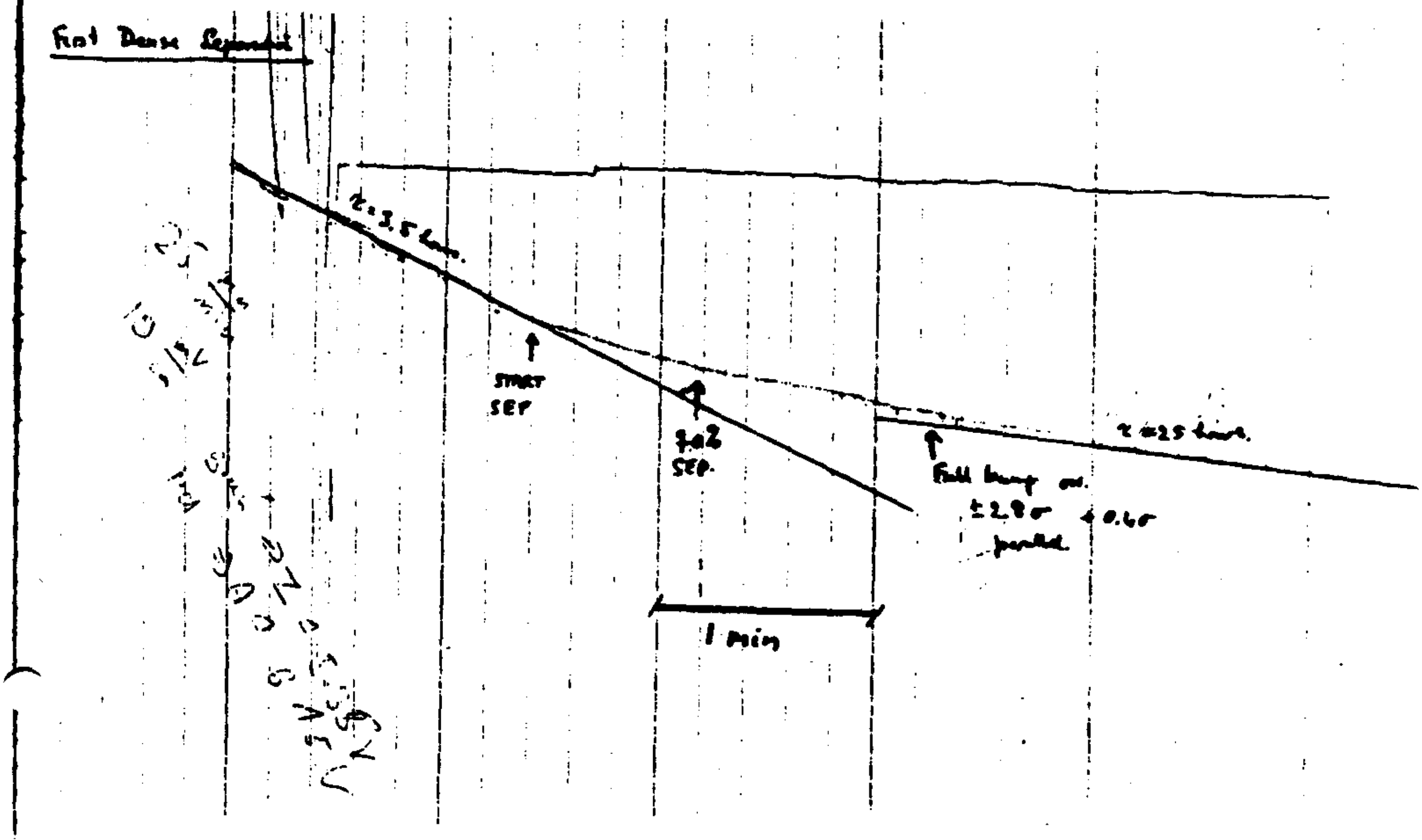
Two physics coasts with separation on
Slots 1428 and 1430.



ELECTROSTATIC SEPARATORS 1984-12-[illegible]-18:26:[illegible]

HORIZONTAL DEFLECTION IN BA4 414	416(turned)	HORIZONTAL DEFLECTION IN BA[illegible] [illegible]	[illegible](+)
Motors status:			
dwd: 19.9 19.9	24.9 24.9	50 49.9	19.9 19.9
hdw: 19.9 19.9	24.9 24.9	50 40.9	19.9 19.9
Gap..: 39.9 MM	49.9 MM	100 MM	40.0 MM
Amplitude Trims in I4 I5 Parallel separation (all in sigma)			
Field: [illegible]	[illegible]	[illegible]	[illegible]
dwd: -20.0 -20.0	-25 -25	-50 -50	-[illegible].0 -[illegible].0
hdw: -20.0 -20.0	-25 -25	-50 -50	-[illegible].0 -[illegible].0
ZD1 HV PS	ZD2 HV PS	ZD: HV PS	[illegible] HV PS
MAINS ON	MAINS: ON	MAINS: ON	MAINS: ON
STATUS: OK	STATUS: OK	STATUS: OK	STATUS: OK
sparks: 0	sparks 0	sparks 0	spark 0
DWD.HV:163.4KV	DWD.HV: 58.7KV	DWC.HV: 81.2KV	DWD.HV:118.8KV
HDW.HV:163.4KV	HDW.HV: 58.2KV	HDW.HV: 81.3KV	HDW.HV:118.2KV

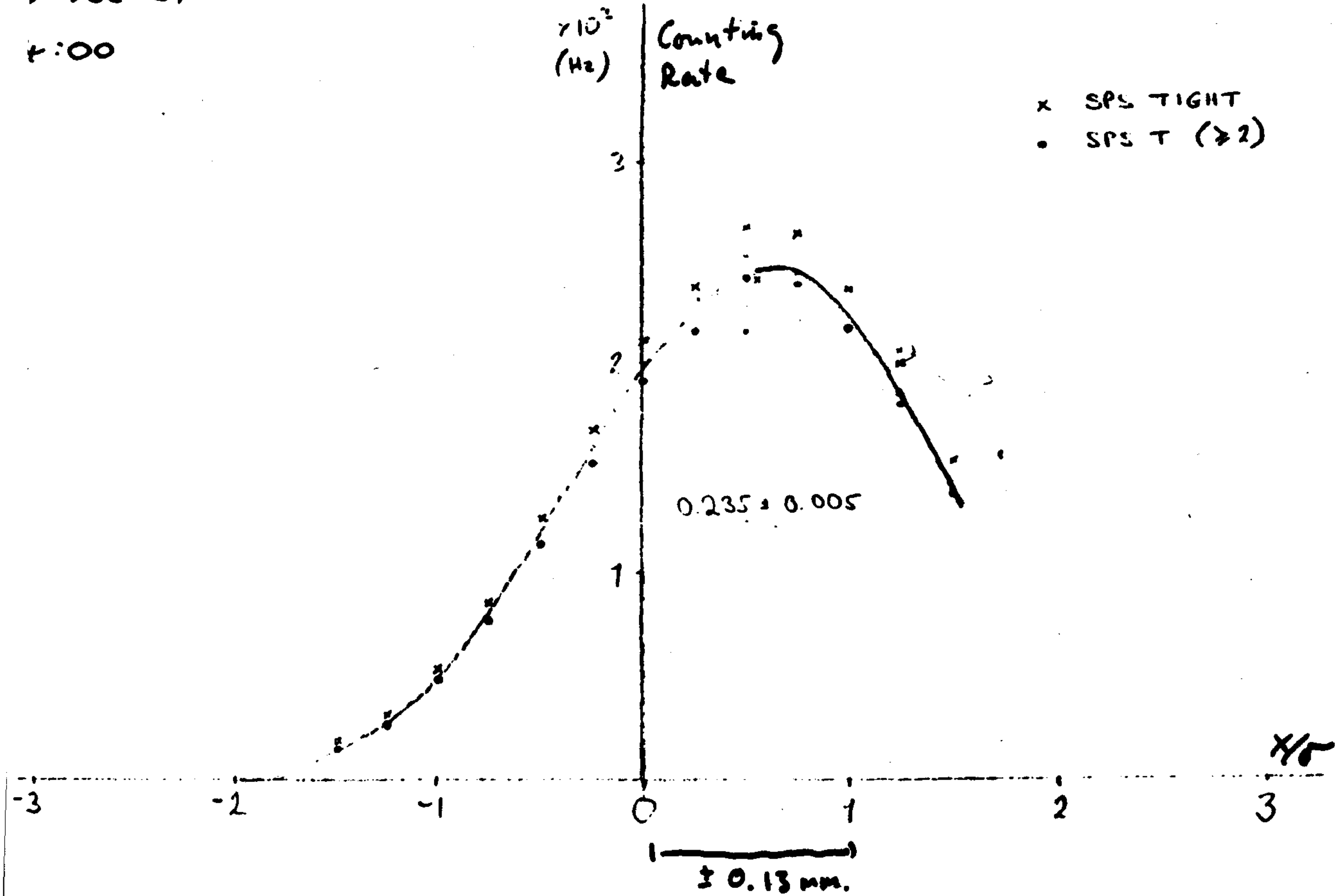
Separation 2.7 σ + 0.5 σ parallel (for 25σ beam).



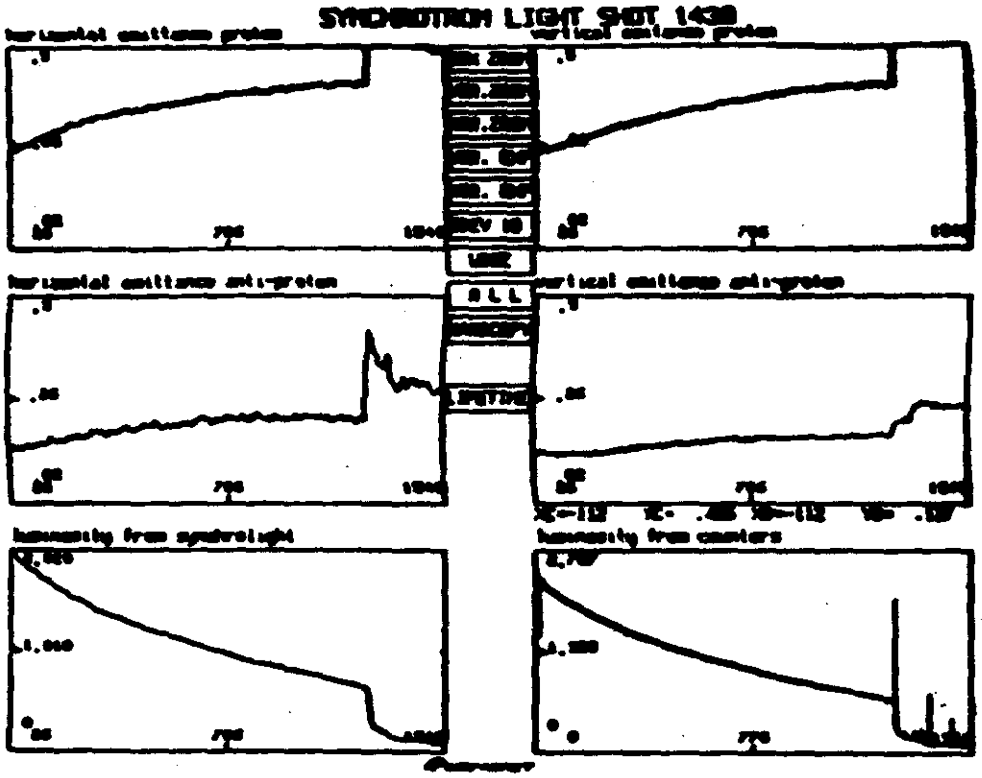
Bruiser uses the separation on the last dense shot

?-DEC-84

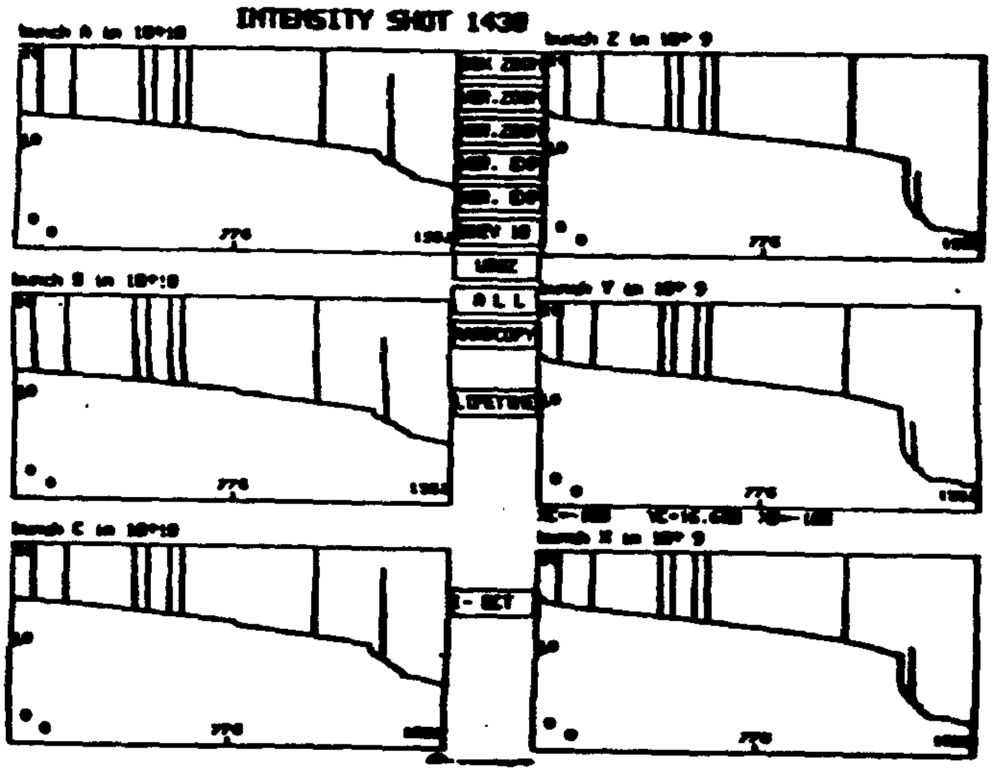
?:00



(fit) = 0.90 ± 0.001
(from VA1)



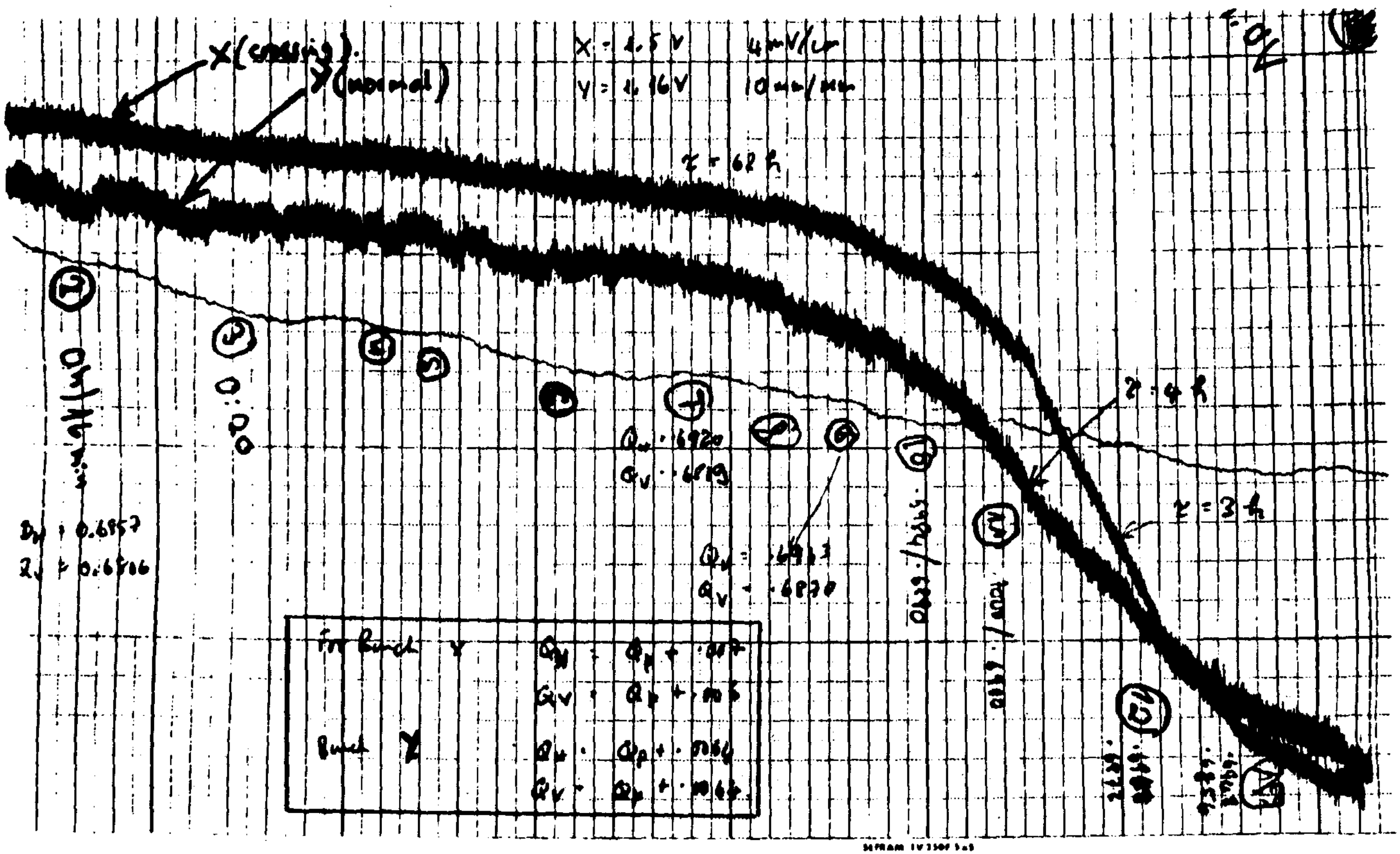
↑ Emittance blowup of all beams (predominantly radial ?) coincides with luminosity loss.



$\sigma_L = 27.5$ mm

$\sigma_R = 0.13$ mm (at center)

$\Delta = 0.16$ mm.



Crossing angle ± 0.15 mrad

EDC
1/17/85
SSC C&O Workshop
E. Courant
Talk - Thu 17 Jan

Collider Performance vs Magnetic Field

Compare rings with different B (therefore different R), same Energy

Designs A, B, D vs C

Scaling of Lattice Functions:

$\nu \sim R^{1/2}$

$\beta \sim R^{1/2}$

Cell length $L \sim R^{1/2}$

No. of cells $M \sim R^{1/2}$

Quad Foc. length $F \sim R^{1/2}$

$\gamma_{tr} \sim R^{1/2}$

Dispersion fn $\eta_p \sim R^0$

Aperture requirements:

Betatron oscillations $\sim \beta^{\frac{1}{2}} \sim R^{1/4}$

Synchr. " $\sim \frac{\delta p}{p} \cdot \eta \sim R^{0}$

Orbit errors:

Orbit error due to error in one element:

$\Delta x \sim \beta \Delta\vartheta$ ← deflection due to element error.

Total orbit error $\Delta x_{tot} \sim M^{\frac{1}{2}} \Delta x = M^{\frac{1}{2}} \beta \Delta\vartheta$

$\Delta\vartheta$ due to: Quad misalignment δx: $\Delta\vartheta = \frac{\delta x}{F} \sim R^{-\frac{1}{2}} \delta x$

Mag field error δB: $\Delta\vartheta = \frac{\delta B \cdot L}{B\rho} \sim \frac{R^{\frac{1}{2}}}{R} \frac{\delta B}{B} = R^{-\frac{1}{2}} \frac{\delta B}{B}$

Magnet tilt angle $\delta\vartheta$:
$B_x = B_0 \,\delta\vartheta$; $\Delta\vartheta_y = \frac{B_x \cdot L}{B\rho} = \frac{L B_0 \,\delta\vartheta}{B\rho} \sim R^{-\frac{1}{2}} \delta\vartheta$

Thus: Total orbit error $\Delta x_t \sim M^{\frac{1}{2}} \beta \Delta\vartheta$

scales with $R^{\frac{1}{4}} R^{\frac{1}{2}} R^{-\frac{1}{2}} = R^{\frac{1}{4}}$

for all three error types.

Orbit errors are corrected out; this says correctors have to work harder prop. to $R^{1/4}$. Residual errors in Δx also probably scale $\sim R^{1/4}$?

LUMINOSITY

$$L \sim \frac{N^2 f}{4\pi \sigma_x \sigma_y \sqrt{1 + (\alpha \sigma_z / 2\sigma_x)^2}}$$

(N: p/bunch; f ← Bunch frequency; α: cr. angle)

$\sigma_x \sigma_y \sim \beta^* \epsilon_0 / \gamma$ ϵ_0 = invariant emittance.

Same bunch structure same in rings of different R, i.e. N, bunch spacing, f the same. ~~tends~~ 3 tends to scale as $R^{1/2}$. But lattices can be devised so as to keep β^* unchanged, provided "low-B" ring still has the same ~~high~~ high-gradient quadrupoles as high-B ring:

Maintain $\beta^* = 1$ m

Instabilities

Consider quasi-coasting model, valid for modes n corresponding to wavelengths $\lesssim \sigma_s$

$$n \geq R/\sigma_s$$

Longitudinal:

$$e\hat{I}\, Z_\parallel/n \lesssim F \cdot \eta \cdot \delta^2 \cdot \gamma m c^2$$

(arrows: F ← Fudge factor; η ← $\frac{1}{\gamma_t^2}$; δ ← $(\delta p/p)$)

$$\hat{I} = I_0 \cdot \frac{S_b}{\sqrt{2\pi}\,\sigma_s} \leftarrow \text{Bunch spacing}$$

Assume: Bunch parameters independent of R;

Scaling gives $\eta \sim \frac{1}{R}$:

Threshold $\frac{Z_\parallel}{n} \sim R^{-1}$

Transverse:

$$e \hat{I} Z_\perp \sim F \frac{\gamma m c^2}{\beta_\gamma} \cdot n \cdot \eta \cdot \delta$$

$\hat{I}$ invariant

$\beta_\gamma \sim R^{1/2}$

$n \sim R$

$\eta \sim R^{-1}$:

$$\left(Z_\perp\right)_{thr} \sim R^{-1/2}$$

Scaling relation between $Z_\perp$ and $Z_\parallel$:

$$Z_\perp \sim \frac{2R}{b^2} Z_\parallel / n$$

$$\left(\frac{Z_\parallel}{n}\right) \sim \frac{b^2}{2R} Z_\perp \sim \frac{b^2}{R^{3/2}}$$

Synchrotron Radiation

U = energy loss/unit distance $\sim B^2\gamma^2 \sim \gamma^4/R^2$

Total power $P \sim 2\pi R \cdot I \cdot U \sim \gamma^4/R$

Finally something that gets *better* with large R!

SUMMARY:

Betatron oscillations $\sim R^{1/4}$

Synchr. oscill. $\sim R^{0}$

Closed orbit errors (residual) $\sim R^{1/4}$

$Z_{\parallel}/n$ threshold, long. instability $\sim R^{-1}$

$Z_{\perp}/n$ ", transverse " $\sim R^{-3/2}$

synch radiation loss, per m $\sim R^{-2}$

power $\sim R^{-1}$.

Conclusion: Everything (almost) is harder at larger radius, but R dependence fairly weak (except transverse instability).

Friday Morning 18 Jan 1985

SUMMARY TALKS

SSC C&O Workshop
Cryogenic Group Summary
W. Fowler, Fri. 18 Jan 85

Cryogenics

People:		
	W. Fowler	FNAL
	D. Brown	BNL
	C. Rode	FNAL
	P. VanderArend	CCI
	J. Van Sloan	Air Products
	D. Wolgast	LBL
	R. Byrns	LBL

Cryo Talks

<u>Mon</u> P. Vander Arend
Cryogenic Problems of SSC MAGNETS

<u>Tues</u> C. Rode
SSC MAGNET CRYOGENIC
COMPARISONS
Design A, B, C + D
Impact of common failures

<u>Wed</u> 1. J. Van Sloan
Commercial Plants
Startup and Operational Problems

2. D. Brown
Cryogenic System Performance
Assumptions - Lower Temp. Op.

Cryogenics News Report
Bill Fowler Wed 16 Jan 85

Cryogenic Questions

C-1 • **Large Scale Cooldowns**
Time, cost, how often?

C-2 • **Magnet Replacement**
Time required, beam valves, how is it done, how often?

C-3 • **Steady State Operation**
Removing heat from synchrotron radiation and ramping.

C-4 • **Two Phase Flow**
Is it stable?

C-5 • **One Phase Flow**
What do the recoolers look like?

C-6 • **Quench Recovery**
Two-in-one implications.

C-7 • **Separate Cryogenics**
Should one-in-one magnets have separate cryostats?

1/11/85

Cryo Group Work List

F 1. Review heat leaks, weights etc.

F 2. Cool Down

F 3. Magnet Replacement

F 4. flow areas — flow rates

Conduction cooling and/or porosity of coil package

F 5. Quench recovery

F 6. Magnet Shields, Type (air, LN, He) flow and σ area required.

F 7. Mobil Refrigerators for cool-down & magnet replacement.

1/16/85

Cryo Group Work List

Item	Subject	Responsible Person	Due
F1 & F4	Review heat leaks, weights etc flo areas - flo rates	WBF	end of workshop
L1/F2	Large Scale Cooldown	CR	MAR 1
L1a	Large Industrial Plants	J VanS	MAR 1
L2/F3	Magnet Replacement	PVandA	Apr 1
L3	Steady State Operation	PVandA	1st Draft Complete Review + 2nd Draft MAR
L4	Discarded		
L5	Recoolers	DB	MAR 15
L6/F5	Quench Recovery	CR	MAR 15
L7	Separate Cryogenics	DB+DW	MAR 1
F6	MAGNET Shields	DB	MAR 1
F7	Mobil Refrigerators	R.B	Mar 1

Thursday Morning 17 Jan 1985

NEWS REPORTS

SSC : C&O Workshop "Ways Confer."
Bill Fowler 1/17/85

MAGNET CRYOGENIC FEATURES

#	DESCRIPTION		IMPORTANCE	A	D	B	C
1	~~Required~~ Maximum Operating Temperature	(Merit: 10 = 4.[illegible] 5 = 4.[illegible] 0 = 4.[illegible])	10				
2	~~Required~~ allowable Δ T	Stability	8				
		Half Cell	2				
		Sector	8				
3	Magnet Mass	a) Heat Leak b) Cooldown c) Warm-up	8				
4	Pressure Drop		10				
5	Helium Inventory		5				
6	Design Pressure		8				
7	Space for Recooler		7				
8	Piping (Distribution)		8				
9	Heat Shield at 80K and 10K - 20K		8				
10	Magnet Stiffness ~~of Supports~~	Bowing during cooldown	5				
11	Quench Recovery Time	(Merit: 10 - ¼ hr. 5 = ½ hr. 0 = 1 hr.)	5				
12	Ring Length		5				
13	Magnet Replacement	Merit / DAYS: (2 / 10, 4 / 5, 6 / 0)	8				
14	Studies in "Good Ring" during may warm-up & cool-down in other ring.						

Importance

10	exceptionally well
5	possible
0	not at all

SSC C&O Workshop. "Morning News" 01/17/85 – J. Bryant

Summary (Tentative)

Magnet Type	Particle Physics Capability	Accelerator Physics Capability	Special Requirements	Disadvantages
[illegible] 1	All posibilities p-p, p-$\bar{p}$, heavy ions, asymmetric energies	Best for commissioning and accelerator R and D while one ring is down or rings have asymmetric energies	This flexibility is reduced if IR's cannot be decoupled	- Higher cost for plant - More maintenance and repair? - Longer installation?
Dual (non-mag. coupled)	Same as above	Accelerator R and D is stopped if magnet is replaced or cryostat has fault.	Adequate separation needed to ensure coupling is at a trivial level. Correctors must be fully decoupled	- If one magnet quenches both rings will stop either by a quench or abort being forced. - Change of separation in long straights
2 in 1 dual fully coupled.	No p-$\bar{p}$ No asymmetric energies	Least flexible. Must commission rings together.	Needs a more flexible corrector system or more highly engineered magnet for int-ring alignment.	- Same as above - Harder to decouple correctors - Guaranteed higher energy [illegible]!!

SSC CDO Workshop - Morning News
Christoph Leemann Thu 17 Jan 85

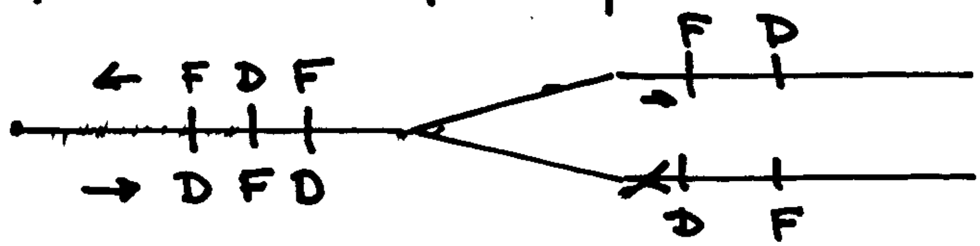
Activities of 1/17/85

- 2:45 to 3:45 (?) talk by Lyn Evans
- following ↑ (or possibly already beginning after lunch) group discussion on proposed report layout/outline
- otherwise individual work

Results of Yesterday's Work

Lattice discussion with A. Garren

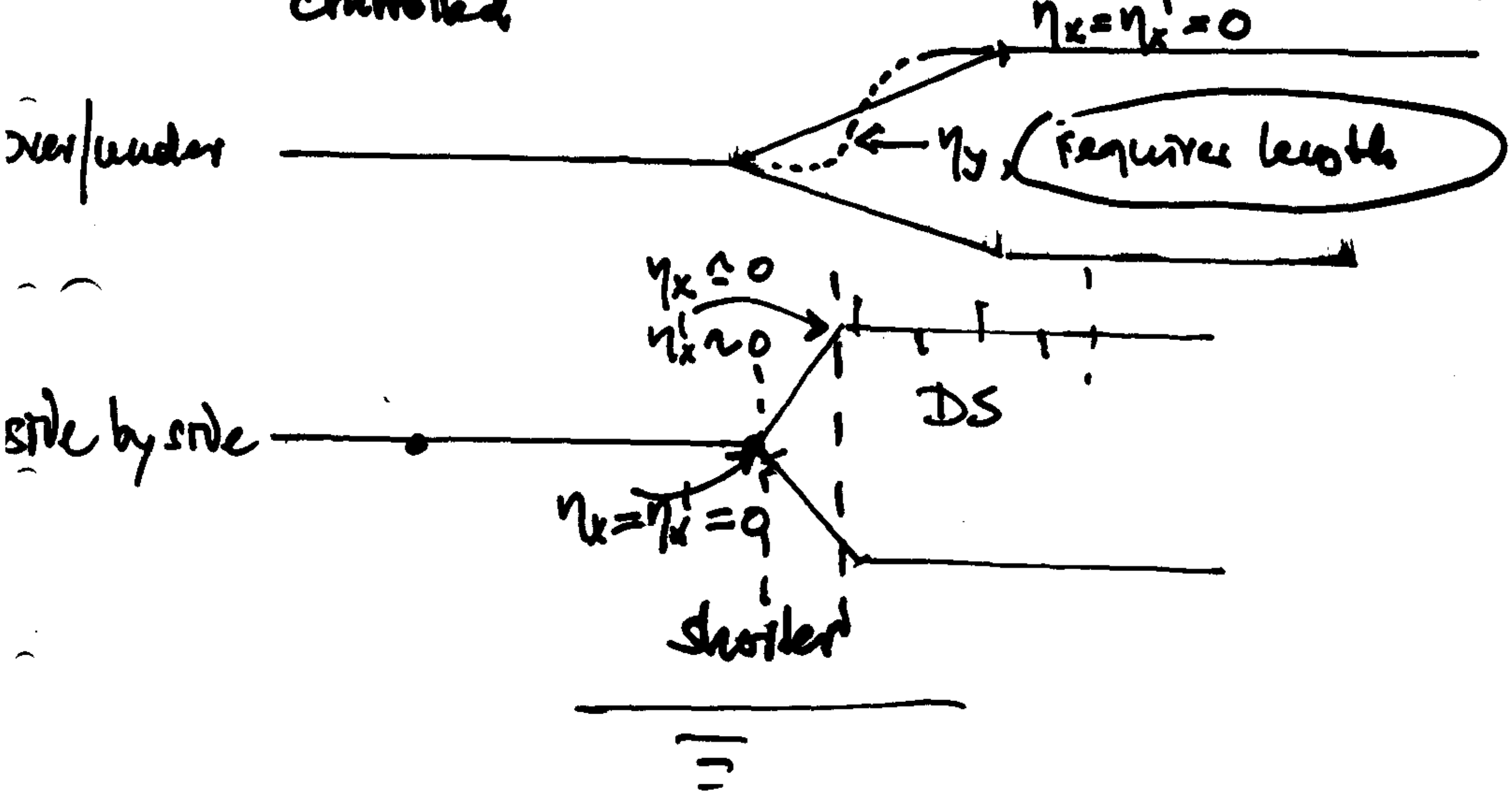
o Any optics constraints from 2 in 1 ?
  - not really; strongest constraints come from shared quadrupoles



o Discussion of "uncoupled" IR design
  - incentives strongly diminished
  - injection lifetime arguments not very powerful
  - If required: proof by doing it!

o Discussion of (possibly) larger beam separation and under/over vs side by side in 1:1

- no real problems here
- study (existing) designs
- of main interest: how is dispersion at IP controlled



o Comment on FQ, correction element discussion

SSC C&O Workshop Morning News Report
Don Hartill - Thu 17 Jan 1985

Systems

No Talks Today

Discussion Today

1. RF

2. Beam Stabilization

3. Controls

4. Failure Modes

Activities Yesterday

Power Supply

i. Dick Cassel's Talk

a. 12 vs 1 regulator

$\Delta v \simeq .002 \Rightarrow \frac{\Delta I}{I} \simeq 10^{-5}$

b. 3T with independent Dipole + Quad circuits
$\Rightarrow$ both must track to
$\frac{\Delta I}{I} \simeq 10^{-5}$ even during ramping

c. Fe vs no Fe implications for injection conditions after quench

d. Sensitivity to trim power supply trips

Homework Assignments

Quench Protection	<u>KK</u>, GT, JZ	Mar. 1
PS Regulation	<u>RC</u>, JZ	Mar. 1
PS Trans. Line Eff.	<u>RC</u>, GT	Mar. 1
Power Levels	<u>RC</u>, GT	Mar. 1
Correction Elements	<u>GT</u>, KK	Mar. 15
Fe vs No Fe Inj. Implications	<u>DH</u>	Mar. 1
Vacuum	<u>DH</u>	Feb 15
Beam Diagnostics	<u>DB</u>	Feb 24

CRYOGENIC SYSTEM PERFORMANCE ASSUMPTIONS

- 4.5°K MAX. MAGNET OPER. TEMP.
- CRYOGENIC LOOP $\Delta T = 0.2°K$
- 2 WEEK COOLDOWN IS O.K.
- 5 DAY NOM. MAGNET REPLACE. TIME IS O.K. – SHORTER IS BETTER
- 10 "EVENTS" PER YEAR → 75 $\frac{\text{DAYS DOWN}}{\text{YEAR}}$
- SCHEDULED MAINTENANCE = 10%, CAN OVERLAP WITH OTHER ACCEL. MAINTENANCE
- COOLDOWN MASS $(1\text{-}\overset{D}{\text{IN}}\text{-}1)/(2\text{-}\overset{A}{\text{IN}}\text{-}1) = 1.3$

DPB
1/16/85

MAGNET COMPARISON

	A	D	B	C
MAGNET				
Field (T)	6 1/2	6	5	3
Cold Mass (MJ)	5.10^6	6.10^6	$2.4\ 10^6$	$3.3\ 10^6$
Cold Mass/Ref (MJ)	420.10^3	500.10^3	200.10^3	140.10^3
Cold Mass/Section (MJ)	35.10^3	20.10^3	12.10^3	33.10^3
Section (M)	600	600	1070	150.
Section/Ref	12	24	16	42
MAGNET COOLING				
Type	Orifice Flow	Direct + Cond.	Direct	Conduction
Main Flow	Two 2" holes	? Ring Between iron & collar	Bore + 8 wedges	Two 4" high D's
Pressure (atm)	4	4	4	2
Flow (g/sec)	2 x 140	? 4 x 100	4 x 50	2 x 56
Temp. Gradient (^{0}K)	~ .05	.04 alum/.07 SS	.03	.07
Subcooler Spacing (M)	200	200	107	300
Subcooler	Dewar	Dewar	20 exch.	Dewar
Shields	80^0	80^0+10^0	80^0+10^0	80^0+10^0

WORKSHOP ON COMMISSIONING AND OPERATION OF THE SSC

II. RESULT OF WORKSHOP SHOULD BE:

- TO DETERMINE THE IMPORTANCE OF VARIOUS MAGNET FEATURES TO THE EFFICIENT OPERATION AND/OR COMMISSIONING OF THE MACHINE. GRADED FROM 0 TO 10, SUCH THAT:

  0 = IRRELEVANT
  5 = IMPORTANT
  10 = CRUCIAL

- TO DETERMINE HOW WELL A MACHINE BUILT WITH A PARTICULAR MAGNET TYPE ACCOMMODATES THOSE FEATURES. GRADED FROM 0 TO 10, SUCH THAT:

  0 = NOT AT ALL
  5 = POSSIBLE
  10 = EXCEPTIONALLY WELL

- TO ASSIGN AND SCHEDULE COMPLETION OF THE WORK BY APRIL 1, 1985.

9 1/19/85

MAGNET CRYOGENIC FEATURES

	DESCRIPTION	IMPORTANCE	A	D	B	C
	~~Required~~ Maximum Operating Temperature (10 - 4.7K, 5 - 4.5K, 0 - 4.3K)	10	5	5	5	5
	Allowable ~~Required~~ ΔT Stability	8	5	5	5	5
	Half Cell	2	5	5	5	5
	Sector	8	5	5	5	5
	Magnet Mass a) Heat Leak b) Cooldown c) Warm-up	8	6	5.4	6.2	5.8
	Pressure Drop	10	6.8	6.8	6.8	7.0
	Helium Inventory	5	6.6	5.2	6.0	7.0
	Design Pressure	8	5.6	6.0	6.0	4.8
7	Space for Recooler	7	6.2	4.6	4.8	6.4
8	Piping (Distribution)	8	5.6	5.8	6.2	6.8
9	Heat Shield at 80K and 10K - 20K	8	4.6	6.6	6.6	7.0
10	Magnet Stiffness ~~of~~ + Supports	5	7.8	6.2	2.6	5.0
11	Quench Recovery Time (10 - ¼ hr., 5 - ½ hr., 0 - 1 hr.)	5	5.0	6.6	7.2	5.6
12	Ring Length	5	7.0	7.0	6.4	4.2
13	Magnet Replacement	8	5.6	5.8	6.8	4.8
14	Studies in one ring while warm-up + cooldown in other	5.7	0	10	10	0

Importance
10 Crucial
5 important
0 irrelevant

Merit
10 exceptional
5 Possible
0 not at all

SSC C80 Workshop
Design Group Summary
Christof Leeman 18 Jan 85

"Design Group"

A. Chao
E. Courant
[D. Edwards]
E. Fisk
{A. Garren}
A. Hofmann
Ch. Leemann
S. Peggs
J. Peterson

o **Nature of questions/problems for this group:**

- "Are there magnet characteristics that drive certain design features with operational impact?"

  or

- "Are there design features (with operational importance) that demand certain magnet properties?"

o Key questions/decisions with respect to magnets:

  - High field vs. low field
  - degree of magnet to magnet coupling (simplified: 2 in 1 vs 1:1)

o Comments:

  - For this group "beam gymnastics" aspects of operation were of prime interest
  - There are significant but not magnet related beam dynamics/operations issues unsolved. Some may impede discussion of magnet related ones (eg. long range bb)

Design Questions

- **Magnet Selection**

  Is it desirable? What are the two-in-one implications?

- **Fractional Testing**

  During commissioning, how many magnets will have to be changed?

- **Field Level**

  What is the difference between very large and ultra large rings?

- **Optics Restrictions**

  How do they depend on magnet type? How important are they?

- **Beam Crossing**

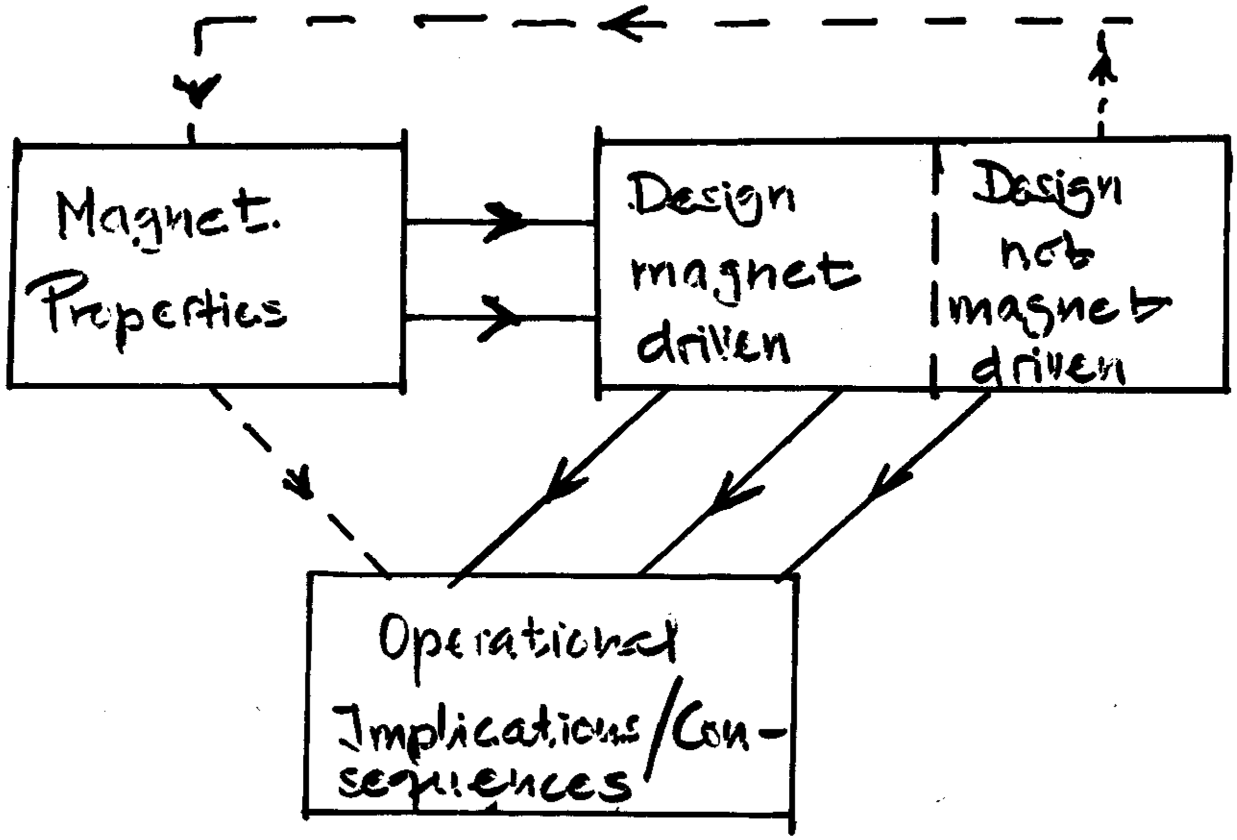
  Problems related to magnet type.

- **Correction Elements**

  Problems related to magnet type. What level of redundancy?

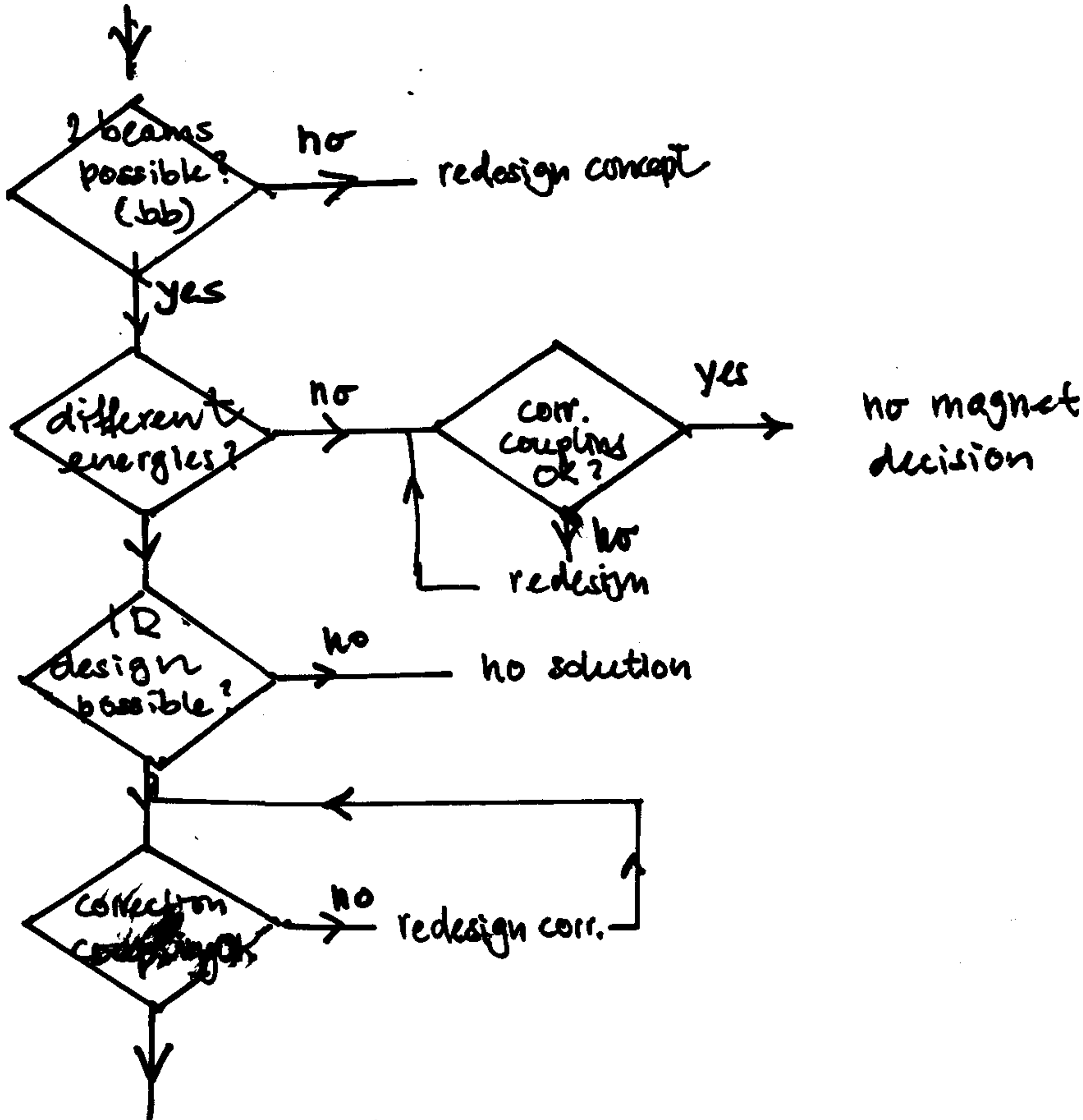
"Design Group"; a Proposed Structure to Organize Thoughts

1)



2)

Misc. Issues that do not fit strait jacket (!)



linl magnet, any field level, any bore arrangement

Apparent key issues:

- long range bb O.K.?
- how desirable/necessary are different energies?
- design of correction elements

1. Magnet Description

1.1 "Gross" features/properties

1.1.1 Field level
1.1.2 Superferric vs. conductor dominated
1.1.3 Geometry: aperture, length, 2 in 1, 1 in 1 etc
1.1.4 stored energy; other electrical properties

1.2 Field Quality Related {DAF statement?}

1.2.1 systematic multipoles
1.2.2 persistent current effects
1.2.3 random errors
1.2.4 Filament size, other conductor properties
1.2.5 Description of in situ correctors

1.3 Fabrication/Installation Related

1.3.1 % cold tested
1.3.2 magnet selection & placement
1.3.3 Alignment/tolerances

2. Design

2.1 Magnet Type Driven

2.1.1 Consequences of field [illegible]

2.1.2 Correction strategies: types, placement, excitation etc of correctors

2.1.3 Impact on IR design / collision maintenance

2.1.4 Coupling between rings: concise description, rel. importance of magnet type

2.1.4 Any other magnet derived optics constraints

2.2 Not (or only weakly) Magnet Driven

2.2.1 Chromaticity correction scheme

2.2.2 PS- regulation / arrangement requirements

2.2.3 Lattice periodicity / symmetry / clustering of IR's, injection/abort / rf

3. Operational Implications

3.1 Impact on commissioning:

3.1.1 1st turn
3.1.2 initial c.o.
3.1.3 final c.o.
3.1.4 accel 1 to 2.0 TeV

3.2 Impact on Availability

3.2.1 general redundancy considerations
3.2.2 analyze typical cycle / exp. time vs. total cycle time

3.3 Analyze importance of Field Quality in present context

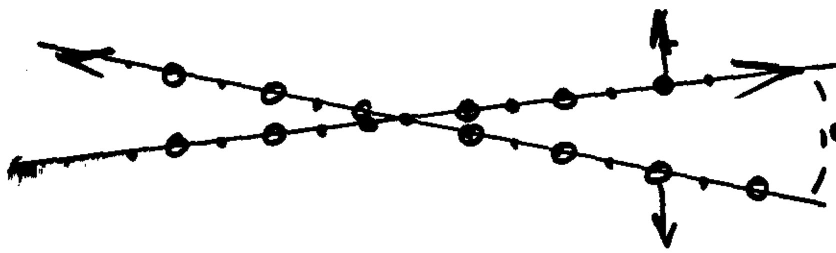
3.4 Independent Manipulations of Beams

3.4.1 Importance / Merits
3.4.2 Design Requirements

Tentative & preliminary conclusions

- Within the present performance specifications for the SSC no significant and compelling arguments for or against any particular proposed magnet can be made.
- Scenarios can be constructed that favor particular solutions (and rule out others); the need for SSC operations to follow such scenarios is not sufficiently documented
- Following examples from our work illustrate this:
  - arguments with respect to beam coupling
  - considerations of lattice constraints, issues
  - general consequences of B field level
  - field quality considerations [not yet exhaustively discussed!]

- long range beam beam interaction, concerns:
  - leads to additional tuneshifts
  - leads to closed orbit distortions
  - is an intrinsic property of SSC IR arrangement



  - during injection effects most severe and different for different bunches
  - beam separation at injection?

- Might be a "non problem" but definitive answer needed
  - qualitative arguments during RDS
  - workshop results by S. Peggs
    ($\sim 1/10$ mm c.o. distortions, $\sim .02\ \Delta Q$, without specific measures; $\propto 1/\beta^*$ favors moderate β^* at injection)

"Why would anyone want different beam energies in the two rings?"

The following arguments have been advanced:

- o (α) Assume one beam lost during collider operation (or at any other point except injection); reload only one beam! (Speculation: it is easy and saves time)

- o (β) Assume injection lifetime is marginal; the capability to accelerate the 1st injected beam to 5 TeV (e.g.) will help.

Possible answers:

for (α):
(i) Decel to 1 TeV
(ii) Decel to ~5 TeV
(iii) ~~Decel to~~ stay at 20 TeV } inject at 1 TeV

for (β) obvious

o Almost definitive results:

- (α) is not a good idea (it's difficult and does not save much time),
  (β) might well be but needs further thought!

o Difficulties of (α) include:
  - rf implications
  - might not be possible with any magnet: hysteresis, required response of correction elements
  - does not save much time (see John Poole)
  - surviving beam has substantially altered properties after some hours of operation

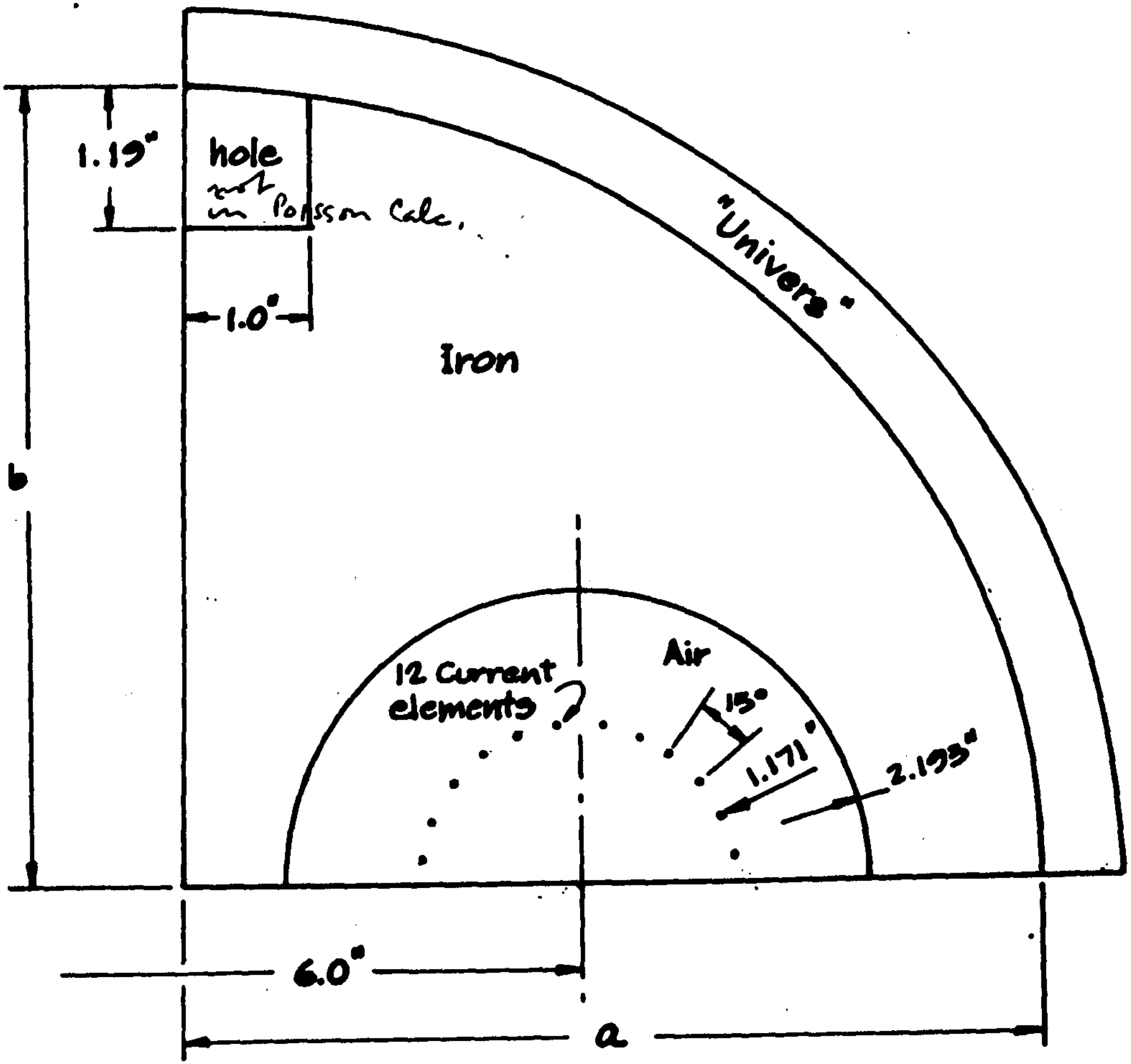
o Solution of (β) requires careful analysis of injection lifetime (difficult; does it imply more stringent criteria for 2 in 1 magnet?)

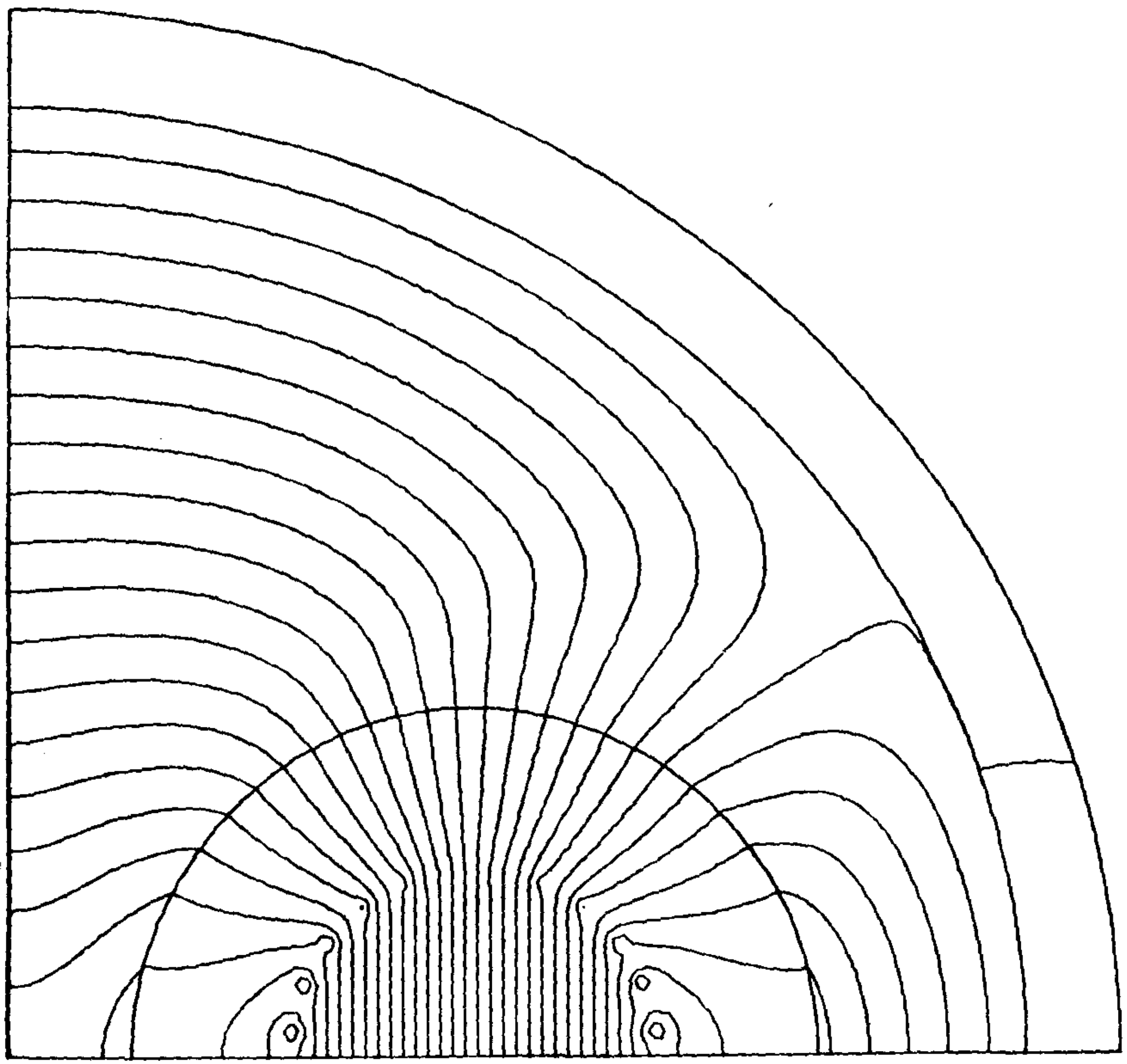
o For implementation:
  - 1 in 1 required
  - 2 Energy IR needed: ⟹ existence proof by design

- Correction elements: a key issue but possibly a "non problem"
  - no coupling (cross talk) at beam level tolerable? (what does "no" mean?)
  - hardware / software? (The conservative answer is obvious!)
  - could be an argument against 2 in 1 (but probably is not!)

- Relevant calculations to date:
  - A. Chao, A. Hofmann (this workshop)
    - iron-free dipole corrector
    - 4 Tm (max rating RDS)
    - coil ID 5cm; separation 50 cm (1 in 1), 15 cm (2 in 1)
    - calc coupling dipole, quad, sextupole
    - $X_{c,0} = 7 \cdot 10^{-5}$ m vs $8 \cdot 10^{-4}$ m
    - $\Delta Q = 1.4 \cdot 10^{-5}$ vs $5 \cdot 10^{-4}$

  - Computer modelling: S. Caspi (LBL)


"Univers"
Iron
hole
not in Poisson Calc.
1.19"
1.0"
b
Air
12 Current elements ?
15°
1.171"
2.193"
6.0"
a

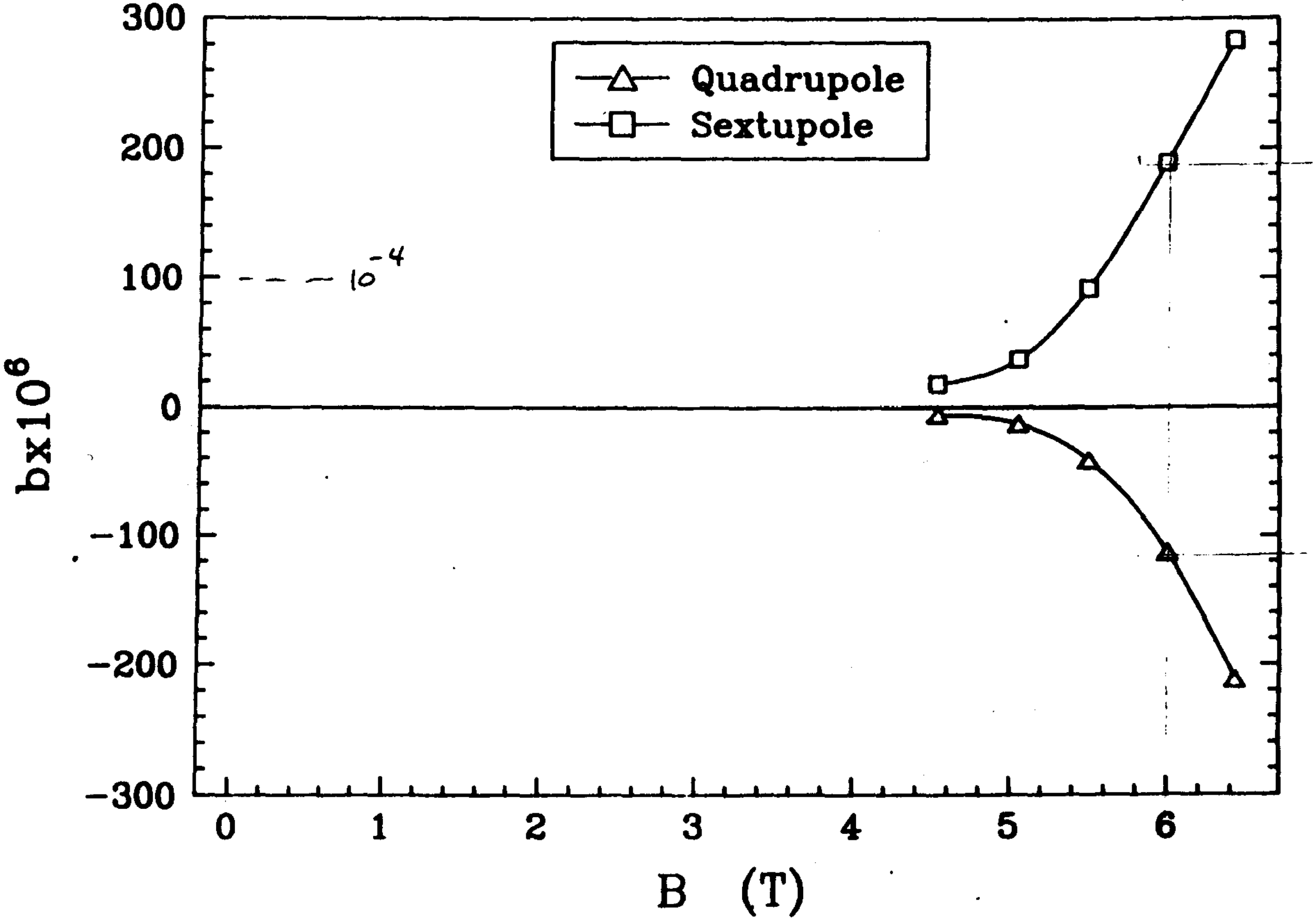


PROB. NAME = SSCNEW9 / S. CASPI nov. 20 1984.   CYCLE = 6950

Wolgast 46-161

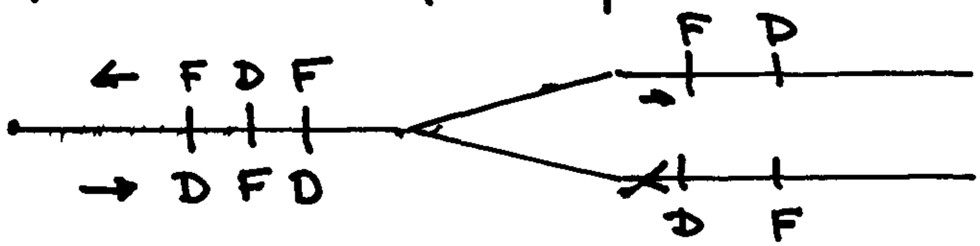
Coupling Mult'poles in 2 in 1 by S. Caspi

SSC elliptical iron



Lattice discussion with A. Garren

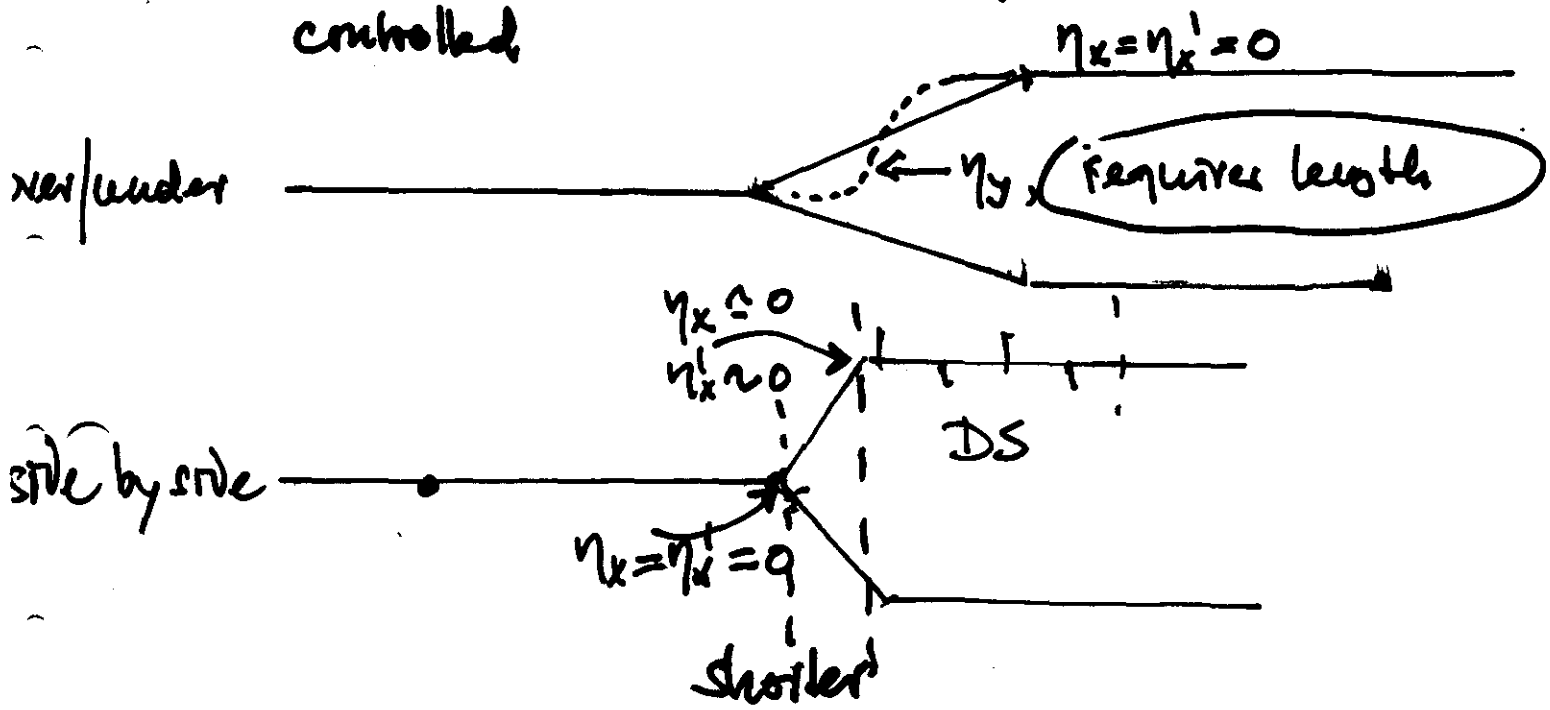
o Any optics constraints from 2 in 1 ?
- not really; strongest constraints come from shared quadrupoles



o Discussion of "uncoupled" IR design
- Incentives strongly diminished
- injection lifetime arguments not very powerful
- If required: proof by doing it !

○ Discussion of (possibly) larger beam separation and under/over vs side by side in 1:1

- no real problems here
- study (existing) designs
- of main interest: how is dispersion at IP controlled



Very tentative: need talk to those who designed over/under IR's !

~~[illegible]~~

Consequences of B Field level Choice

- o E. Courant provides the following (summarized):
  (assuming $R \propto 1/B$; simple expressions for
  stability related quantities)

  $\hat{\beta} \propto R^{1/4}$

  $x_{c,0} \propto R^{1/4}$

  $(Z_\parallel/n)_{th} \propto R^{-1}$

  $(Z_\parallel/n)$ from $\perp$ considerations $\propto R^{-3/2}$

  synchrotron radiation/m $\propto R^{-2}$

  total $\propto R^{-1}$

- o Additions, refinements may be called for
  - impedance & stability criteria
  - rf considerations
  - beam phase space density evolution

- o Tentative conjecture
  - no "dramatic" differences will strongly help in the choice of field level!

Only partially and superfizially covered: the field quality issue

- Persistent current related issues, correction schemes for - dealt with by E. Fisk
- Topic of Random Errors
  - any correlation with magnet types?
  - different requirements for different magnets?
  - operational impact of N (?) (n independently powered) correctors
  - operational aspects of magnet selection / "shuffling"
- Most of these topics will have to be dealt with "post workshop"

Work on the following items will be required

- Field quality (persistent current aspects)
  - E. Fisk — ~~Mrch~~ Feb 25
- Field quality (other aspects)
  - D.A. Edwards
  - (C.L., S. Ohnuma (?), L. Michelotti (?))
    - tentative overview — Feb 15
    - definitive — Mrch 25
  - Multipole corrector system (S. Peggs) — Feb 25
- Corrector MP coupling
  - [P. Wanderer, S. Caspi, S. Snowdon]
    - show off no problem — Feb 1
    - If failure new designs — Mrch 15
- Need for decoupled IR's
  - CDG + consultants — Mrch 15 (?)
- IR Design
  - A. Garren, [E. Courant, D. Johnson, T. Collins]
    - 2 in 1 vs 1:1 — Mrch 15
    - 2 Energies — Feb 15

SSC C&O Workshop
Operations Group Summary
L. Paul Reardon Fri. 18 Jan 84

A. BASIC REQUIREMENTS FOR REASONABLY RAPID COMMISSIONING

- MAGNETICALLY DE-COUPLED CORRECTIONS OF SUFFICIENT MAGNITUDE TO COMPENSATE FOR ERRORS AND CYCLING PHENOMENA IN THE MAGNETICALLY COUPLED BENDS AND QUADS [2-IN-1; AND, POSSIBLY, DUAL MAGNET STYLE]

B. DESIREABLE REQUIREMENTS FOR COMMISSIONING

- DE-COUPLED BEAMS IN THE IR'S
- SINGLE BEAM OPERATION WHEN ONE RING IS DOWN OR NOT COMPLETED
- CAPABILITY TO OPERATE BOTH RINGS AT DIFFERENT ENERGY LEVELS WITH OR WITHOUT BEAM
- CAPABILITY TO RAPIDLY ACCELERATE AND HOLD BEAM IN ONE RING AT LOW ENERGY (SAY 3 TeV) WHILE FILLING AND ACCELERATING BEAM IN THE OTHER RING

PJR 1/17/85

BASIC REQUREMENTS FOR OPERATING EFFICIENCY

- Simplicity of Design

  (e.g. Not too many multiple corrector systems and associated complex software systems)

- Installed redundancy in control, RF, power supply and other distributed systems

- Very high reliability (and design simplicity) in magnet and cryogenic systems

- Use of identical components whenever possible

- Demonstrated reproducibility of performance in subsystems

PJR 1/17/85

OPERATING COSTS

- DIFFERENCE BETWEEN LARGE RING AND ULTRA-LARGE RING PROBABLY LESS THAN 10% AND PROBABLY MORE LIKE 5%

- PRESENT APPROACHES TO MAGNET REPLACEMENT INADEQUATE, MUST BE IMPROVED, TOO TIME CONSUMING

- MAGNET RELIABILITY MUST BE IMPROVED TO ESSENTIALLY ELIMINATE MAGNET REPLACEMENT REQUIREMENT

- BASE OPERATING COST ESTIMATE LIKELY TO DECREASE AS A RESULT OF IMPROVED SITE LAY-OUT AND ADVANCES IN AUTOMATION

OBSERVATIONS

A. <u>ALL MAGNET STYLES MEET BASIC SSC REQUIREMENTS</u>

B. <u>ORDER OF STYLE PREFERENCE</u>

(IF COST OR OTHER FACTORS NOT OVERRIDING)

1. 1-IN-1 MAGNET SYSTEM WITH NEITHER MAGNETIC OR CRYOGENIC COUPLING
   - (a) MOST FLEXIBLE FOR COMMISSIONING, OPERATIONS, MACHINE DEVELOPMENT
   - (b) ALSO ALLOWS FOR ACCELERATOR DEVELOPMENT STUDIES WHEN ONE RING IS DOWN
   - (c) ALLOWS FOR ASYMMETRIC ENERGY OPERATIONS
   - (d) ALLOWS FOR $\bar{P}$ P OPERATION USING BOTH RINGS

2. <u>NON-MAGNETICALLY COUPLED DUAL MAGNET</u> SYSTEM
   - (a) ALLOWS FOR ASYMMETRIC ENERGY OPERATION
   - (b) ALLOWS FOR $\bar{P}$ P OPERATION USING BOTH RINGS

3. 2-IN-1 MAGNET SYSTEM

FINAL COMMENTS

THERE ARE NOW NO OBVIOUS SHOWSTOPPERS IN PRESENT SET OF PROPOSED MAGNET STYLES IF BOTH BEAMS ARE ALWAYS TO OPERATE THROUGH THE IR'S IN THE COUPLED MODE AND ASYMMETRIC ENERGY OR ENHANCEMENT OF SINGLE RING OPERATIONS FOR ACCELERATOR TUNE-UP, OPERATIONS, OR PARTICLE PHYSICS IS NOT REQUIRED OR DESIREABLE.

Nuts + Bolts Issues Requiring More Effort (Ready Feb 26 / Final March 26)

1. Complete total operation cost estimate (RO, DL, RM, RH, EP)

2. Refine big ring vs ultra big ring differential (RO, DL, RM, RH, EP

3. Beam to beam magnet installation (replacement time) as a function of magnet style and length (RO, DL, RM, RH, EP

4+5 Definition of magnet decoupling requirement and correction coil requirements as a function of magnet style. How well do they meet the requirement? (PB, JP, LV, MH, PW)

6. Need for different energy operation? MT et al

7. Possibilities for thermal isolation in dual case RH, WBF

8. More definitive review of cost (capital, operat...) of duals vs single as a function of length (RO, RM, RH, DL, EP)

9. Beam induced quenches in other ring (vertical vs horizontal) (PW.

10. Is there a magnet style especially favorable for beam induced quenches? RH

11. Repair scenarios which would allow accelerator experiments during repair (~10 typical examples) - magnet evaluation (RO, DL, RM, RH, EP)

12. Injection, abort, IR's operational consequences as a function of magnet style (MH, PB, JP, LV)

13. Is there a format to compare and/or quantify the issues and conclusions as a function of magnet style (PJR).

14. Commissioning scenario (JP)

<u>Global Issues</u> (Ready March 26, Final April 1)

1. Site layout to make operation more efficient (RO, DL, RM, RH, EP,

2. Injector energy or exotic main ring pulse to minimize commissioning and operations issues.

3. Reliability factor to add to plant costs to minimize operational problems and costs (RO, DL, RM, RH, EP)

4. Are IRs using decoupled rings achievable?

SSC C & O Workshop
Operations Group Summary
2. Phil Bryant Fri 18 Jan 85

Beam Gymnastics Sub-Group.

P. Bryant, L. Evans, M. Harrison, J. Poole
P. Wanderer

Contents

1.5 Decoupling Correctors

1.6 Summary Criteria and Provisional Rating of Magnet Types.

2. OPERATIONAL SCENARIOS

2.1 Routine Operation of SSC

2.2 Impact of Faults on SSC Routine Physics Operation

2.3 Commissioning

2.3.1 Establishing injection

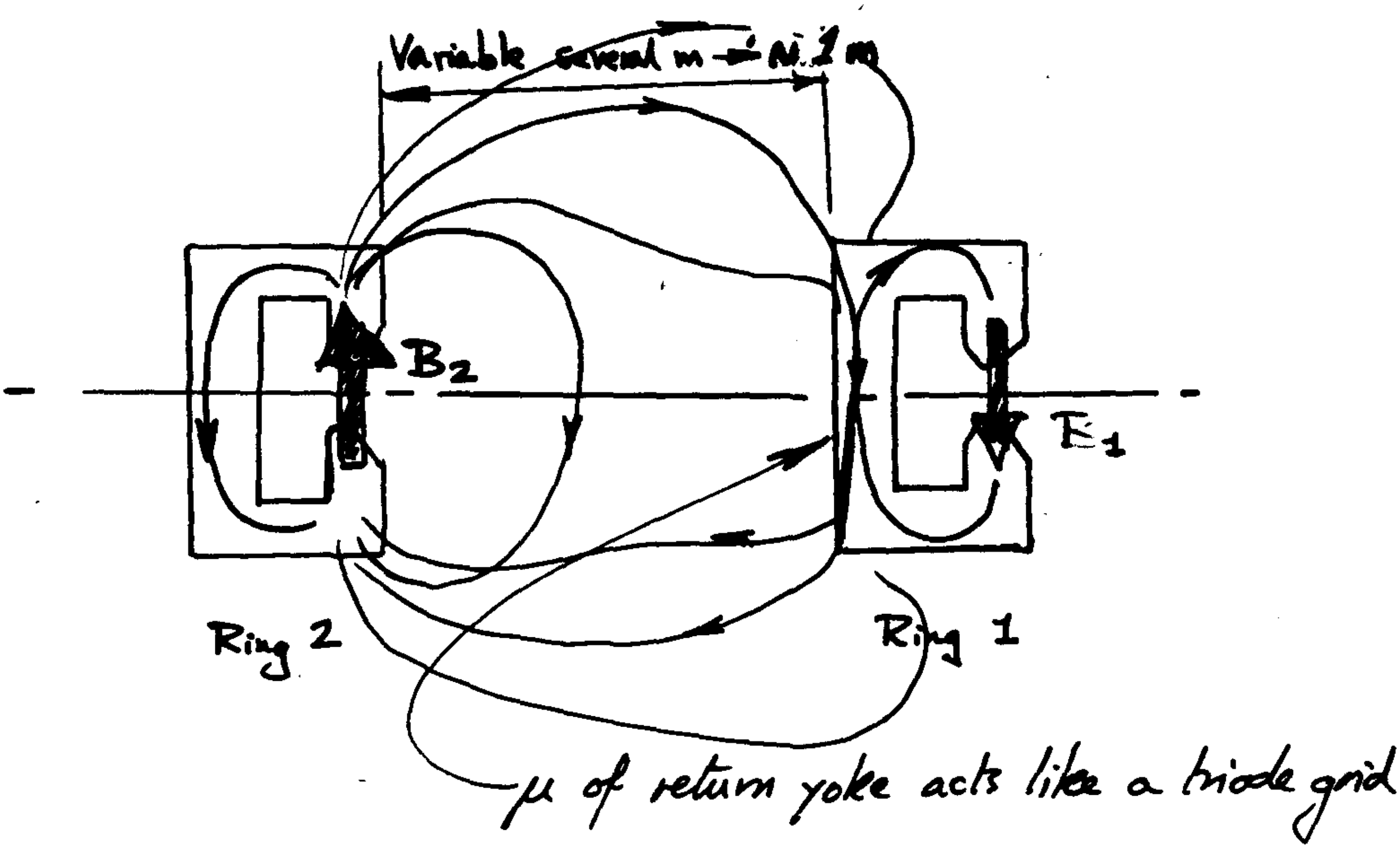
2.3.2 Establishing ramping

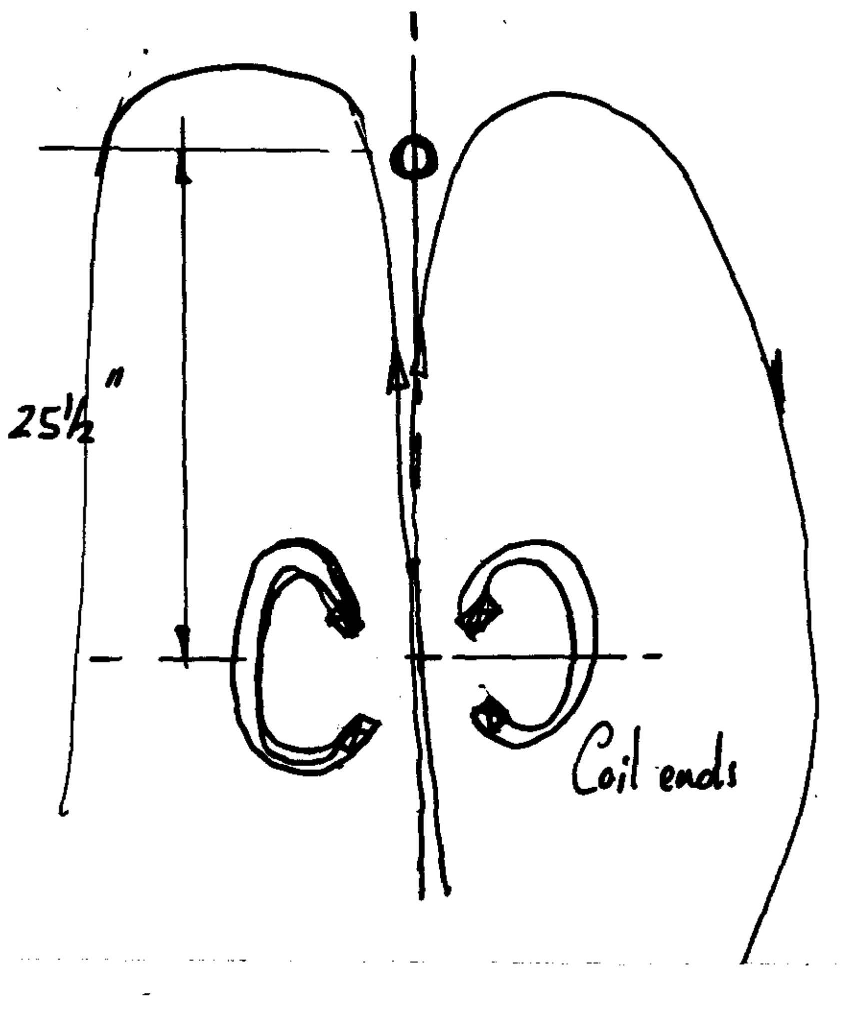
2.4 Accelerator Studies

Appendix A. FINAL EXPERIENCE WITH STRAY-FIELD COUPLING FROM COIL ENDS

Appendix B. CERN ISR EXPERIENCE WITH COUPLING VIA PERMEABILITY VARIATIONS

Appendix C. OPERATIONAL HISTORY OF THE CERN ISR.


Variable several m → ~1 m
B2
E1
Ring 2
Ring 1
μ of return yoke acts like a triode grid


0
25½"
Coil ends

1. CORRECTORS MUST ALWAYS BE DECOUPLED

2. FOR COUPLING OF MAIN DIPOLE AND QUADRUPOLE FIELDS

2.1 Commissioning. Clear advantage in being fully decoupled magnetically and cryogenically (Scenario in 2.3)

2.2 Accelerator Studies.

40% to 50% increase in time needed if fully coupled.

Group \ Category	A Independent experiment in each ring	B Experiment needing joint use of rings	C Exclusion or priority over other ring	Total Hours
1. 10 consecutive schedules in 1973	113.5	118.0	56.5	288
2. 10 consecutive schedules in 1977	172.5	94.5	58.0	325

2.3 Running for Physics

- Coupling excludes asymmetric energies
- Coupling excludes heavy ions with different e/m ratios
- Coupling excludes $p\bar{p}$
- Coupling excludes independent acceleration

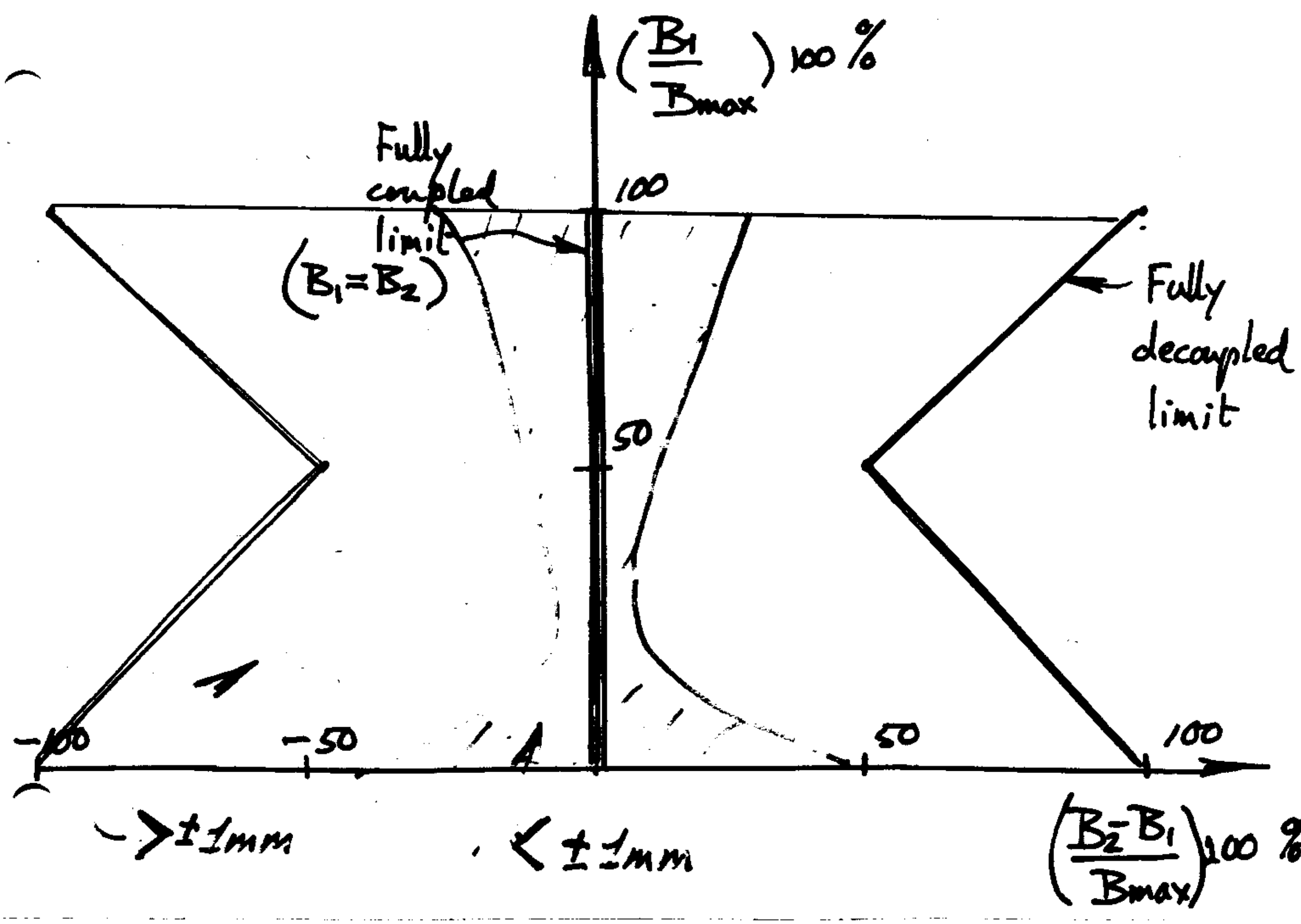
Lifetime of inj. beam

Tolerances for coupling

1/ Negligible — Normal field tolerances respected
MUST BE SO FOR CORRECTORS

2/ Acceptable level for main fields
Use ±1mm criteria used in ISR in 1982 for fringe field compensation scheme.
(dependent on optics)

3/ Merit Curves.

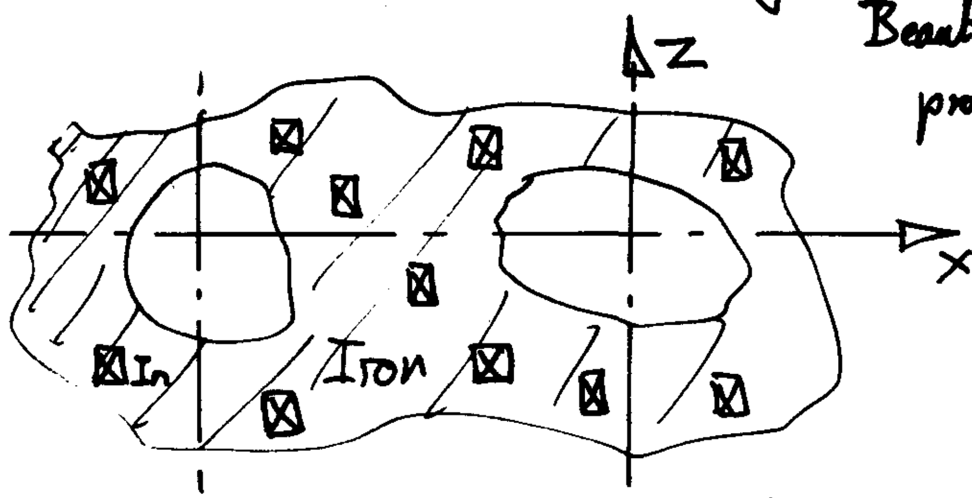


Decoupling Correctors.

1/ - Hardest for 2 in 1 where a minimum beam separation is imposed.
- Easier in dual magnets.
- Easiest in 1 in 1 magnets.

2/ Software decoupling.

Beautiful academic problem.



$$B(x,z) = f(I_1, I_2, I_3 \cdots I_n)$$

(i) Persistent currents and iron saturation make this very non-linear

(ii) Some correctors (most) are in series groups which of course do not overlap. To solve this one requires separate power supplies on <u>all</u> correction units (cost, reliability, efficiency)

Beam loss and quenching

1./ Question Is one of the magnet types intrinsically more tolerant to beam losses?

We assume not, but needs an expert answer.

2./ Cryogenic coupling virtually ensures that the loss of one beam will cause the loss of the other, either by quench or safety abort.

This is a disadvantage for accelerator studies, but for physics routine running it is less of a problem.

However 1 in 1 magnets are clearly better since they do not mutually quench easily and it would be possible to keep one beam.

General Statements

- Correctors must be fully decoupled

- If ever I.R.'s are decoupled, it would be a great loss to have 2 in 1 magnets. Either a good dual or 1 in 1 magnets are needed.

- Before installing 2 in 1 magnets be sure future physics will not be critically restricted
  - no $p\bar{p}$ (single ring may not work)
  - no asymmetric energies
  - no heavy ions with differing e/m ratios

- Before installing 2 in 1 be sure that future upgrading of injector intensity does not make low-energy lifetime poor, so that independent acceleration is needed. Poor injector turn-round has same effect.

- With coupled magnets be prepared to double commissioning time and to add 50% to accelerator studies time.

1 in 1	Best one can do
Dual	Depends on merit curve
2 in 1	Be prepared to: Limit physics, double commissioning time, add 50% to accelerator studies time; possibly endanger future intensity upgrades.

1 in 1 — Perhaps higher plant cost, higher maintenance, longer installation, more alignment in tunnel

2 in 1 — Fixed alignment error between bores makes engineering tolerance stricter or closed orbit correction scheme needs a little more flexibility.
Magnet shuffling probably made impossible or at least ineffective

SSC REGULAR REFILL

	FILL	"RE-FILL"
CYCLE AND SET UP	.45	.30
SET UP INJECTION	.15	10
SEPARATE BEAMS	.15	–
FILL	.45	25
ACCELERATE	.15	.15
LOW BETAS	.15	.30
EXPERIMENTAL MAGNETS etc.	.15	.30
LUMINOSITY STEERING	.15	.15
ADJUSTMENTS	30	15
	3h 30m	2h 50m
CONTINGENCY	30m	
	4h 00m	

Commissioning

1. Simplify machine
   - No low-β
   - Provisional decoupling of I.R.

X 2. Add: Zero-angle insertion
   Low-β

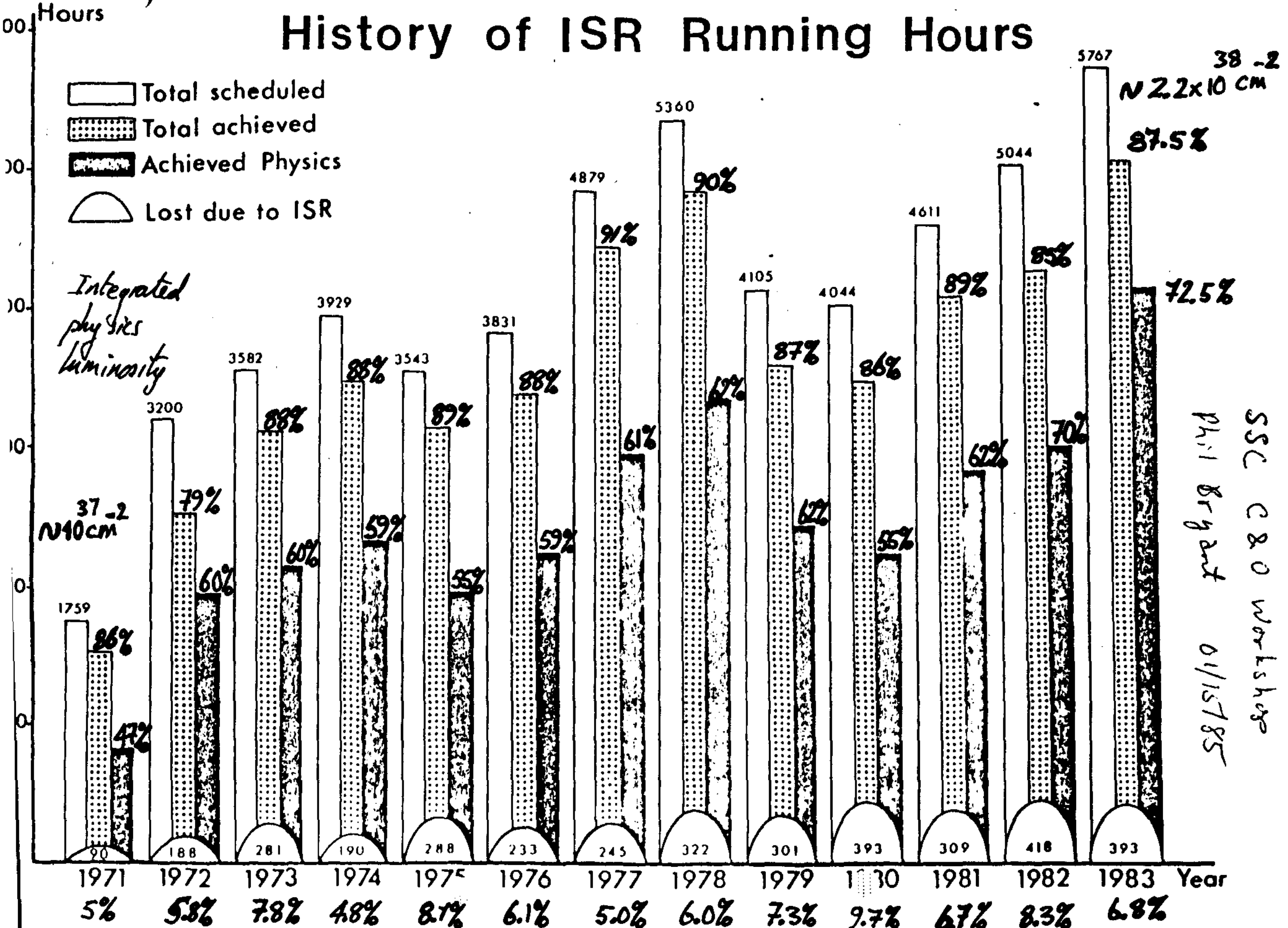
3. Search for working regions

4. Establish empirical model for ramp.

5. Establish good physics conditions.

$$\text{Commissioning time} \propto \frac{1}{\text{simplicity}}$$

History of ISR Running Hours



SSC C&O Workshop Phil Bryant 01/15/85

SSC C&O Workshop
Systems Group Summary
Don Hartill - Fri 18 Jan 85

[illegible]

[illegible]	[illegible]	F[illegible]
	[illegible] *	[illegible]
	[illegible] *	[illegible]
	[illegible]	F[illegible]
	[illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	[illegible]

* [illegible], KR .. Quench [illegible] ([illegible])

[illegible] .. Power Supplies ([illegible])

A short list includes

i. Quench Detection + Protection KK, GT, JZ

ii. Magnet Power Supplies + Regulation RC, JZ

iii. Correction Elements RC, JZ

iv. Vacuum System DH

v. RF DH

vi. Beam Stabilization DH

vii. Beam [illegible] and Loss Monitoring DB

viii. [illegible] DB, JF

ix. [illegible] DB, DH

⋮

[illegible] Detection [illegible]

1. THE [illegible]

[illegible]

4. [illegible]

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	+	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

5. [illegible] – [illegible] [illegible]ked f[illegible] ST

Item	ST	ST (R)
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

[illegible] 4.5[illegible]

[illegible]

Power Supply

1. Specifications

   - Orbit Distortion 0.1 [illegible] $\Rightarrow \left.\frac{\Delta I}{I}\right|_{Bend} < 10^{-4}$

   - $\Delta\nu$ spread (Quad - Bend Tracking)

     $\Delta\nu$ [illegible] $\Rightarrow \frac{\Delta I}{I} \approx$ [illegible] $\times 10^{-5}$

     ([illegible] requires $\Delta\nu$ [illegible] due [illegible] [illegible] $\frac{\Delta I}{I} <$ [illegible] $\times 10^{-5}$ [illegible] [illegible] Bend [illegible])

2. [illegible]

   - [illegible] with [illegible] [illegible] [illegible] [illegible] Each [illegible] [illegible] circuit and [illegible] regulated to $\frac{\Delta I}{I} \times$ [illegible] .

b. 12 power supplies in series with only one [illegible] the regulation [illegible]. Requires [illegible] current [illegible] (and [illegible]) [illegible] which are [illegible] [illegible] conditions.

[illegible]

[illegible]

[illegible]

[illegible]

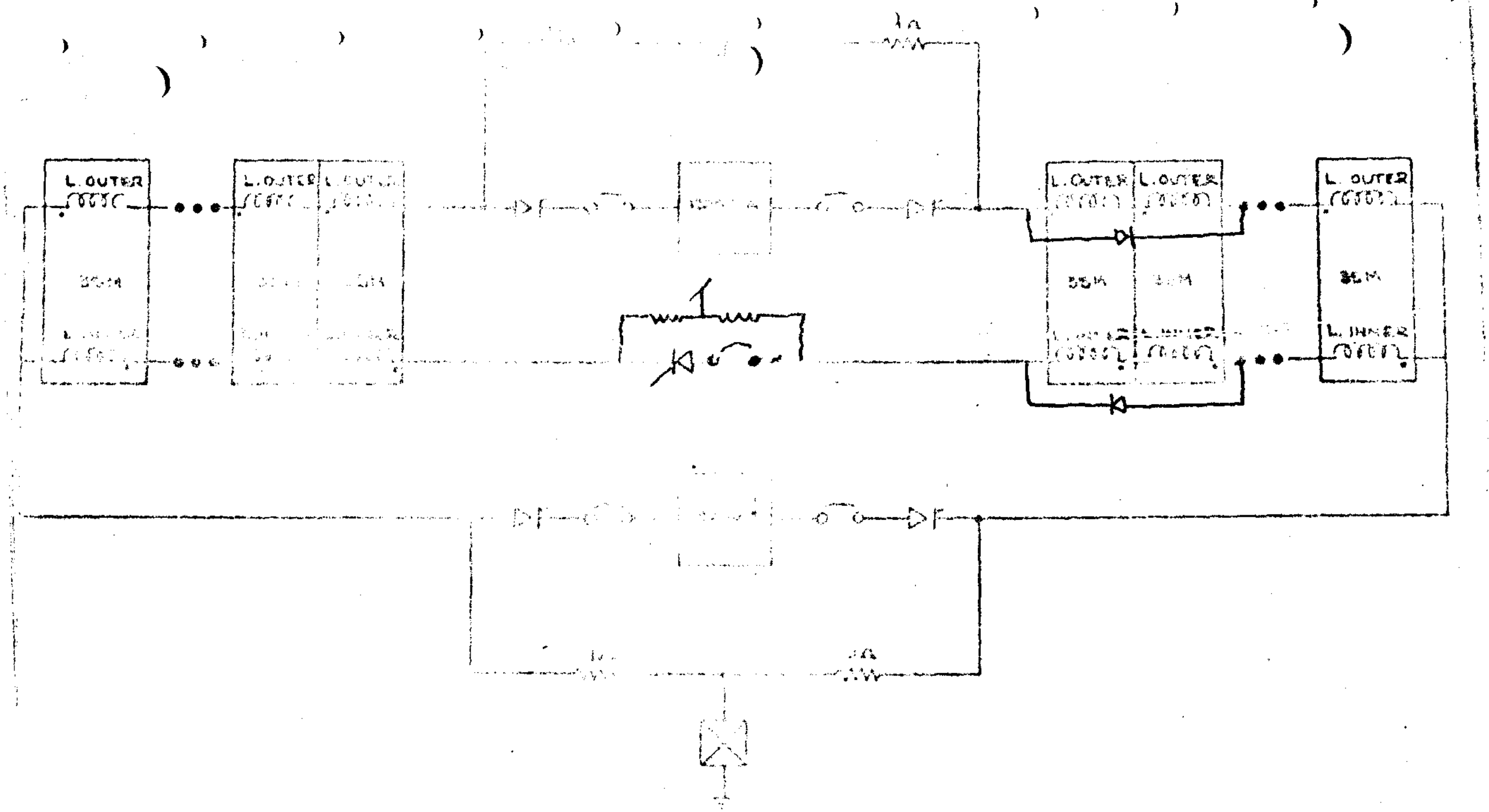
$u = \frac{1}{r^2} E^4$ [illegible]

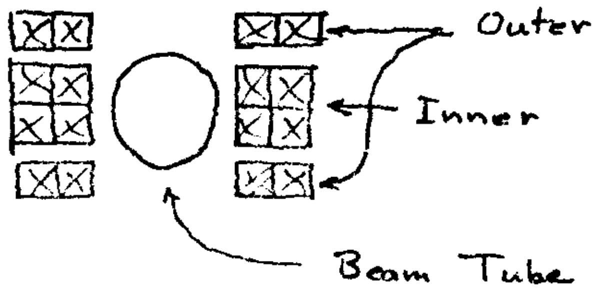
[illegible]

$u = u \times N$

[illegible]

[illegible] Conversion [illegible] with [illegible] [illegible] [illegible]





@ $B_0 = 3T$

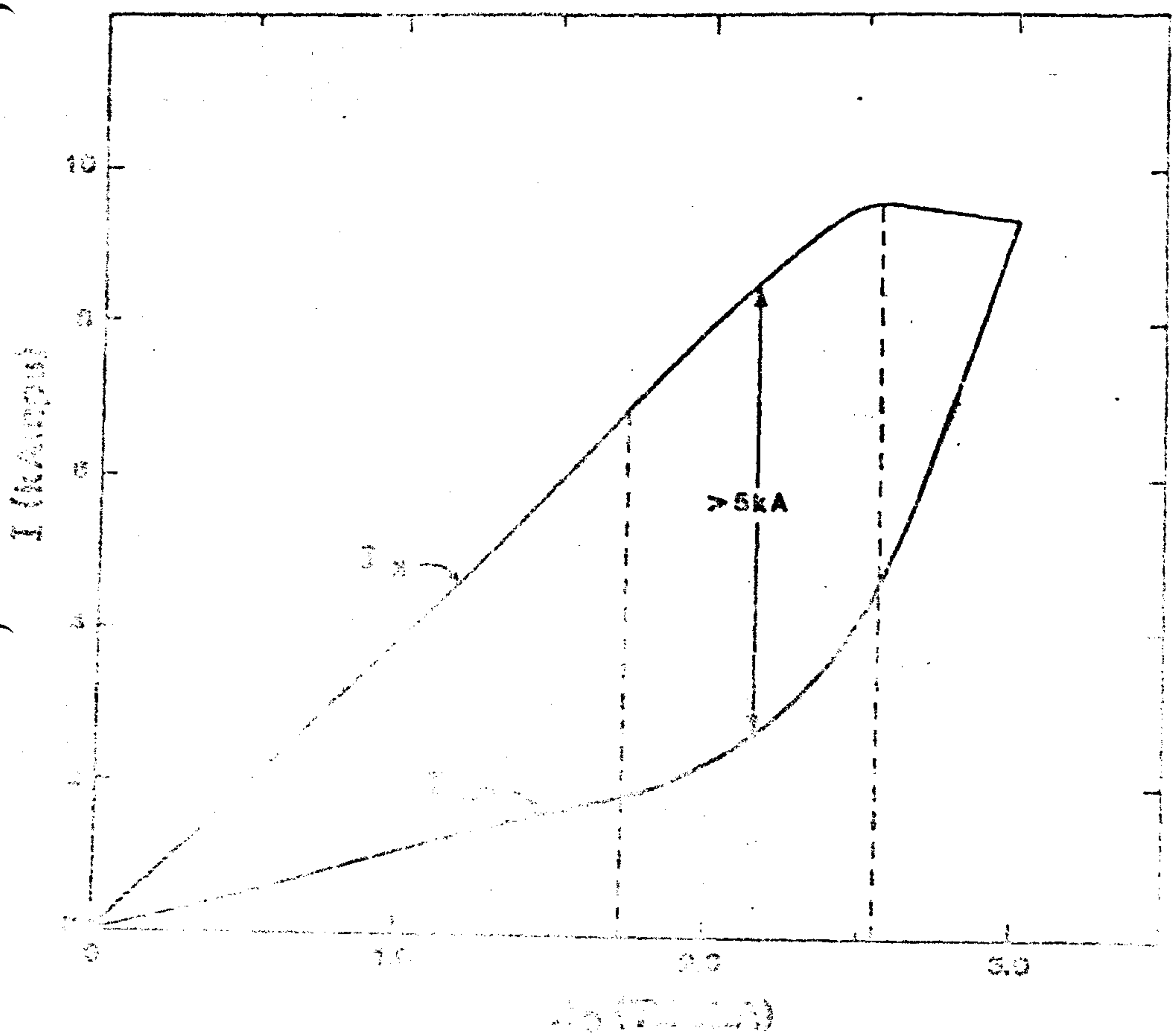
$I_{inner} = I_{outer} \approx 10\,kA$

$L_{inner} = 3.3639 \times 10^{-5}$ H/m

$L_{outer} = 3.1169 \times 10^{-5}$ H/m

$M = 2.822 \times 10^{-5}$ H/m

$k = 0.869$



10
> 5kA
5.0

Vacuum System

1. [illegible] plant considerations

2. Synchrotron radiation

   Power [illegible] $\propto B E^3$ (fixed [illegible])

3. [illegible] vs Dual [illegible]

   [illegible] considerations

4. [illegible] for [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

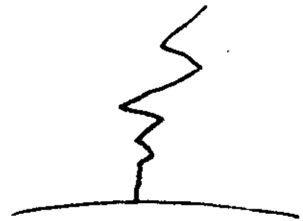
[illegible]

[illegible]

1. [illegible]

2. [illegible]

Failure Mode Analysis

1. Sensitivity to 

2. Power Supply trips

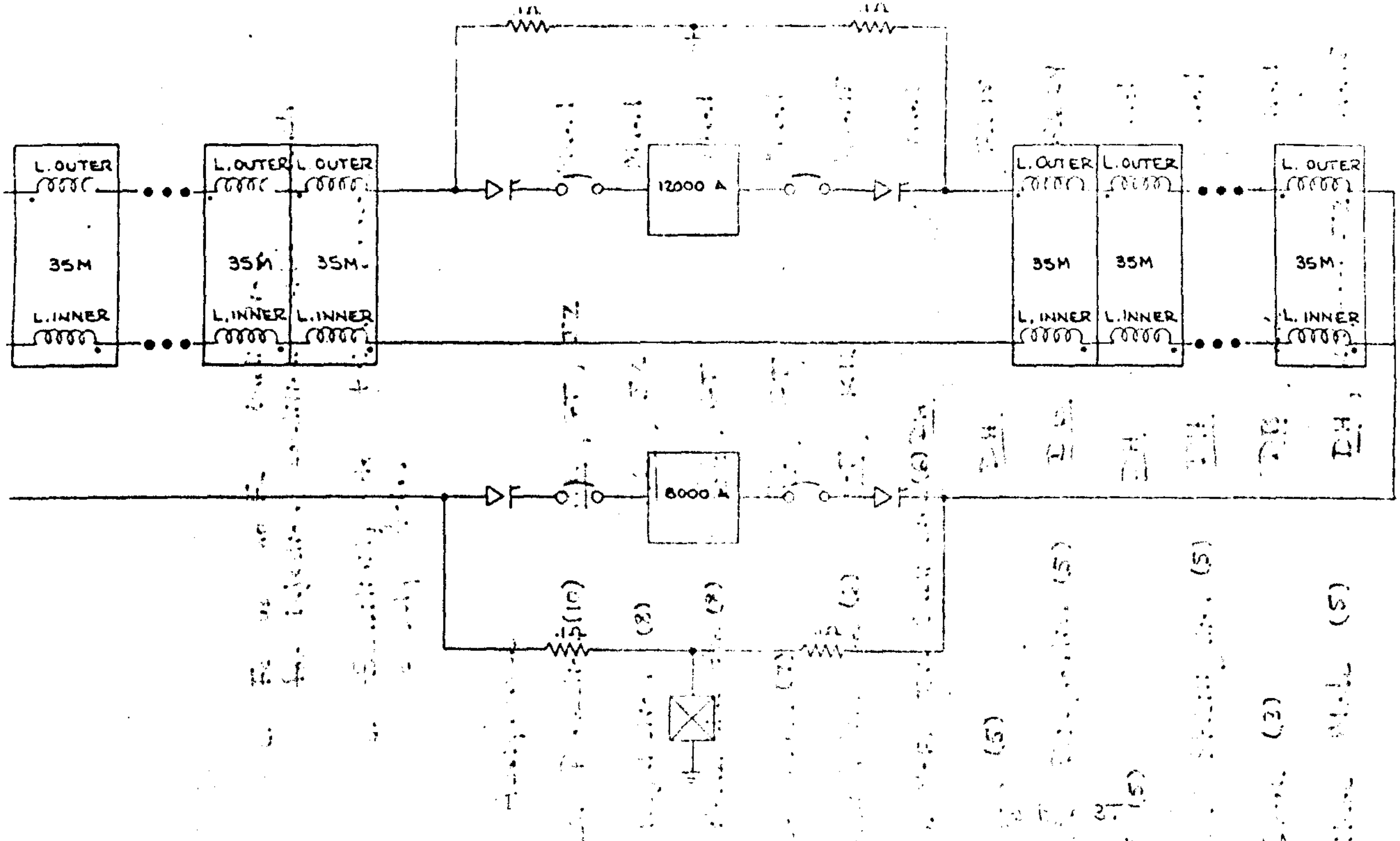
3. Component failure chains

   any single event OK but sum

   leads to magnet damage

4. Its the little things that keep

   us colliders from producing luminosity!

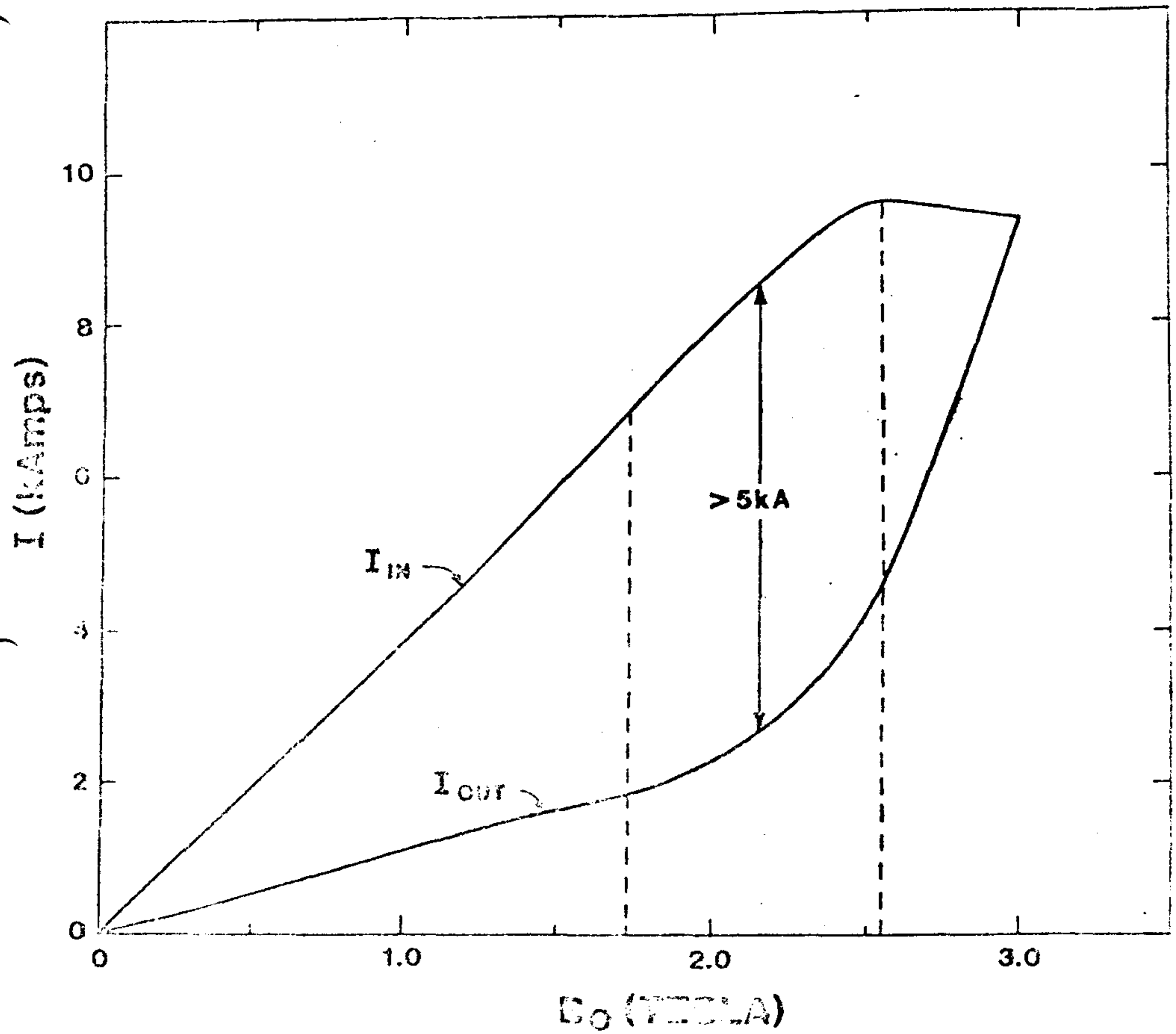


L_{inner} = [illegible] $\times 10^{-5}$ H/m

$L_{outer} = 3.1164 \times 10^{-5}$ H/m

$M = 2.622 \times 10^{-5}$ H/m

$k = 0.869$


I (kAmps)
10
8
6
4
2
0
0
1.0
2.0
3.0
I IN
I OUT
> 5kA

SSC Commissioning and Operations Report

(Tentative table of contents - 12 Janaury 1985

TABLE OF CONTENTS

Preliminary Agendas for SSC Commissioning and Operations Committee meetings

1. 26 - 27 February 1985 at Fermilab (Tuesday and Wednesday). Have ready and discuss:

   a. Outline of forthcoming report from each

   b. Written-up sections on "important features"

   c. Drafts of reports on obvious problems.

2. 26 - 27 March 1985, place yet to be decided. Have ready and discuss:

   a. Semi-final drafts of working group reports (Section 4 of the Report)

   b. Draft of "Summary and Conclusions" section for Report (Section 3). (in outline form, with prose by those in residence at LBL.)

   c. Most of appendices (N.B. - Working group reports should be at LBL by the following Monday).

January 17, 1985

MEMORANDUM

TO: SSC C & O Steering Committee Members

FROM: Don Groom

SUBJECT: Technical comments about report preparation

While any typed or otherwise legible manuscript would be welcome, substantial effort could be saved if the format was compatible with word processors available at LBL. In order of preference, these are:

1. Either size disk for a Wang using OIS 140;
2. Disk made by a Xerox Star version 5.0;
3. 9-track tape legible to a VAX using UNIX (aDI-TROFF source file would be particularly good);
4. IBM PC (MS/DAS) floppy;
5. Any ASCI file of known format.

In addition, we could digest:

6. Tape of a TeX source file in either IBM/VM or VAX/VMS format.

DG/kl