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Superconducting Super Collider Laboratory

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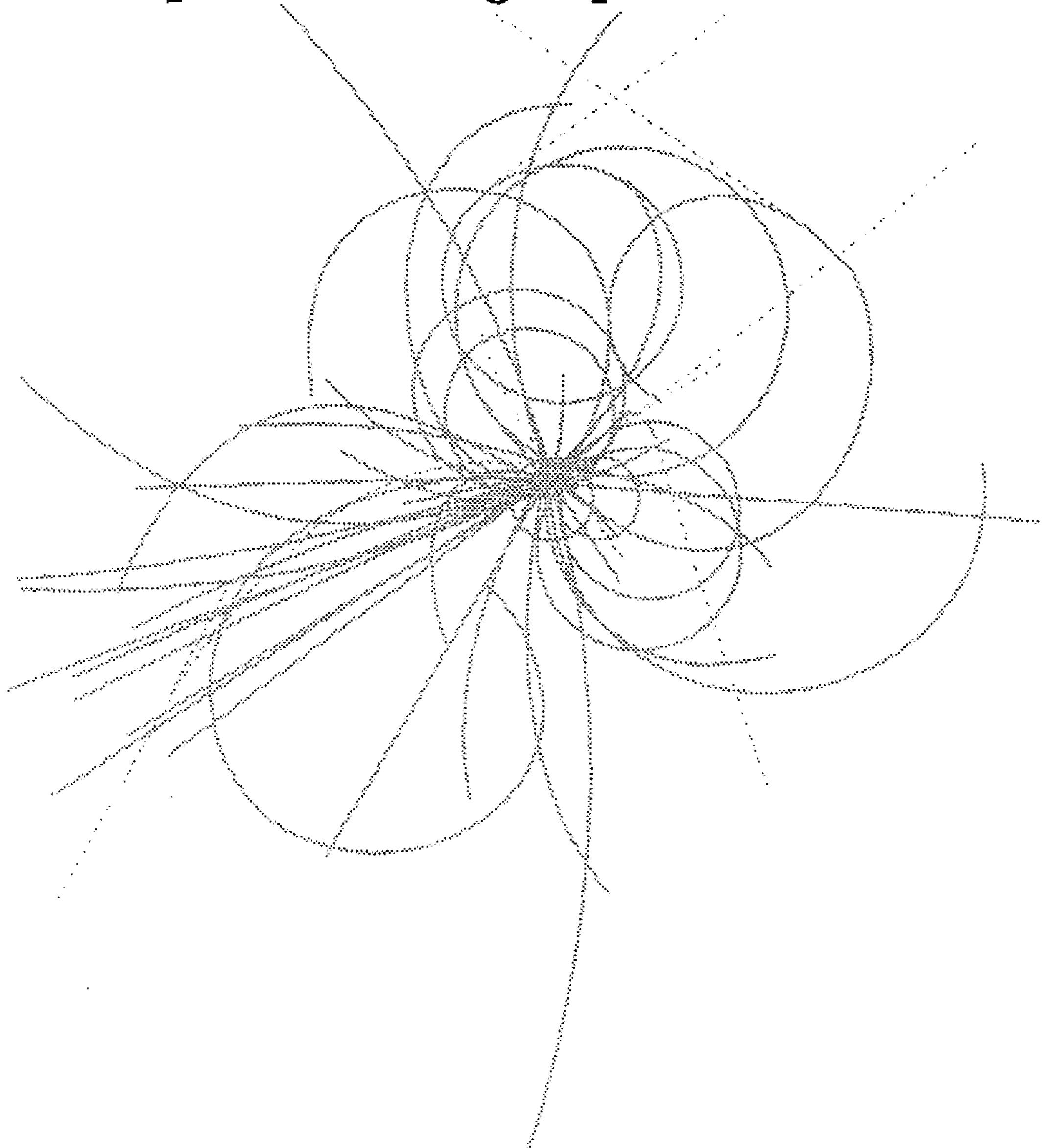

SSC Monthly Report

April 1986

SSC MONTHLY REPORT

APRIL 1986

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A. Project Summary

Central Design Group (CDG)

- Work continued on the Conceptual Design Report (CDR) attachments during April. They will be available in June.

- A Department of Energy Review of the Conceptual Design Report was held the last week of the month. The review actually consisted of three separate ones, including an OER review composed of 38 committee members, an Independent Cost Estimating (ICE) review composed of 7 members, and a Validation review composed of 2 DOE members. In total, there were 56 DOE and DOE invited committee members and staff, the CDG, and 30 CDG invitees (technical consultants) at the CDG the week of April 28. The OER Report (DOE/ER-0267) will be completed by next month while the ICE and Validation reports will be prepared separately.

- The CDG has prepared an outline of magnet R&D activities with the main emphasis on the remainder of FY86 and FY87. The scope of work and desired schedule of accomplishment was transmitted to BNL, FNAL, and LBL for their comments and budget estimates.

- On April 1, CDR staff gave a presentation to the Independent Cost Estimating (ICE) team in Washington, D.C.

- The Detector R&D Task Force met at the CDG April 3 and 4 to prepare their final report. Copies will be available next month.

- Schedule 44 was prepared and mailed to Washington.

- Another Magnet Systems Integration meeting was held at Fermilab on April 8 and 9. The agenda is given on page 5.

- The Off-Line Computing Advisory Panel met April 14 and 15 to prepare their final report which will be available next month.

- The Detector Cost Evaluation Panel met April 19 and 20 to write their final report which will be available next month.

- The Proton-Antiproton Task Force chaired by Barry Barish concluded their study. Their report will also be ready next month.

- The program for simulating synchrotron oscillation is expected to be ready soon. The program uses a concatenation scheme that is valid to fourth order in x and y coordinates and numerically fits the nonlinear FE/E behavior. Preliminary tracking results are expected next month.

- One operational issue expected for the SSC at the starting phase is whether the beam can be guided to complete one revolution before the normal orbit correction system can be applied. A procedure of how to guide the beam for the first turn was designed in April and the process was simulated numerically, taking into account the various magnet and beam-position-monitor misalignments envisioned for the SSC. It was found that the procedure was effective and can be used for first-turn beam operation.

Brookhaven National Laboratory (BNL)

- The highlight of activities was the completion of the first full-length dipole and its preliminary "warm" tests. Having successfully passed these, it departed from BNL in the early hours of April 24 aboard its special 60-ft long trailer bed in an air-conditioned enclosure, arriving at Fermilab the following morning after a largely uneventful journey.

- Assembly of magnet No. 2 made good progress.

Fermi National Accelerator Laboratory (FNAL)

- The SSC Heat Leak Model repairs were completed at the end of April. The damage was sustained in early April by an estimated 50 g impact of the model with the concrete slab at the ER test site while unloading the finished model. The damage was limited to the support posts. On the positive side, replacing the posts and reassembling the model has given us additional experience which will be valuable in the assembly of D001.

- The first coil/cold mass assembly for D001 was received from BNL on April 25. Problems with the interface of the post assembly to the cold mass have required modifications that will delay magnet completion approximately two weeks.

- A program of cryostat design improvements has been undertaken as a result of experience with the assembly of the Heat Leak Model.

- Preparations of MTF for SSC magnet testing continue. Refrigeration and measurement hardware are on schedule. Development of software for the testing program is receiving increased attention to insure its timely completion.

Lawrence Berkeley Laboratory (LBL)

- Fine filament superconductor was produced from full-size billets with satisfactory piece lengths after slight modification of the drawing and heat treatment schedule at both Supercon and IGC.

- Quadrupole design is being optimized and improved for both ARC quads and for the special IR quads.

- Magnet D14B-I with 15 mm aluminum collars was assembled in the BNL-type circular iron yoke with a two-point support scheme. Tests showed the coil prestress increased on cooldown as expected (by about 600 psi) and that low temperature "conditioning" eliminated training as with previous tests. The next two 1 m models have cross section NC6, a slight modification of NC515, which is designed to give a more uniform field.

Texas Accelerator Center (TAC)

- During the past month many measurements have been made on the first 28 meter General Dynamics' magnet. Measurements along the length of the magnet are made every four feet. These measurements indicate that the variations along the magnet are small. The magnetic field of the 28 meter magnet is the same as with the equivalent 1 meter magnet models. The quench field was equivalent to 3.4 Tesla at 4.5 degrees.

- Tests on seven 1 meter magnets also show a strong consistency between magnets. Two problems are left in the magnetic field; first is the low field variation and second is the B_6 multipole at high-field.

- The superconductor ordered from Intermagnetics General Corp. (IGC) for the correction magnets was received on May 7, 1986. A total of 293,387 feet was received on 24 spools. Short sample results on this material were 171 A at 3 T and 4.2 K.

B. Project Report

I. Central Design Group

Magnet Program. Major activity during this month was preparation for the Conceptual Design and Costs Schedule review by DOE and integration of various R&D activities.

The CDG has prepared an outline of magnet R&D activities with the main emphasis on the remainder of FY86 and FY87. The scope of work and desired schedule of accomplishment was transmitted to BNL, FNAL, and LBL for their comments and budget estimates. Preliminary comments from the laboratories have been received but not budgetary details.

A Magnet System Integration meeting was held on April 8 and 9, 1986, at Fermilab. Top priority of the meeting was long magnet readiness. BNL and FNAL presented fabrication and assembly status. FNAL presented status of MTF and ER test stands and progress on test stand. No major problems were encountered, but scheduling remains a concern. The CDG urged the participants to apply necessary overtime to achieve test readiness by the first week in June. The agenda for this meeting is provided on the next page.

In last month's progress report the analytical approach for solving a number of complex structural and thermal problems was developed. The object of the approach was to determine the effect of combined time-dependent pressures, displacement and temperature gradients, without resorting to numerous simplifying assumptions.

The first problem consisted of a 2-D plane strain solution of copper plating on the inside of the beam tube and composite (representing Kevlar) on the outside. The effect of the 12 lb tensile load during wrapping on the hydrostatic pressure on the beam tube was investigated. This simple problem was chosen to check-out various communication links between the LBL VAX and the Livermore CRAY computer. The second problem is a 2-D solution to entire cool-down of the magnet cold mass. Modeling was completed.

Agenda High Field Magnet Collaboration Meeting
April 8-9, 1986

Tuesday, 10 a.m.		
I. Long Magnet Production Schedule		
A. Single Phase Assembly #1 at BNL	W. Schneider	20 min.
B. Status of Superconductor Availability	E. Willen C. Taylor	20 min.
C. Schedule for #2, #3, #4 1 Phase Assembly	W. Schneider	15 min.
D. Schedule for Cryostat Fabrication and Assembly of D001-D004	N. Engler	15 min.
E. HLM II	J. Carson	15 min.
F. Unresolved Construction Issues	V. Karpenko	20 min.
II. Tests and Protocols		
A. Pre/Post Shipment Protocol	J. Carson W. Schneider	15 min.
B. Magnet Cool Down/Warm-Up Scenario	R. Niemann T. Nicol	20 min.
C. ER Test Protocol	R. Orr J. Theilacker K. Koepke G. Tool	30 min.
D. Status of Safety Reviews	R. Lundy N. Engler	15 min.
E. MTF Progress Report	J. Strait A. McInturff	30 min.
F. Mole Testing REsults	E. Willen P. Wanderer	20 min.
G. MTF Test Data Format	R. Hanft J. Strait	15 min.
III. FY87 Plans/Budget	V. Karpenko	20 min.
Wednesday, 9 a.m.		
IV. R&D Reports		
A. Pressure Transducers	P. Wanderer	20 min.
B. Texas Magnet Performance/Magnetic Field Measurements	R. Huson	40 min.
C. B_2, B_4 vs. Time	R. Hanft	40 min.
V. Future Meeting Dates		

Conventional Systems. RTK completed the non site specific conceptual design (CDR) for the SSC in March. Their work consisted of three complete designs, including cost estimates for three site examples. The examples spanned different geological conditions, each attacked by different methods of construction for the collider ring enclosure: hard rock tunneling, soft ground tunneling, and cut/cover using preformed segments. In the course of the work, over seventy technical drawings were produced, as well as three construction schedules. The entire effort was described in a report containing fourteen chapters and two appendices.

Work continued with RTK in preparation for the several major reviews of the design. The first one began on April 28 when three teams from the Department of Energy came to the Central Design Group for a week long review. They were joined by representatives from Gilbert Commmonwealth, Inc. who studied the design and cost of the conventional systems. Special efforts were made by RTK to analyze the claims made in the TAC challenge to the CDR. This consisted of evaluating the geological assumptions and doing a series of model calculations to study regional labor and material costs for enclosure construction.

After receiving the three designs from RTK, it was necessary to analyze the results of the different approaches and to decide upon the description of the design and related cost estimate to use in the overall CDR. This consisted of a thorough evaluation of the differences in order to determine the cost to use and the associated contingency assignment. Similar steps were taken with respect to the schedules. Contributions to the CDR chapters on cost and schedule were also prepared. Together with RTK, CDG personnel presented the generic design to DOE at the end of April. Interleaved with this major task was handling the charges made by TAC on the design assumptions, and cost consequences of the CDR design.

A draft tunneling R&D plan was developed. It was presented to the Underground Technology Advisory Panel in March and subsequently shown to DOE. An indication of the intense interest in the subject of tunneling R&D is shown by the several groups of visitors who have come to the CDG in recent weeks to advance individual propositions. Considerable attention must be given to the matter of technology enhancements in the future.

Accelerator Systems.

R&D

1. Texas Accelerator Center

a. Program Plan. There are still difficulties with the R&D that is being pursued at TAC on behalf of the CDG. In general, work on the bypass diodes is progressing better than work on correction elements, at least from a qualitative point of view, but neither is moving as fast as it could.

As of the end of March, the half way point of the fiscal year, the spending on these two programs was as follows:

Program	Anticipated FY86 Costs	Costs to April 1
Bypass diodes	$ 550 K	$ 62 K
Correction Elements	$1025 K	$155 K

Clearly, the effort has not been as expected at the beginning of the fiscal year, and care must be taken in planning the rest of the program.

b. Reports

Bypass Diodes. An interim report on bypass diodes was received in April, as scheduled. The report indicates that the planning for tests is well along and has been modified somewhat from the original plans. These modifications had been done with the knowledge of the CDG.

Some electrical and cryogenic testing of the bypass diodes has started. The RA-20 diodes received from Westinghouse appear to have been passivated with the wrong material, and tests on those diodes cannot proceed until that problem is resolved. The first radiation exposures were scheduled for the middle of April. Results have not yet been communicated to the CDG.

It is becoming apparent that the scope of work on this project that was outlined at the start of the fiscal year is smaller than the amount of funding. A change in the scope of work, or in the funding, should take place soon.

Correction Magnets. As indicated last month, a report on the progress and planning for the correction element design and prototyping is overdue. The report was not received during April and is now over two months overdue.

A one meter long model of a superferric correction dipole has been completed, but the testing of it was delayed in order to use the test facility to operate the long superferric dipole from General Dynamics.

Other parts of the correction program:

i. Calculations of the 3-D fields of the superferric correction magnets is moving very slowly.

ii. Design of cos theta types of correction magnets has not progressed at all.

Again, it is becoming apparent that the funding for the correction element program exceeds the scope of work that was agreed on at the start of the fiscal year. Also, in the case of the correction element program, TAC has failed to perform as well as expected. A review of the scope of work and the performance should be held soon.

2. Fermilab

Fermilab is proceding satisfactorily on the construction of the E4 test area for the Half-Cell Test. During April, Fermilab riggers accidentally dropped the Heat Leak Model (HLM) as it was being lowered onto the pad at the E4 test site. All of the supports in the cryostat were broken in the accident. No one was injured. The HLM has been repaired and will be returned to the test site soon. Operation of the HLM is expected to start near the end of May.

The test site itself is essentially complete, at least as far as the cryogenics is concerned, and will not be a critical item in the Half-Cell Test.

<u>Accelerator Theory and Computation</u>. Most of the effort in April was devoted to preparing for the DOE review of the Conceptual Design Report to be held at the end of the month. Such preparations were regarded necessary and given high priority. Documenting the results of studies made in supporting the Conceptual Design continued in April.

The program for simulating synchrotron oscillation is expected to be ready soon. The program uses a concatenation scheme that is valid to fourth order in x and y coordinates and numerically fits the nonlinear FE/E behavior. Preliminary tracking results are expected next month. In parallel with this tracking study, an analytic study was initiated to evaluate the effect of tune modulation due to synchrotron oscillation in the presence of nonlinear magnet field errors. The result of this study, to appear as a SSC technical note, reconfirmed the study made in the Conceptual Design that this tune modulation effect is rather weak for the SSC.

Studies on coherent beam-beam effects are summarized as two SSC reports, one on tracking studies of the coherent dipole modes and one on the analytical study of the coherent modes in general. Results of these studies, reported in the CDR, show that the coherent beam-beam effects are rather weak for the SSC parameters.

Tolerances of the systematic multipole field errors have been specified in the Conceptual Design Report, which addressed the allowed multipoles only. Tolerance on the (non-allowed) skew multipoles was studied in April. By splitting the horizontal and vertical tunes by an integer, the tolerances can be considerably relaxed as compared with the (allowed) normal multipoles. Nevertheless, these tolerances are being supplemented to the tolerance specifications of the CDR.

One operational issue expected for the SSC at the starting phase is whether the beam can be guided to complete one revolution before the normal orbit correction system can be applied. A procedure of how to guide the beam for the first turn was designed in April and the process was simulated numerically, taking into account the various magnet and beam-position-monitor misalignments envisioned for the SSC. It was found that the procedure was effective and can be used for first-turn beam operation. It was found that special attention was needed to guide the beam through the interaction regions.

During the month the Proton Antiproton Study Group concluded their study. The accelerator theory members of the group worked mainly on the accelerator issues, which included the antiproton source and the main ring. The antiproton source work involved the design of an antiproton source which was consistent with the CDR and with an antiproton production rate which would give a luminosity of $10^{32}cm^{-2}s^{-1}$. This design required several modifications of and additions to the injector complex as described in the CDR. Work on the main ring consisted of examining the possibility of having simultaneous beams of protons and antiprotons in the same beam tube and its consequences. The required separation between the protron and the antiproton beams and the necessary aperture increase for a range of luminosities were examined. Methods of producing these beam separations were described as were the required additions to the SSC. The conclusions of the proton antiproton option study can be found in the report, "An Assessment of the Antiproton-Proton Option for the SSC," SSC-SR-1022.

II. Laboratory Programs

A. BNL.

1. Model Magnets. The assembly of LLN-001 was completed, including closure of yoke support tube, completion of electrical and mechanical end details, leak checking, interconnections (electrical bus, flexible joints, bellows), and final electrical and (warm) magnetic tests prior to shipping to Fermilab. The shipping trailer, with its magnet support mechanism, air conditioners, fans, generators, etc., was also made ready. Meanwhile, assembly operations for LLN-002 continued. In particular, its collaring was successfully completed, despite some problems with bad collar laminations, instrumentation gauges, and several electrical shorts which necessitated repairs.

A finite element model of the collars, using ANSYS, was completed, and analysis started. The first loading conditions studied, which are completed, consider the present keyed collar design and loading levels (7 kpsi for inner coil, 6 kpsi for outer coil). Other loading conditions under study include wider collars, various pins, and different welding schemes.

In the area of trim coil activities, work has started on an optimized trim coil design incorporating sextupole, decapole, and 14-pole coils deposited on a single substrate using 8 mil wire. The second long trim coil was mounted in LLN-002, and the third coil produced in record time ($\leq$8 hours) at Multiwire.

Additional samples of copper plated bore tube were received from PCK and dispatched to LBL for testing. Tests of the system to be used for plating 5 m bore tubes were started at PCK. Following heat load tests, the prototype bore tube was disassembled. Some superinsulation problems were uncovered and repaired. Finally, components for the photodesorption experiment are being constructed in the Physics Department and assembled in Bldg. 902.

2. Tooling and Facilities

In the area of coil fabrication tooling, engineering details progressed on the 1.8 m coil winder tooling. Work on a new pre-production press continued; layout of the loading section is generally complete, except for hydraulic lines and controls. Design modifications started on the small collar press to facilitate its use in producing long magnets. The press is being modified to allow pressing collar packs at several locations along the magnet to verify shim sizes. Design modifications to the collar pack assembly fixture were also made.

Additional work was performed on the magnet transporter, principally affecting the air-conditioning system and instrumentation.

Drawings for the horizontal test facility were reviewed prior to fabrication release in the shops. A proposal for a test facility for SSC dipole and quadrupole magnets is in progress.

Mole BI has been bench tested. Coil vibrations have been reduced to acceptable levels. The Mole was utilized in warm measurements on LLN-001 (described more fully under Electrical Systems). Work resumed on the Mole support equipment; meanwhile, the Mole is being prepared for shipment to Fermilab. Work has started on the second Mole, BII.

3. Superconductor

The SSC inner cable (SI-34) manufactured by LBL, but rejected by BNL, will be annealed during the month of May. Labor restrictions have forced this delay in annealing. Due to labor shortages during this month, there was little accomplished in tooling. However, some items were initiated: field testing of the hand-held Keystone Measuring Gauge, and commencement of design modifications to the "On Line Cable Measurement Device" returned to BNL from Fermilab.

4. Tests and Measurements

Heat leak measurements were made on a 4.5 m length of cold bore tube of the type being used in the long SSC dipole. The bore tube was mounted in SLN-015. Additional measurements of the stray field at 7.0 T were also made in SLN-015. Harmonics were measured in LLN-001, both with measuring coil No. 23 (by inserting it in either magnet end) and with the Mole (see Section 5, below). The current excitation was 15 A. Personnel of the Magnet Test Group also assisted with the production of wedges in Bldg. 924, and in the construction of the box for transporting LLN-001 to Fermilab.

5. Electrical Systems

The Mole magnetic measurement system made numerous measurements in the calibration magnet and in LLN-001 (warm measurements) this month. During these measurements the electronic support equipment was tested. Both the speed control system and the speed correction system performed as per specifications. The speed control system provides a coarse control of the speed of the Mole's measurement coil. The speed correction system senses small changes in speed of the measurement coil. This information is used to correct the measured data such that small speed variations do not affect the measurement. Continued testing will verify overall system performance.

6. Cryogenic Systems

Possible conceptual designs for the Accelerated Life Test Cryogenic System have been under review. Two problems which have required some careful consideration are (1) the means to provide refrigeration for the 20 K heat shield and (2) how to provide a quench dewar on short notice for low or zero cost. Some likely solutions have been found and will be reported during May in a conceptual design report on this activity.

Good progress has been made in converting the NBS helium properties computer program to a faster running format for use on PC systems. A factor of three improvement has been achieved for a typical helium system calculation.

B. FNAL.

1. Cryostat Design and Development

a. Cryostat Development

Investigation of reentrant post alternate materials continues. Discussions continue with vendors relative to the nature of the reinforced composites and the resulting material properties. At present, filament winding appears to offer the greatest flexibility to tailor the properties of the composite. Graphite reinforced composites have higher stiffness and strength than glass reinforced composites. Unknowns relative to graphite components needing evaluation are low temperature toughness, coefficient of thermal contraction, thermal conductivity, and coefficient of friction.

A 5 in. x 7 in. post of G11CR construction has been installed in the Suspension Heat Leak Dewar and is being prepared for heat leak measurements.

A test program is being formulated to study the sliding action of the cradle assemblies that connect the cold mass assembly to the support post.

b. Cryostat Design

A program has been initiated to improve the design of the cryostat based on the experiences of the fabrication of the Heat Leak Model II and subsequent long magnet models. The incorporation of the improvements for future models will depend on the nature of the improvement, its cost effect, and the program schedule.

c. Heat Leak Model II

The Heat Leak Model II center section was damaged when it was dropped during the off loading operation at the ER Test Facility. The model was returned to the fabrication facility and disassembled. The items damaged in the incident were the five support posts. The model has been rebuilt reusing all components with the exception of the five posts and the MLI blankets which were replaced with new blankets for reasons of convenience.

The model will be assembled with the end vessels and be prepared for heat leak measurements. Testing at ER is expected to begin in May.

2. Long Magnet Fabrication

a. <u>HLM II-Heat Leak Model</u>

The production, engineering, support and management teams had their emotional levels tested during April.

There was elation when HLM II was loaded for transport to the ER test area, frustration when the cryostat was damaged during the off loading operation, and finally a real sense of pride when all of the related groups worked together seven days a week to rework and rebuild the model. HLM II was ready for transport on April 30 and was actually installed at ER on May 2.

Related to these fabrication operations, a record-keeping system for the rework labor and material costs was initiated. An incident report was prepared describing the rigging failure at ER.

b. <u>SSC Magnet D001</u>

The first magnet cold mass was received at Fermilab on April 25. The assembly together with its trailer was stored in ICB until April 26. The magnet was off loaded under the supervision of both FNAL and BNL engineers and placed on an inspection stand set up to duplicate inspections at BNL.

Initial measurements of the fiducial positions indicate no change during shipment, but as built dimensional tolerances are not to drawing specifications. A complete analysis of data will be complete by May 5 for evaluation. Some mounting parts will require rework to make them work as designed.

The required modifications to the cryostat design and assembly procedures in order to simplify the assembly of D001 have been instituted.

Overtime effort will be utilized to regain some of the time lost due to the cold mass out of tolerance condition. The initial estimated completion date was May 27, 1986. The actual date will be later by as much as two weeks. A record keeping system has been initiated to segregate and log all overtime labor.

Work on upgrading the magnet traveler is continuing during the production operation sequence.

3. Magnetic Measurements

During April, preparations at MTF for testing the first full-length SSC dipoles continued. The 17 meter test stand was aligned and grouted and plates for mounting the magnet were attached; the placement of holes for mounting the feed and turn-around cans will be determined when the cans are complete. Work on the gauge panel and on plumbing to distribute warm high pressure gas (helium for leak checking and nitrogen for running the mole) is well underway. All ac power for the control room and the test stand (separate transformers for instrumentation and vacuum pumps) has been installed. The 10 kA buss from the switchyard to the feed can is complete except for the final bends which await the arrival of the feed can. This buss includes a 7500 A transductor, a 12 kA shunt, a dI/dt bucking coil, and brackets to hold diodes for tests of passive quench protection. Work has begun on stand, power supply, and safety interlocks to allow operation of the power system in the SSC mode as well as any of the previous configurations.

Most of the commercial electronics for the measurement system have been received, including two LeCroy data loggers, a Kinetic Systems transient recorder, a Kiethly scanning DVM system, crate controllers, input registers and a Unibus-GPIB interface. Other electronic modules have been or are being built here. A dual Tevatron quench heater supply has been modified to allow variable voltage operation. Twenty channels of optically isolating amplifiers have been built for the quench detection and data collection system. A module to automatically ramp the main power supply to zero in a controlled manner when a ground fault is detected was designed and built. Four current sources and 25 amplifier channels for resistance thermometry are almost complete. (All resistance thermometers have been calibrated and sent to the Accelerator Department Cryogenics Group for installation in the feed and turn-around cans.) Circuit boards for delay modules (for quench protection experiments) and for the controller for the trim coil power supply have been made but are not yet stuffed.

Code to control the main power supply and monitor the current has been written as well as quench data collection and display code. The Hewlett Packard computer that collects data from the mole was received from BNL at mid-month, and efforts to establish communication between it and the MDTF VAX have begun. A number of "basic building blocks" of the cryogenic data collection and monitoring code have been written, including programs to read the LeCroy data logger and the Kiethly DVM system, and programs to allow data to be passed between the cryogenic monitor process and the main measurement process. A data base system has been established to define the locations (in physical, electronic, and software spaces) of each of cryogenic transducers and to manage the resistance thermometry calibrations.

4. Accelerator R&D

The Collider Power Supply and Quench Protection chapter (5.5) of the Conceptual Design Report was reviewed and edited, as was the cost estimate for these systems. A review of the power supply and quench protection portions of the injector cost estimate was conducted. A presentation of the collider technical design and cost estimate details was made at the DOE review during the last week in April.

A technical memo, TM-1397, "Magnet Current Regulation in the SSC," also designated as SSC-N-161 was written. A few last minute corrections are being made in this document.

The work for the numerical study of the interaction of SSC beam with matter is continuing. The first steps of coding all the various types of interactions up to 20 TeV have been completed and documented. The systematics of the processes are being analyzed and used as input for general Monte Carlo transport calculations. The initial application of the program will be to study the radiation background and the cross-talks of beam-interaction regions.

5. Half-Cell Test Support

The electronics racks have been laid out and installed at the E4 half-cell test site portakamps. Installation of equipment and cabling into these racks is proceeding. Construction of the SECAR ramp control processor is about 90% complete; testing should be underway in May.

a. String Test

Design of the end boxes and turn-around box was completed. One turn-around box for the MTF test was completed. The MTF end can is about 70% complete. Engineering notes for these vessels have been started. Cable tray and cable pulls have been completed at the ER facility. Termination continues. The portakamps have been installed.

b. <u>Low Temperature Operation</u>

A visit was made to the Sulzer plant in Switzerland to look at cold compressors and turbines. DESY was also visited.

c. <u>Power Leads</u>

Leads are in hand for the MTF end box. Problems arose on the outside order for more leads, delaying their arrival. As a result, more leads are being made inhouse.

C. LBL.

1. Superconductor. As we reported in February, both IGC and Supercon experienced poor piece lengths from the first fine filament material being produced for LBL. Several small batches of material were processed under various conditions while the bulk of the material was held at large diameter. These tests showed that the fine filament conductors, with a high tensile strength, as well as a high J_c, required somewhat different processing conditions than strand with 20 μm filament sizes. These relatively minor changes were made at IGC and Supercon; subsequent processing yielded strand lengths an order of magnitude longer than previously obtained. Piece lengths for the latest material processed at Supercon (LBL-2) averaged over 11,000 ft, and only 1% of the material was below the SSC minimum length specification of 2500 ft. While it appears that the piece length problem has been resolved, it is also obvious that we must process a series of 15-20 billets in order to develop a statistical basis for predicting piece length.

Fine filament strand for the fourth full length SSC model to be built at BNL was delivered by Supercon to LBL at the end of April. This material will be cabled and sent to BNL for insulation during May. Additional fine filament material from IGC and OST is scheduled for delivery in May and June. This material will be used for the fifth and sixth long model magnets.

2. High Gradient Quads. Several cross sections of a 2-layer quadrupole were investigated. The latest design has an 8-turn inner and a 12-turn outer layer for a total of 20 turns per octant with 2 wedges, one in each layer. The pole angle for both layers is the same and the iron location leaves room for a 12 mm collar. The gradient at 6500 A is 211.5 (T/m) with good higher harmonics.

3. Analysis.

a. Dipoles. Two dipole cross sections, NC6 and NC7, were calculated. Cross section NC6 is a modified version of NC515 cross section and includes a number of improvements based on the three MD magnets. It is designed for a SS collar and should result in low multipoles (i.e., $b_2 = 1 \pm 1$ units). This cross section is being incorporated into magnets D14-B2 and B3.

Cross section NC7 is an upgraded version of NC6. It is designed, however, for Al collars based on magnet D14-B1. In addition, we have modified the second block in the first layer by tilting it somewhat to be more radial. We have looked into the effect of coil distortions. The available digitized x,y coordinates of magnet MD2 were distorted elliptically by program "02zero" to estimate sextupole sensitivity to such distortions. These estimates were backed up with simplified analytical calculations.

4. Fabrication. The following tasks were carried out during this period:

a) Completed B-1 collaring and yoke assembly.
b) Completed 4 coils to be used in B-2.
c) Orders were placed for modified LBL coil fabrication tooling which will be the same in cross section as BNL's.

During March, dipole B-1 was completed using stamped 15 mm aluminum collars. The collared coil assembly was installed and measured two times in the yoke assembly, with and without a 0.009 in. interference on the horizontal diameter of the yoke assembly. Forces to close the yoke assembly with the interference were about 1200 lbs per inch. Coil prestress during assembly and cooldown was measured. Prestress during cooldown increased about 600 psi on the inner layer.

5. Instrumentation and Measurements.

Magnet D-14B-1, cross section NC515, with 15 mm aluminum collars was tested between April 21 and May 1. The stages of testing are as follows:

a. Magnetic field quality and coil prestress (via strain gauges) were measured during cooldown from 300 K to 1.8 K.

b. The magnet was conditioned at 1.8 K by ramping it to 7.2 tesla, without quenching. Magnetic field and prestress were determined during the current cycle.

c. The magnet temperature was raised to the Helium I value of 4.4 K, and the magnet was quenched to find its plateau value. The first quench was within 2% of the plateau (6.4 tesla), again showing the effectiveness of low temperature conditioning.

d. The magnet was again cooled to 1.8 K and quenched at successively higher temperatures. The quench currents followed the expected rise of critical current with temperature with the 1.8 K value some 30% higher than the 4.4 K value.

e. The magnet was then warmed to 300 K with magnetic field and coil stress measurements taken at numerous temperatures.

f. A second cooldown to check on magnet memory will be carried out in early May.

D. TAC.

1. Superferric Magnets. During the past month many measurements have been made on the first 28 meter General Dynamics' magnet. Measurements along the length of the magnet are made every four feet. These measurements indicate that the variations along the magnet are small. The magnetic field of the 28 meter magnet is the same as with the equivalent 1 meter magnet models. The quench field was equivalent to 3.4 Tesla at 4.5 degrees. TAC therefore feels that the 28 meter magnet has proven that long superferric magnets are very feasible to construct in industry.

Tests on seven 1 meter magnets also show a strong consistency between magnets. Two problems remain in the magnetic field; first is the low field variation and second is the B_6 multipole at high-field. We have chosen to correct both of these at this time. The low-field problems will all be corrected by utilizing iron with approximately 1.6% silicon and less than 0.01% carbon. This will give a coercive force of 0.5 Oersted rather than the present 2.7 Oersted found in our 1008 steel. The B_6 multipole will be corrected by opening the width of our magnet by 0.2 inches in the aperture. The largest multipole will then be 0.4 units. At the same time in making these minor modifications we will also change to 6,000 Amp conductor rather than 12,000 Amps. This doubles the number of turns, but reduces the winding difficulties considerably. As we have always stated, the bulk of the problems in winding a magnet is at the ends. By going to this smaller cable, the end configuration is much easier to achieve. This has been worked out in conjunction with General Dynamics Corporation. With these minor modifications, we feel the Superferric Magnet is now ready for final prototyping and starting of production plans.

2. Correction Magnets.

a. Superconductor

The superconductor ordered from Intermagnetics General Corp. (IGC) was received on May 7, 1986. A total of 293,387 feet was received on 24 spools. Short sample results on this material were 171 Amps at 3T and 4.2K. This is well above the specified 115 Amps at 3T and 4.2K.

b. Flat Conductor

Fabrication of 16 strand conductor on 2 mil Kapton insulation has begun using the IGC superconductor.

c. Superferric Dipole Correction Magnet

Design. The following drawings represent the design of a pre-prototype superferric dipole:

- D16-112 Correction Dipole Assembly
- D116-111 "L" Bracket
- D16-010 End Block
- D16-009 Conductor Pack Mounting Assembly
- B16-008 Side Plate
- D16-007 C-Channel
- D16-006 Beam Tube/Conductor Assembly
- B16-005 Beam Tube
- D16-004 Lamination Outer

Analysis. The design has been analyzed using POISSON. It meets the 1% field accuracy requirement.

Fabrication. The fabrication of a superferric dipole to this design has been completed. Excess FNL superconductor was used in this coil.

Testing. The preprototype superferric (FNL conductor) has been tested. It initially quenched at 85 Amps, after five (5) quenches it reached 109 A. This conductor was of poor quality. It was not expected to meet full current of 100 A.

d. Superferric Sextupole Correction Magnet

A design has been produced for the preprototype superferric sextupole correction magnet:

- D16-205 Assembly of 15 cm Sextupole Magnet
- B16-206 Conductor
- B16-204 Side Plate
- C16-203 C-Channel
- D16-202 Beam Tube/Conductor Assembly
- C16-201 Sextupole Lamination
- B16-200 Cold Iron Lamination

e. Cosine Theta Magnet

Analyses. The cosine theta CDR design for the correction magnets has been analyzed using the POISSON magnetic code. Some changes are required to achieve design fields. TAC has made a cos theta correction magnet design that slightly exceeds the SSC CDR criteria. The design parameters for this modification are shown in Table I. The results of an investigation into the mutual effects associated with this design are shown in Table II.

f. Schedule. The preprototype correction packages (superferric and cosine theta) are nearing completion and will be provided by 1 June 86. With the receipt of the IGC conductor, assembly of the first prototype is close to being on schedule (2 May 1986). The completion of model testing by 1 August 1986 has not been impacted.

3. Quench Diodes

The first radiation test of the quench protection diodes has been performed at the Texas A&M Nuclear Science Center. Sixteen diodes were tested in two groups, eight at room temperature and eight near liquid nitrogen temperature. Each group of eight diodes consisted of four R9 diodes and four RA20 diodes. The reactor was operated at 100 kW for approximately five hours over a period of approximately nine hours of clock time.

Electrical performance tests were performed on the diodes at periodic intervals during the irradiation procedure. The forward voltage of each diode was measured as a function of current in the range of 0-20 adc. High current pulses of approximately 1000 A were also used to measure the forward voltage drop of each diode. These data are currently being analyzed to determine the damage to the diode as a function of dose.

PRIMARY COS θ CORRECTION

	B(1cm) Required (T)	Inner Radius mm	Outer Radius mm	Strands Per Cable	Cable Layers PerPole	Turns Per Pole	B(1cm) (T) Achieved	B(1cm) (T) Achieved
Beam Tube	--	16.5	18.0	--	--	--	--	
Dipole	2.12	18.5	25.82	16	38	608	2.17	2.1754
Sextupole	0.09	30.82	34.02	7	21	147	0.092	0.0923
Quadrupole	0.40	39.02	43.13	9	40	360	0.41	0.4116
Steel	--	50.00	103.00	--	--	--	--	
							Approximate Formulas	POISSON

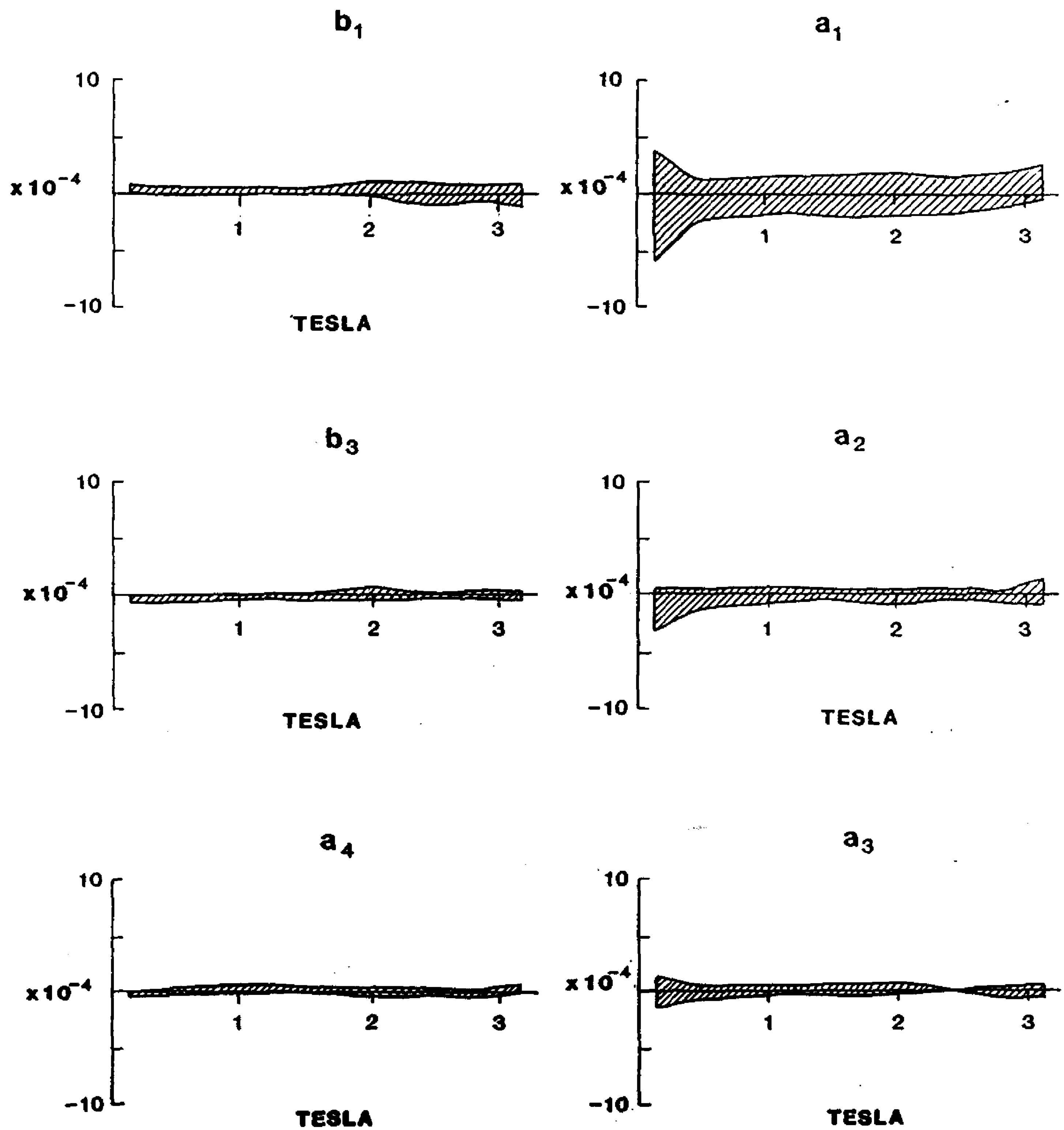
Current = 100 A
Strand Dia. = 0.018 in.
Kapton = 0.002 in

TABLE 1

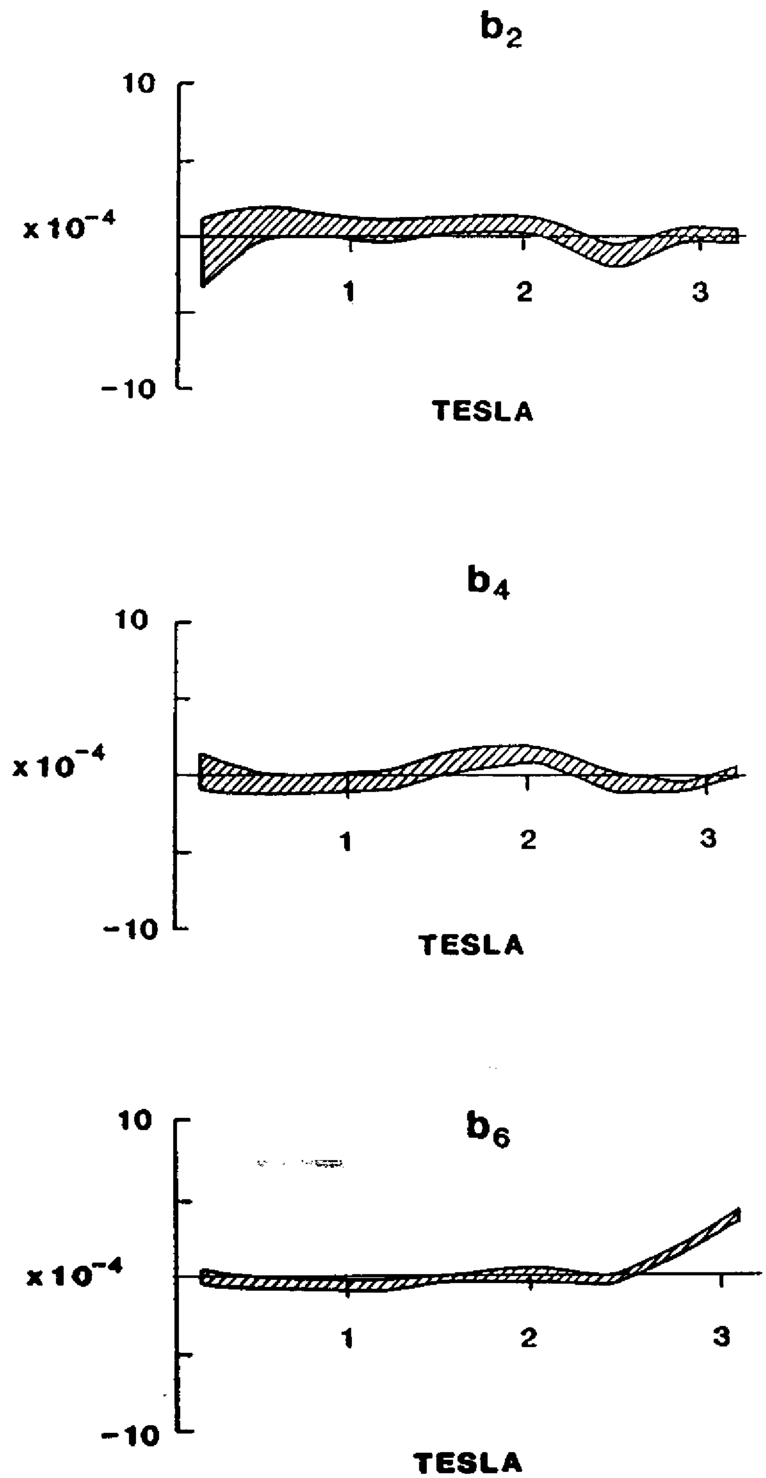
MUTUAL EFFECTS

Excited Coils	$B_o(T)$	$b_1(T)$	$b_2(T)$
Dipole	2.1754	--	--
Quadrupole	--	0.4116	--
Sextupole	--	--	0.0923
D+Q	2.1753	0.4115	--
D-Q	2.1753	-0.4115	--
D+S	2.1756	--	0.0920
D-S	2.1753	--	-0.0926
Q+S	--	0.4116	0.0923
Q-S	--	0.4116	-0.0923

TABLE 2



b₁
a₁
b₃
a₂
a₄
a₃
10
$x10^{-4}$
-10
1
2
3
TESLA



NOTE b_2 & b_4 CA BE CENTERED AT ALL POINTS BY ADJUSTING CURRENT RATIOS.

C. PROJECT COST DATA
(Index)

TABLE C-1

CENTRAL DESIGN GROUP - SUPERCOLLIDER

APRIL 1986 COST REPORT (K$)

	PROGRAM ELEMENT	LABOR	MAT'L & SERVICES	G & A	MONTH TOTAL	YEAR TO DATE	ANNUAL BUDGET
1.1	ADMINISTRATION	93	135	96	325	1736	2710
1.2	PROGRAM PLANNING & MANAGEMENT	24	2	13	39	237	650
1.3	ACCELERATOR R & D	99	51	65	214	1312	4018
1.4	CONVENTIONAL SYSTEMS DEVELOP.*	54	310	34	398	2161	2560
	PROGRAM COSTS	270	498	208	976	5446	9938
	COMMITTMENTS					101	
	CHANGE IN COMMITTMENTS (Delta)					-121	

*Includes RTK Costs

TABLE C-2

BROOKHAVEN NATIONAL LABORATORY - SUPERCOLLIDER

APRIL 1986 COST REPORT (K$)

	PROGRAM ELEMENT	LABOR	MAT'L & SERVICES	G & A	MONTH TOTAL	YEAR TO DATE	ANNUAL BUDGET
2.1	MAGNET FABRICATION	106	106	76	288	1824	3020
	PROGRAM COSTS	106	106	76	288	1824	3020
	COMMITMENTS					416	
	CHANGE IN COMMITTMENTS (Delta)					169	
	EQUIPMENT	16	0	0	16	64	250

TABLE C-3

FERMI NATIONAL ACCELERATOR LABORATORY - SUPERCOLLIDER

APRIL 1986 COST REPORT (K$)

	PROGRAM ELEMENT	LABOR	MAT'L & SERVICES	G & A	MONTH TOTAL	YEAR TO DATE	ANNUAL BUDGET
3.1	GENERAL	0.2	-1.7	-0.4	-1.9	91.4	140
3.2	CRYOSTAT DESIGN & DEVELOPMENT	15.2	8	7.1	30.3	418.6	960
							1300
3.3	LONG MAGNET FABRICATION	112.4	62	53.7	228.1	1208.9	
3.4	MAGNETIC MEASUREMENTS	28.9	29.2	18	76.1	242.5	600
3.4A	CRYOGENIC SYSTEM	0	16.7	5.2	21.9	38.5	42
	PROGRAM COSTS	156.7	114.2	83.6	354.5	1999.9	3042
	COMMITMENTS					146.1	
	CHANGE IN COMMITTMENTS (Delta)					-28.8	
	EQUIPMENT				12.7	282.9	550

TABLE C-4

LAWRENCE BERKELEY LABORATORY - SUPERCOLLIDER

APRIL 1986 COST REPORT (K$)

	PROGRAM ELEMENT	LABOR	MAT'L & SERVICES	G & A	MONTH TOTAL	YEAR TO DATE	ANNUAL BUDGET
4.1	GENERAL	8	1	5	14	64	120
4.2	SUPERCONDUCTOR	10	0	5	15	150	560
4.3	HIGH GRADIENT IR QUADRUPOLES	-21	0	-11	-32	78	270
4.4	MAGNET MODELS	107	4	55	166	474	450
	PROGRAM COSTS	104	5	54	163	766	1400
	COMMITMENTS					251	
	CHANGE IN COMMITTMENTS (Delta)					-55	

TABLE C-5

TEXAS ACCELERATOR CENTER - SUPERCOLLIDER

APRIL 1986 COST REPORT (K$)

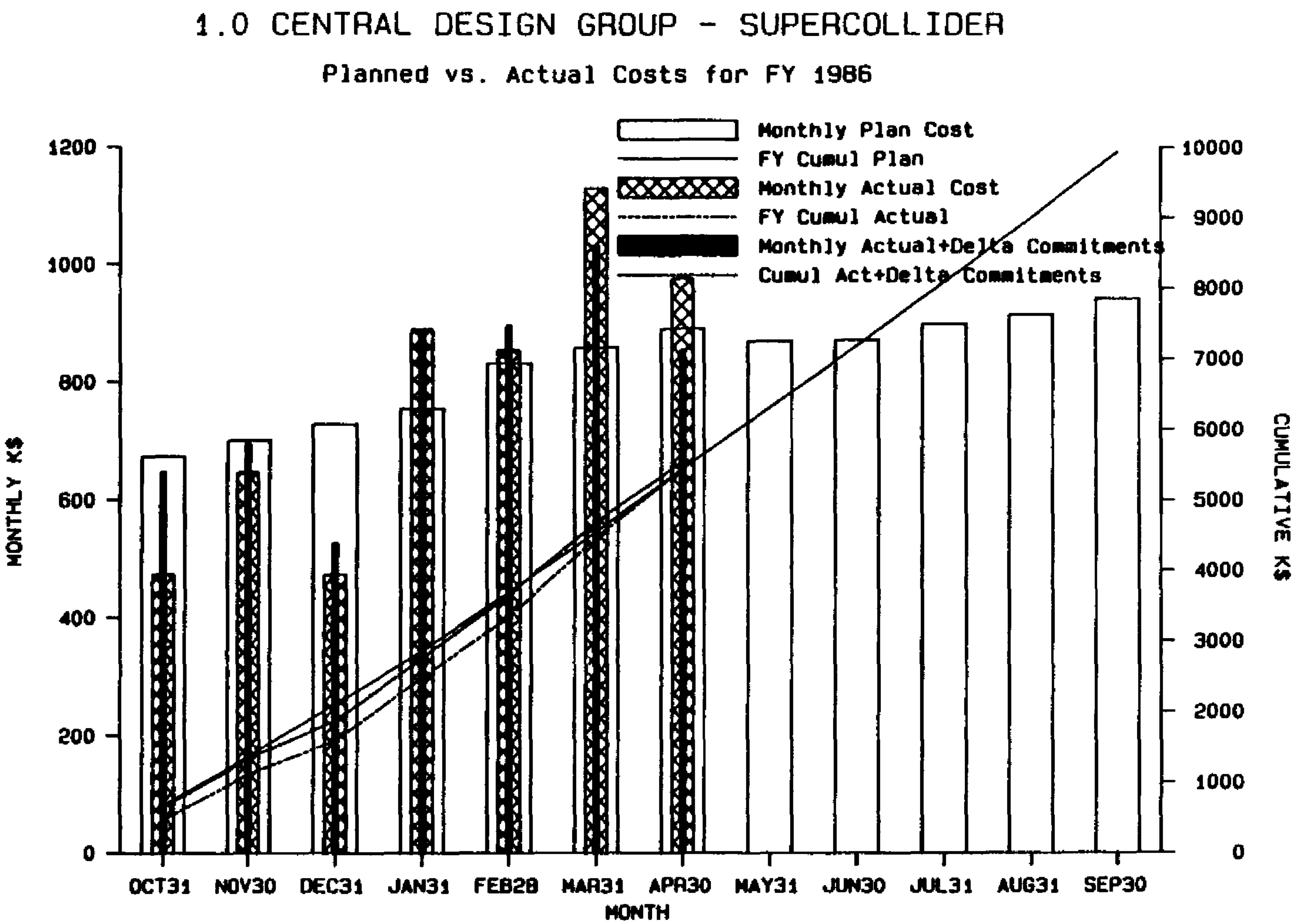
	PROGRAM ELEMENT	LABOR	MAT'L & SERVICES	G & A	MONTH TOTAL	YEAR TO DATE	ANNUAL BUDGET
5.1	DIODE QUENCH PROTECTION	8.2	11.9	27.7	47.8	109.8	550
5.2	CORRECTION ELEMENTS	7.5	0.5	18.9	26.9	184.5	1025
5.3	ACCELERATOR PHYSICS	3	0.4	7.6	11.0	67	275
5.4	SUPERFERRIC MAGNET	31.8	44.7	106.8	183.3	786.3	750
	PROGRAM COSTS	50.5	57.5	161	269.0	1147.6	2600
	COMMITMENTS					429	
	CHANGE IN COMMITTMENTS (Delta)					26.2	

TABLE C-6

PROGRAM SUMMARY - SUPERCOLLIDER

APRIL 1986 COST REPORT (K$)

	PROGRAM ELEMENT	LABOR	MAT'L & SERVICES	G & A	MONTH TOTAL	YEAR TO DATE	ANNUAL BUDGET
1.	CDG PROGRAM	270	498	208	976	5446	9938
2.	BNL SSC PROGRAM	106	106	76	288	1824	3020
3.	FNAL SSC PROGRAM	157	114	84	355	2000	3042
4.	LBL SSC PROGRAM	104	5	54	163	766	1400
5.	TAC SSC PROGRAM	51	58	161	269	1148	2600
	TOTAL SSC PROGRAM COSTS	688	781	583	2051	11184	20000
	COMMITMENTS					1343	
	CHANGE IN COMMITTMENTS (Delta)					-10	



	FISCAL YEAR 1986											
	OCT31	NOV30	DEC31	JAN31	FEB28	MAR31	APR30	MAY31	JUN30	JUL31	AUG31	SEP30
Monthly Plan	674	701	728	755	832	859	891	870	872	899	916	943
FY Cumul Plan	674	1375	2103	2858	3690	4549	5440	6310	7181	8080	8995	9938
Monthly Actual	474	647	473	890	855	1130	976					
FY Cumul Actual	474	1121	1594	2484	3339	4469	5445					
Actual+Delta	648	696	527	890	897	1033	855					
Cumul Act+Delta	648	1344	1871	2761	3658	4691	5546					

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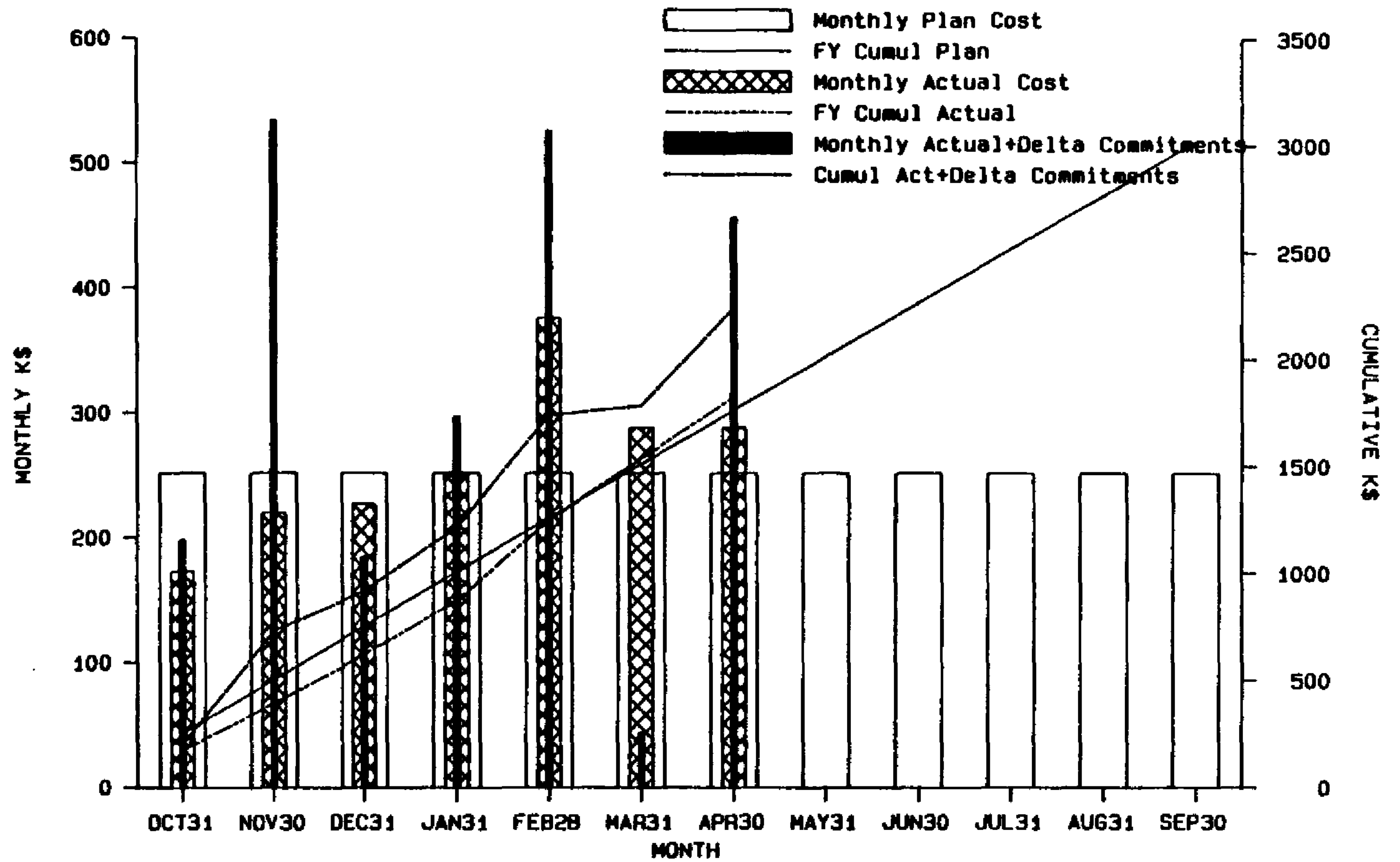
28-MAY-86

Figure 1

2.0 BROOKHAVEN NAT'L LAB - SUPERCOLLIDER

Planned vs. Actual Costs for FY 1986



	FISCAL YEAR 1986											
	OCT31	NOV30	DEC31	JAN31	FEB28	MAR31	APR30	MAY31	JUN30	JUL31	AUG31	SEP30
Monthly Plan	252	252	252	252	252	252	252	252	252	252	252	252
FY Cumul Plan	252	503	755	1007	1258	1510	1762	2013	2265	2517	2768	3020
Monthly Actual	173	220	227	252	376	288	288					
FY Cumul Actual	173	393	620	872	1248	1536	1824					
Actual+Delta	198	534	185	297	525	44	457					
Cumul Act+Delta	198	732	917	1214	1739	1783	2240					

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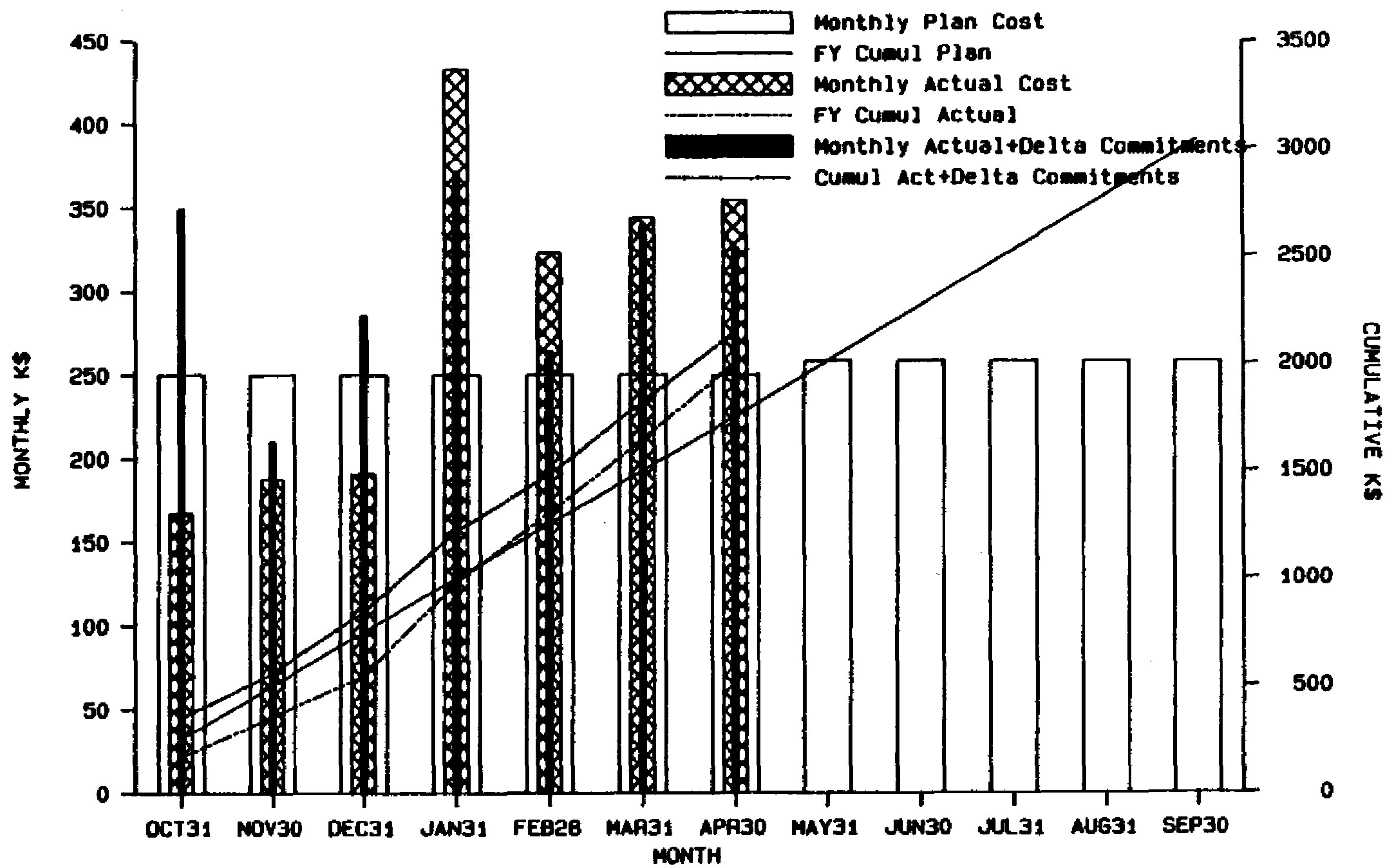
Figure 2

3.0 FERMI NAT'L ACCEL LAB - SUPERCOLLIDER

Planned vs. Actual Costs for FY 1986



	FISCAL YEAR 1986											
	OCT31	NOV30	DEC31	JAN31	FEB28	MAR31	APR30	MAY31	JUN30	JUL31	AUG31	SEP30
Monthly Plan	250	250	250	250	250	250	250	258	258	258	258	258
FY Cumul Plan	250	500	750	1000	1250	1500	1750	2008	2267	2525	2784	3042
Monthly Actual	167	188	191	433	323	344	355					
FY Cumul Actual	167	355	546	979	1301	1645	2000					
Actual+Delta	349	210	285	372	264	339	326					
Cumul Act+Delta	349	560	845	1217	1481	1820	2146					

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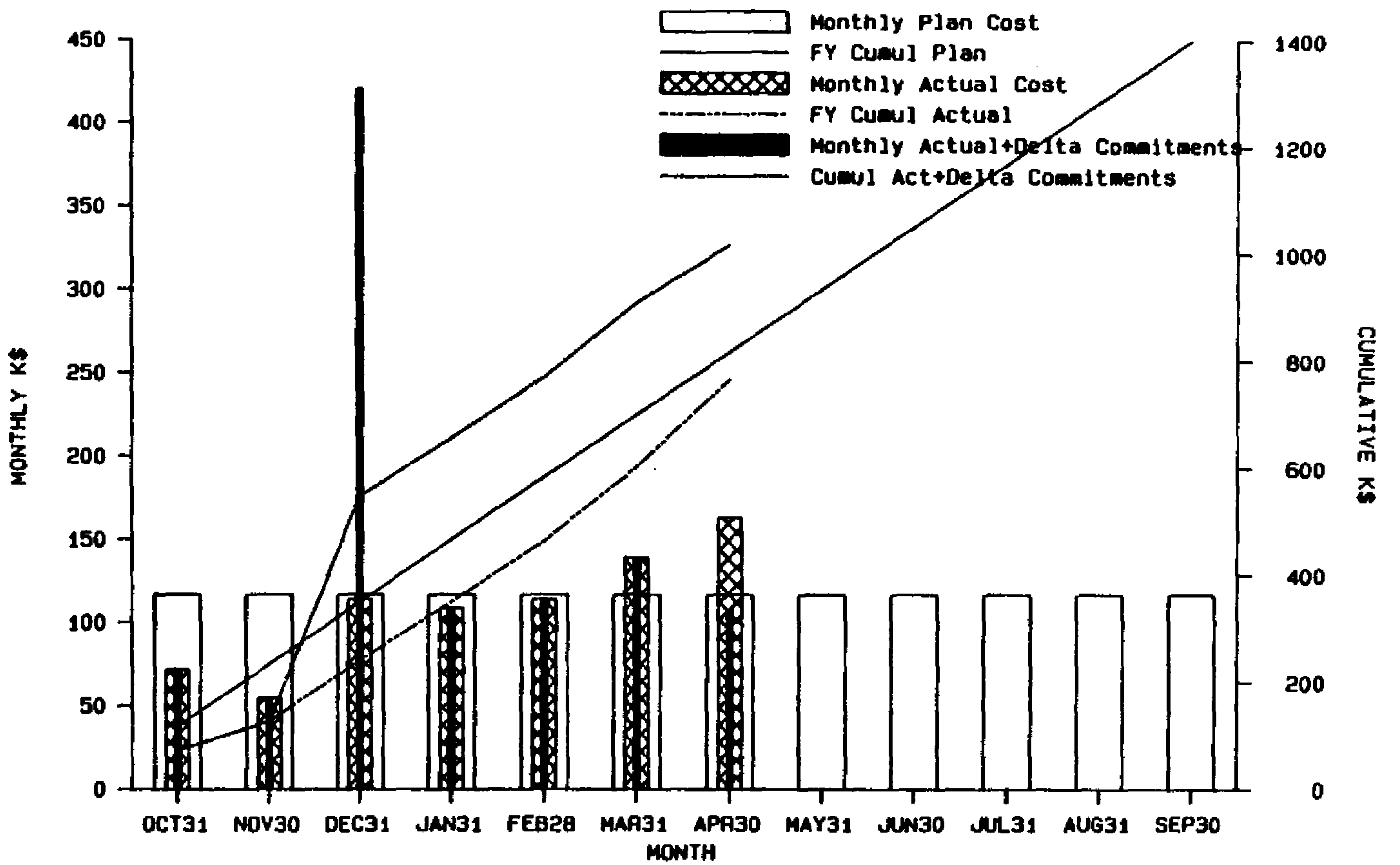
Figure 3

4.0 LAWRENCE BERKELEY LAB - SUPERCOLLIDER

Planned vs. Actual Costs for FY 1986



	FISCAL YEAR 1986											
	OCT31	NOV30	DEC31	JAN31	FEB28	MAR31	APR30	MAY31	JUN30	JUL31	AUG31	SEP30
Monthly Plan	117	117	117	117	117	117	117	117	117	117	117	117
FY Cumul Plan	117	233	350	467	583	700	817	933	1050	1167	1283	1400
Monthly Actual	72	55	114	109	114	139	163					
FY Cumul Actual	72	127	241	350	464	603	766					
Actual+Delta	72	55	420	109	114	139	108					
Cumul Act+Delta	72	127	547	656	770	909	1017					

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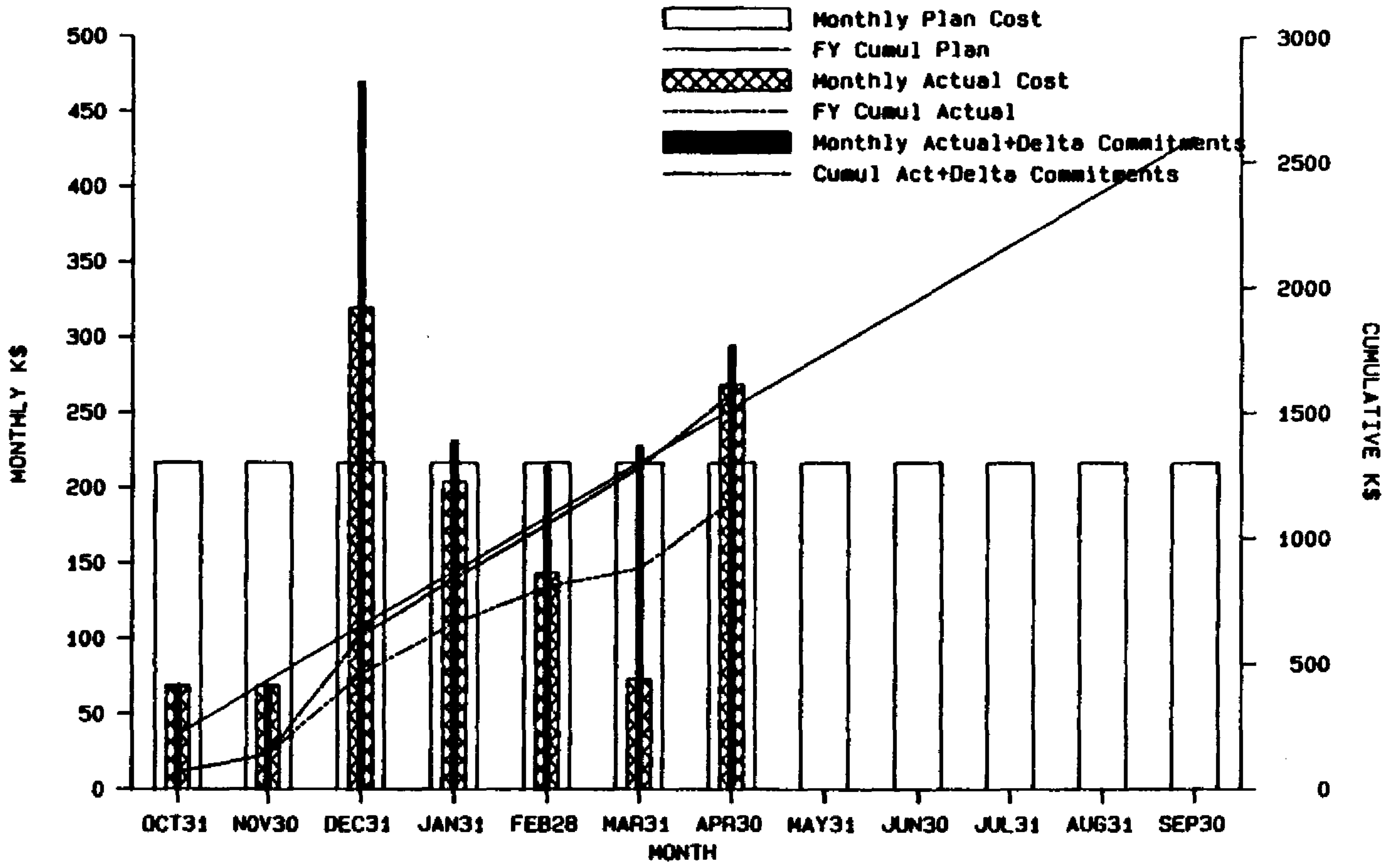
28-MAY-86

Figure 4

5.0 TEXAS ACCELERATOR CENTER - SUPERCOLLIDER

Planned vs. Actual Costs for FY 1986



	FISCAL YEAR 1986											
	OCT31	NOV30	DEC31	JAN31	FEB28	MAR31	APR30	MAY31	JUN30	JUL31	AUG31	SEP30
Monthly Plan	217	217	217	217	217	217	217	217	217	217	217	217
FY Cumul Plan	217	433	650	867	1083	1300	1517	1733	1950	2167	2383	2600
Monthly Actual	69	69	320	204	144	73	269					
FY Cumul Actual	69	138	458	662	805	879	1148					
Actual+Delta	69	69	470	231	214	228	295					
Cumul Act+Delta	69	138	608	839	1053	1281	1577					

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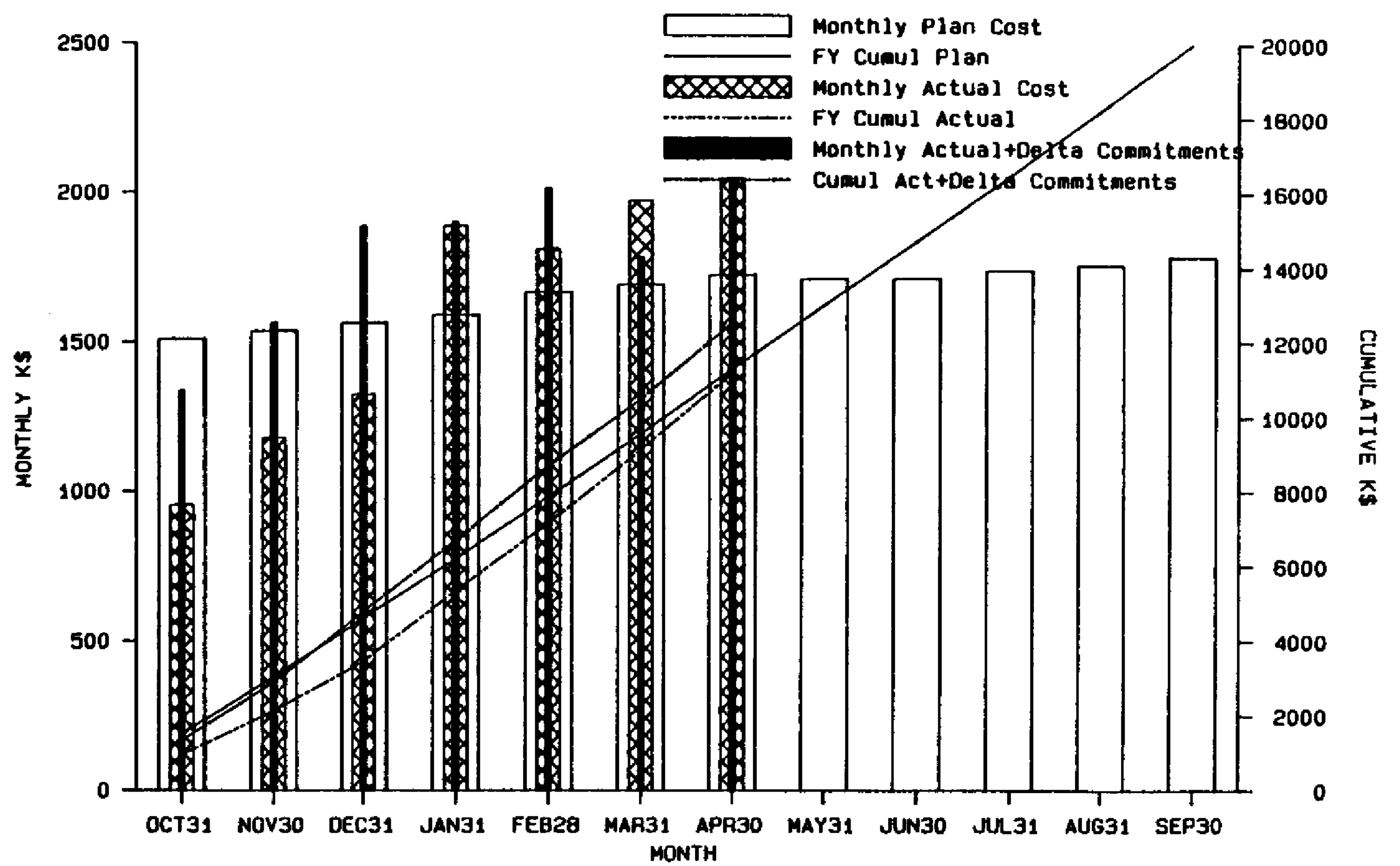
28-MAY-86

Figure 5

0.0 PROGRAM SUMMARY - SUPERCOLLIDER

Planned vs. Actual Costs for FY 1986



	FISCAL YEAR 1986											
	OCT31	NOV30	DEC31	JAN31	FEB28	MAR31	APR30	MAY31	JUN30	JUL31	AUG31	SEP30
Monthly Plan	1509	1536	1563	1590	1667	1694	1726	1713	1715	1742	1759	1786
FY Cumul Plan	1509	3045	4608	6198	7865	9559	11285	12998	14713	16455	18214	20000
Monthly Actual	955	1179	1324	1888	1812	1974	2051					
FY Cumul Actual	955	2134	3458	5346	7158	9132	11183					
Actual+Delta	1336	1564	1887	1900	2014	1784	2041					
Cumul Act+Delta	1336	2901	4788	6687	8701	10485	12526					

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Figure 6