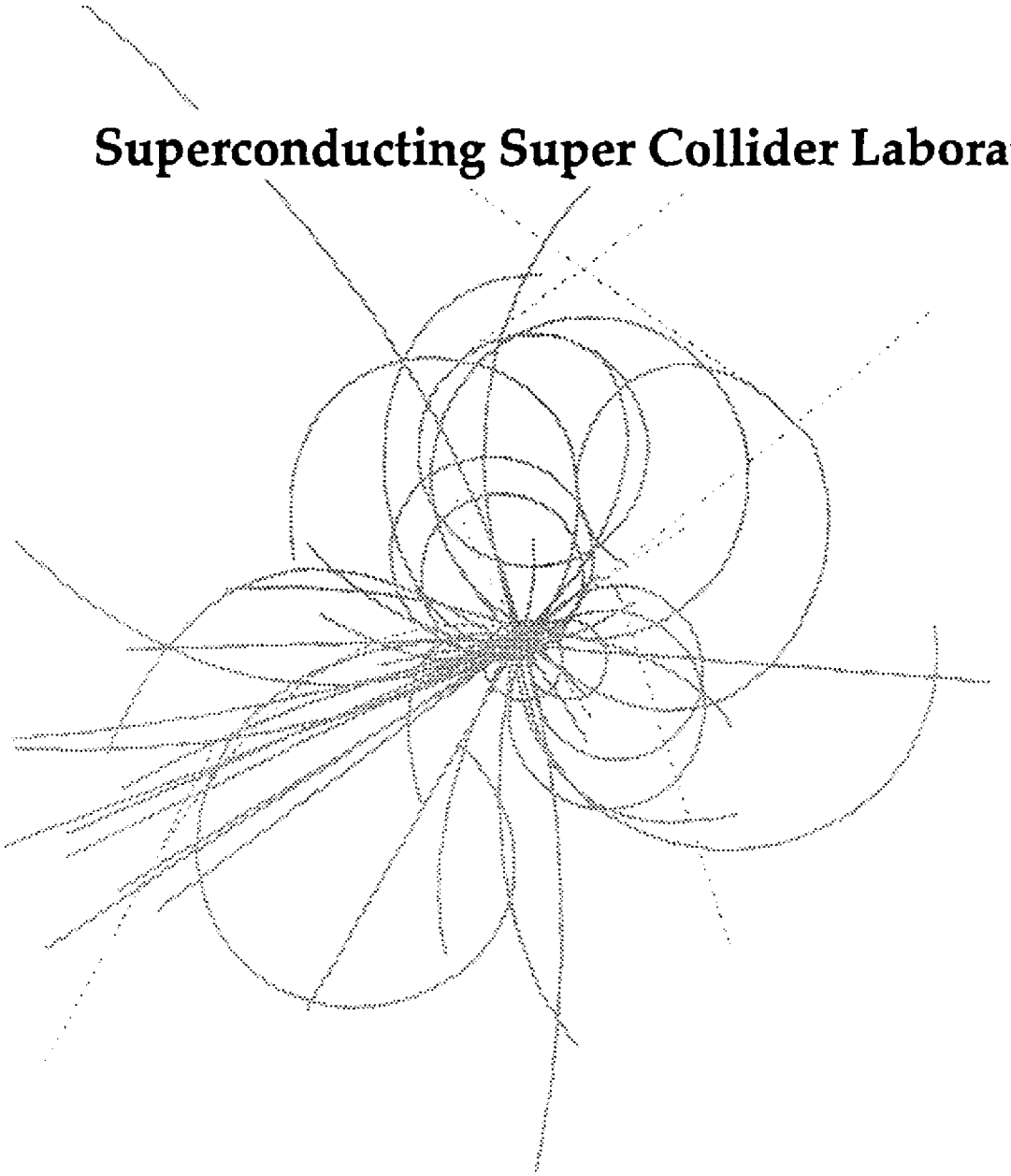
SSC-69

# Superconducting Super Collider Laboratory

SSC-69



# SSC Monthly Report

March 1986

SSC MONTHLY REPORT SSC-69

MARCH 1986

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SSC MONTHLY REPORT

MARCH 1986

## A. Project Summary

### Central Design Group (CDG)

- A major milestone was met on March 31 with the submission of the Conceptual Design Report (CDR) to DOE in Washington. Copies will be available June 1.

- The Magnet Program Advisory Panel met at the CDG on March 6 and 7.

- The Underground Technology Advisory Panel met at the CDG on March 17 and 18.

- The Off-Line Computing Advisory Panel met on March 21 and 22. This Panel has the function of estimating the cost of the initial computing facilities at the SSC. Members are Charles Dickens and Paul Kunz, SLAC; Irwin Gaines and Jack Pfister, Fermilab; Laurence Littenberg, BNL; and Stewart Loken, LBL, Chairman.

- A study was made in March on the range of variation of interaction region optics. It was found that $\beta^*$ can be reduced from the nominal 0.5 m to 0.4 m if the maximum gradient of the triplet quadrupoles can be increased from 230 T/m to 270 T/m, corresponding approximately to lowering the operating temperature from 4.35K to 2K.

- To simulate synchrotron oscillation under a wide range of SSC conditions requires a tracking program that is extremely efficient and yet carries all the essential information that determines the particle stability. To this end, a concatenation scheme that is valid to 4th order in x and y coordinates and numerically fits the nonlinear $\Delta E/E$ behavior is being developed.

- The space charge centrifugal force, whose importance in electron accelerators was recently suggested by Talman, was investigated for the SSC. It was found that the effect was negligible.

### Brookhaven National Laboratory (BNL)

- Major activities centered on the coil assembly and collaring of the first full length dipole magnet. Inner and outer coils were also wound and cured for the next dipole. The first one is on schedule and is expected to be shipped to Fermilab the end of April.

Fermi National Accelerator Laboratory (FNAL)

- The first SSC cryostat (Heat Leak Model II) was successfully completed in March. The objectives of HLM II were two. First it was intended to shake down the design and assembly procedure. A number of improvements have been proposed as a result of this exercise; some of these can be implemented immediately. The assembly of the first complete magnet can now be carried out with confidence.

- The second purpose of HLM II is to measure the thermal performance. These measurements will include not only heat leak but also stress and temperature profiles during cool down/warm up cycling. HLM II, however, was damaged while being unloaded at the ER test site. It has been returned to the industrial area to evaluate the extent of the damage.

- Design refinements to the cryostat and suspension are being evaluated. Use of graphic fiber tubes in place of G-11 tubes in the suspension, for example, is being studied.

- Modifications and additions to MTF to allow the measurement of the first SSC magnets continue.

- The enclosure for the ER string test is being assembled from old main ring tunnel loops. The refrigerator is installed.

Lawrence Berkeley Laboratory (LBL)

- We completed and tested our third magnet having the new 4-wedge cross-section; after testing of MD-1 and MD-2, sections were cut from each magnet, position of each conductor was measured and compared with the "design" position. The measured field was compared with predictions based on the measured position; agreement was good. MD-3 was "conditioned" by ramping it to 7.2 T in HeII without quenching; this eliminated training when it was subsequently tested at 4.4 T. After warm-up and retesting, no-training was experienced.

- 18,000 ft. of cable was completed for use in long models 2 and 3 at BNL.

- Preliminary designs were completed for high gradient quadrupoles.

Texas Accelerator Center (TAC)

- Efforts at TAC centered around correction magnets, quench diodes, and superferric magnets.

## B. Project Report

### I. Central Design Group

Magnet Program. During this month the Conceptual Design was finalized together with the supporting cost estimate and schedule. The CDG cost estimate and schedule was well supported by input from the industry.

The CDG initiated effort to construct an integrated analytical model of the magnet. We have chosen NIKE3D--a vectorized, implicit finite deformation, finite element code. This code has the capability of analyzing the static and dynamic responses to diverse time dependent load input conditions; thermal stress obtained simultaneously by utilizing heat transfer subroutines.

The following operational loads and conditions will be included: (a) the operational helium pressure and temperature gradients; (b) quench generated helium pressure and temperature, (c) eddy current induced loads; (d) assembly loads; and (e) cyclic loading both thermal and structural.

A Magnet System Integration meeting was held on March 11-12 at BNL. The status and progress of the 17.4 meter model was again the main topic of discussion. The agenda for this meeting is provided in Table 1.

Conventional Systems. The RTK report, Attachment C to the Conceptual Design Report, was completed in March and transmitted to DOE. Final review and revisions were made to Chapter 6 of the CDR in order to meet the March completion date. Preparations for the April 1 DOE review were also completed. Funding for the RTK contract has almost been completely expended. If more than a few man-week's of effort is required for the DOE review of April 28, 29 and 30; additional funding will need to be placed on the RTK contract.

Table 1

AGENDA FOR MAGNET SYSTEM INTEGRATION MEETING
Brookhaven National Laboratory

March 11-12, 1986

Tuesday, March 11, 1986

| | | | |
|---|---|---|---|
| I. | Overview from CDG | Karpenko | 9:00 |
| | Status of CD | | |
| | R/D Plans FY86-FY87 | | |
| | Status of Industrialization | | |
| II. | Long Magnet Model Program Status | | 9:30-4:30 |
| | 1. Cold Mass Assembly Status | Schneider | 1 hour |
| | 2. Quench Pressures, Temperature Gradients | Shutt | 1 hour |
| | 3. Cryostat Status | Engler | 30 min |
| | Design & Fabrication Schedule | | |
| | Tour of Fabrication Facilities | | 12:40-1:40 |
| | 4. Tests at MTF | | |
| | Test Protocol | Strait | 30 min |
| | Test Parameters | | |
| | 5. Mole Status | Willen | 20 min |
| | 6. Half Cell Test | Strait/Fisk | 30 min |
| | E4 Progress | | |
| | Test Protocol | | |
| | Schedule | | |
| | 7. Interconnection | Carson | 30 min |
| Parallel sessions topics to be selected | | | 3:30-5:00 |

Wednesday, March 12, 1986 9:00-12:00

| | | |
|---|---|---|
| III. | Summary Sessions | 1 hour |
| IV. | Incorporation of R/D Results in Next Magnet Series | 2 hours |
| | Coil Cross Section | |
| | Cryostat Configuration | |
| | Collaring | |
| | Conductor | |
| | Ends | |
| | etc. | |

Accelerator Systems. The main efforts of the Accelerator Systems Division for the month of March were on the Conceptual Design Report, R&D, and correction magnets. As far as the Conceptual Design Report, all the cost estimates for the technical systems were checked for consistency and double counted with one another and with other systems. Preparations also started for the DOE review of the CDR.

a. R&D

1. TAC

A visit to TAC was made on March 17 to check progress on the bypass diode test program and the correction element development program. Progress is being made although there are some problems.

Reports. An interim report from TAC on the subject of diodes is due at the beginning of April. An interim report on the hardware necessary for the correction element R&D was due in February and has not yet been received. Detailed designs of dipole and sextupole correction elements are due at the beginning of April. Lack of detail in technical reports make calculations difficult.

Bypass diodes. For the diode program, some heat sinks and test fixtures are being made in order to mount diodes and test them in helium dewars. This work is to be done before any radiation exposures are attempted, by agreement with the CDG. Westinghouse has delivered about 20 unencapsulated RA-20 diodes. Tests should start in a few weeks.

Correction magnets. A model of about 1 m in length of a superferric dipole corrector is being made and should be tested soon. This magnet is being constructed out of strand received from Fermilab. The 200 pounds of wire that were transferred to TAC from

Fermilab by the CDG is presently being processed (as of the end of the month, no report of the testing of the correction dipole has reached the CDG).

Calculations of the 3-D fields of the superferric correction magnets are moving very slowly. This work is being held up by transfer of code from one computer to another and by lack of a legal agreement with the writer of the code.

Design of cos theta types of correction magnets has evidently not progressed well.

The designs of the correction coils that were submitted to CDG for inclusion in the CDR were found on inspection to be unsatisfactory. Alternate designs were calculated by the CDG staff, and the TAC-supplied cost estimates were modified by the CDG to reflect the changes.

2. Fermilab

Fermilab is proceeding satisfactorily on the construction of the E4 test area for the Half-Cell Test. The pole building that will serve as the head house for the test is constructed, the floor has been poured, and it is being finished inside. It appears that Fermilab is roughly on schedule, and the test area will not be a critical path item in the Half-Cell Test.

Accelerator Theory and Computation. The main effort in March has been to complete the accelerator physics part of the Conceptual Design Report. Several studies made in February and March in connection with the CDR are documented as SSC reports and notes. (This effort of documenting the study results is expected to continue into April.) In addition, the parameters list for the CDR has been finalized.

A study was made in March on the range of variation of interaction region optics. It was found that $\beta^*$ can be reduced from the nominal 0.5 m to 0.4 m if the maximum gradient of the triplet quadrupoles can be increased from 230 T/m to 270 T/m, corresponding approximately to lowering the operating temperature from 4.35K to 2K. This will keep the maximum beta function in the triplets fixed at 8000 m and allows luminosity to increase by 20% without increasing the beam intensity. Another study of the IR optics shows that the IR pairing that helps to reduce the chromatic aberrations does not rule out the possibility of operating two adjacent IRs with different values of $\beta^*$ in the range between $\beta^* = 0.5$ m to 6 m.

It was found, assuming the superconducting filament of 5 μm diameter, that both the systematic sextupole and decapole fields are most efficiently corrected by bore tube windings in the bending magnets rather than lumped multipole correctors in the spool pieces. In the CDR, these multipole field errors are corrected by a combination of a two-layered bore tube windings and fine adjustments during operation. A study is initiated to investigate the possibility of using single-layered windings which in principle can include other multipole components if desired.

To simulate synchrotron oscillation under a wide range of SSC conditions requires a tracking program that is extremely efficient and yet carries all the essential information that determines the particle stability. To this end, a concatenation scheme that is valid to 4th order in x and y coordinates and numerically fits the nonlinear $\Delta E/E$ behavior is being developed. The map is symplectic and is potentially much faster than the tracking schemes used so far. After being developed, this program will be checked against the other more elaborate tracking programs.

The space charge centrifugal force, whose importance in electron accelerators was recently suggested by Talman, was investigated for the SSC. It was found that the effect was negligible. The chromaticity contribution due to this effect is about 1 unit, which is much smaller than the natural chromaticity of about 200.

## II. Laboratory Programs

### A. BNL.

1. Analytical Studies. A search is underway for a coil configuration to replace C5, which has an undesirable $b_8$ term, and NC515, which uses different coil radii and cable thicknesses than are currently used for coil design at BNL. The best configuration found so far, termed C139, has harmonic content about the same as NC515 and a transfer function of 10.441 G/A, about 1% higher than NC515. Like C5 and NC515, it has a total of 36 turns, 16 in 4 blocks in the inner and 20 in 2 blocks in the outer layer and a minimum wedge thickness of 20 mils. C139 has maximum angles at the poles of 75.87 (inner) and 47.96 (outer) compared to 77.00 and 48.63 in NC515. The coil radii are the same as C5 and the turn thicknesses of both inner and outer are 0.25 mil greater than used in designing C5.

2. Model Magnets. Considerable progress was made on the first two full-length dipoles during the month of March, as noted in the summary, and discussed in some detail below:

- Dipole LLN-001 was successfully collared despite a coil-to-ground short caused by a metal chip on the inner, upper coil, which was repaired. Residual average stress in the coils after collaring was better than achieved in the past: 9 kpsi in the inner coil and 7 kpsi in the outer coil. Maximum collaring stress prior to key insertion was 17 kpsi. A report is being prepared.

- Several important design changes were incorporated in this magnet. For example, a spot heater with an insulation scheme was prepared. Also, the G-10 collar-dog bone insulation spacer to permit proper forced helium flow was redesigned and incorporated. The inner and outer coil wedge tips were redesigned.

- As a result of discussions with Fermilab, a pressure tap was added to the center of the magnet, and temperature sensors were added at the bore tube ends. This will permit an estimate of the pressure and temperature rise during a quench.

- Assembly of the upper shell for LLN-001 has started. This requires that shells be placed on the rotating fixture and circumferential welds be made to anchor the 56 ft overall long half-shell.

- The two 60-ft copper bus lead subassemblies have been straightened, soldered with superconductor along the entire length, insulated with Kapton, installed in the pultrusion, and the ends formed to the proper configuration for installation in a magnet.

- The inner and outer coils for LLN-002 were wound and cured. All four required considerable time each to wind, because "popped" wires in the cable needed to be repaired. These four coils were loaded to 10 kpsi every inch of straight section to check for turn-to-turn shorts. Only one short was found on one of the inner coils, and it was repaired. Regarding coil curing, a computerized curing cycle program was developed for the outer coils.

- A preliminary data base traveler was forwarded to Fermilab. The current one has been revised, and additional travelers are being added. These cover:

  a. Magnet assembly and welding--detailed instructions cover order of stacking and welding, leak check procedures, and mechanical tests.

  b. Helium containment interconnections--detailed instructions cover sequence of parts installation, electrical tests, and welding tools used.

  c. Magnet shipping--gives detailed instructions on strain gauge data, accelerations, etc. In line with this traveler, we are preparing to take strain gauge data at Fermilab at both 4K and 300K.

- In terms of the R&D program, work has started on modeling fiberglass-epoxy collars to investigate the effect of widening them in order to reduce prestress loss in the press due to insufficient overall collar stiffness. In addition, a Technical Note has been prepared on the radiation resistance of Rogers RX630 which will be used in SSC coil components.

- The first full-length trim coil assembly was incorporated in LLN-001. The second trim coil is ready and awaiting shipment to Bldg. 905. Material is being prepared for additional trim coils to be manufactured at Multiwire.

- One-foot copper coated bore tube samples, plated at PCK, have been completed and shipped to LBL for evaluation.

3. Tooling and Facilities

   a. Coil Fabrication Tooling

   - Drawings for 1.7 m inner SSC winding and curing mandrels were completed.

   - Form blocks for the 1.7 m inner SSC curing tooling are progressing in the design room.

b. Coil and Yoke Assembly Tooling

- The collaring cradle was completed and ready for use with LLN-001 on schedule.

- Considerable progress was made on all of the magnet assembly tooling. For example, the interplant coil collar-yoke cart was completed. An extension to facilitate handling the collared coil was added to the lifting beam. The magnet alignment and rotating tooling were revised.

- Restarted design work on the pre-production collaring press capable of 30K pounds per linear inch.

c. Beam Tube and Trim Coil Tooling

- Work is continuing to set up tooling for the plating of 4.5 m bore tubes.

4. Magnet Test Facility

Considerable progress has been made on the horizontal test facility, since funds were appropriated enabling this project to start in FY 1986:

- All shop requests for the work to be done were prepared. Casters, flexible hoses, etc., were ordered.

- A cost estimate for completing the project was prepared.

Significant progress was made on the Mole, warm bore tube, and associated equipment during the past month.

- Assembly of Mole B is finished. Such tests and modifications to reduce coil and drive vibrations are underway. Tests have also started on assembling all of the Mole documentation to be sent to Fermilab in April.

- Mole support equipment is also proceeding. The Mole purge system has been assembled and is awaiting tests. Work has started on preparing for warm measurements on LLN-001.

- The warm bore tube prototype is undergoing tests in SLN-015. The heat load appears to be higher than in previous warm fingers. Additional tests are anticipated. The long bore tube is being assembled. A solder joint has been made and leak checked. Microspheres have been installed. The remaining parts for the warm bore tube injection system is proceeding in the shops.

5. Superconductor

a. Cable Procurement. A length of 3790 ft of SSC inner cable was received from LBL on March 6 and was found during preliminary inspection at BNL to be of questionable quality. The cable serial number is SI-34 (BNL) or SC-313 (LBL). This cable has been set aside until decisions are made on how to anneal the cable and insulate it. Another length of cable, SI-35 (BNL)/SC-316 (LBL) (1795 ft), was received on March 25 as a partial replacement. It has already been insulated and awaits winding into a coil pending the outcome of electrical tests.

b. Tooling. Assembly of the hand held Keystone Measuring Gauge is completed. Field tests of this device indicate the need of a minor modification. This modification along with testing should be completed during the month of April.

Machining of parts for the hand-held Width Measuring Device is completed. The parts have been picked up from Central Shops and assigned to a technician for assembly. Due to workload and labor restrictions there is no estimate, at this time, for the completion of this measuring tool. However, every effort will be made to complete this tool by the end of April.

c. Miscellaneous. As reported last month, during the last week in January, Al Bertsche traveled to LBL to conduct a series of cabling experiments. Five 30-strand outer cable and eight 23-strand inner cable samples were made. The purpose of these samples is to determine the effect of packing factor on degradation. The cable samples have been tested and will be reported on as soon as possible.

As reported last month, during February, representatives of both LBL and BNL traveled to NEEWC to observe the performance of a 3U Turkshead

Rolling Machine which NEEWC converted from a standard pull-through type to a power driven machine. The cables obtained from this run are still undergoing tests and will be reported on shortly. Whether a power driven Turkshead machine has an advantage over the pull-through type should be seen from the results of these samples submitted for test.

6. Tests and Measurements

Testing of SLN015 continued, with attention focused on quench currents at low temperatures, trim coil quench currents, stray field, and measurement of the multipoles of the coil ends. Quench currents in the trim coil improved to the expected short-sample behavior when the "warm finger" which contains the measuring coil was removed from the magnet. Removing the warm finger did not affect the quench currents in the dipole.

After these measurements the magnet was warmed up and the warm finger for the mole was successfully inserted into the magnet. The magnet was then cooled down again for a check of quench currents after a thermal cycle, heat load measurements on the warm finger, and more stray field measurements. The dipole quench currents at 4.5K were the same as before the magnet warm-up.

7. Cryogenic Systems

The draft of the SSC Conceptual Design Report, cryogenic section, was reviewed and comments forwarded.

The requirements for the Short String Test (a.k.a. the Accelerated Life Test) were reviewed in anticipation of possible activation of that program in the next fiscal year.

B. FNAL.

1. Cryostat Design and Development

a. Cryostat Development

Investigation into alternate materials for the 5 in. x 7 in. re-entrant post continues. Several proposals from graphite composite tube vendors have been received. One vendor is supplying a 5 in. tube fabricated from woven material, not unlike that used for the G-11 composites, for evaluation of its structural and thermal properties. The hope is that this material will have an elastic modulus two to three times that of G-11 and will exhibit acceptable thermal performance below 80K. The higher modulus will increase the post's ability to withstand the prescribed seismic loads.

Recalibration of the heat meter in the Suspension Heat Leak Dewar is complete. Preparations are underway to measure a 5 in. x 7 in. post of G-11 CR construction. A test was performed on the cold mass slide mechanisms as installed on HLM II. Measurements were made of the cold mass motion and of the deflection at the top of each post. The slides overcame their own static friction repeatedly at an applied axial load of 3000 lb. Given a normal load at each support of 3000 lb., the resulting coefficient of friction in the slides is very nearly 1.0. This value is higher than expected and is likely caused by sharp edges in the slides themselves. Subsequent assemblies will be evaluated to verify this assumption.

b. Cryostat Design

The mid-span axial anchor has been redesigned to allow a small amount of length adjustment and pre-tensioning. This is required to make up

assembly tolerances and to ensure that the anchor struts carry a small tensile preload after cool down.

A modification is being made to the lifting beam to prevent any tendency of the complete magnet to rotate about its axis due to its high center of gravity.

Lifting arms are being designed to allow jacking of the assembly during installation. Locations like ER that have no overhead cranes will need jacking facilities which permit positioning and alignment.

2. Long Magnet Fabrication

a. HLM II-Heat Leak Model

The Heat Leak Model was completed on the last day of the month. Preparations for shipping to ER will take place the first week of April with the assembly arriving at ER on April 7. Fabrication of the various systems was fairly smooth. Some unexpected problems occurred involving the vacuum vessel and the shield assemblies. The vacuum vessel developed a 1/4 in. bow. This bow became obvious after welding. It is not clear if welding stresses or the inherent straightness of the continuous length pipe contributed to this bow. The assembly was straightened by adding weld at strategic locations. The final result was a straightness of 0.020 in. The straightness, of course, refers to the positions of the post. Substantial thermostresses and resulting distortions to the shields occurred during welding of these assemblies. It was necessary to locally cut holes in the shield at the helium liquid and gas pipes support locations (5) along the length of the shield. This was done to avoid thermoshorting of the shields to the pipe supports. The impact on heat leak is considered to be negligible. Work is ongoing for subassemblies intended for use on the first real magnet scheduled to arrive from BNL at the end of April.

b. HLM II End Vessels

Zero magnet heat leak studies have been completed. The end vessels have been cut apart and have been shipped to ER where they await the arrival of HLM II dummy magnet.

c. Magnet Transport

The air bag suspension system has been designed and is being fabricated. The truck on which to install the air bag assemblies is due to arrive on or about April 1. Following installation of the suspension system on the truck, a dry run will be made with 24,000 lb. of concrete blocks to verify that the air bags do not bottom out and that shipping loads are within allowable limits. A three-axis mechanical accelerometer will be attached to the truck bed and the test load during the test.

d. Interconnect Area

All bellows for all systems have been received with the exception of the beam tube bellows which of course will arrive with the first magnet from BNL. Consumable welding inserts for all systems except the beam tube bellows have been received. The automatic welding equipment to be used for making these connections should be ready for trial by the end of April. Work continues on the mock-up interconnect with the assembly being approximately three quarters complete. Cut off equipment for the shield pipes and helium gas and liquid pipes has been received and tested. It performs to expectations. Cut off equipment for the beam tube and single phase are to arrive the latter part of April. First draft of bellows thermocycling fixtures have been completed and are being reviewed prior to fabrication.

An analysis of direct labor costs and development of the next manufacturing traveler will be completed during April to assure a smooth transition for assembly of Magnet #1.

New parts for support assembly tooling, together with new parts for the supports, have been ordered to assure delivery to meet the production schedule.

Meetings to review improvements of magnet design and production methods will be held early next month.

3. General Magnet R&D

a. Model Magnets

SJ-1012 (wet wound), SK-1004, and SK-1005 (dry wound) have had their outer straight gauges rebuilt and are presently being assembled.

b. Conductor Gauge

New additions of the LVDTs for simplification of base-line calibration have been received and are being calibrated. The LVDTs will be installed the first week of April with measurement of SSC conductor and Energy Saver conductor commencing soon thereafter. Measurements will be made on bare conductor as well as insulated cable.

c. Model Magnet Studies

- The study of time constants and magnitude of the change in $B_2$ and $B_4$ terms on a typical Tevatron "Front Porch" injection ramp cycle was done for an SSC design B and design D coil. The study included variation of magnet temperature and ramp rate.

- A profile of magnetic field width axial position was measured for a design B coil.

- NMR probe work and circuitry has been developed for measurement of SSC design coils. A persistent switch has been designed for use during measurements.

- Power supply control circuits were modified to end over shooting, (~0.1 amp level) and the ability to maintain constant current has improved.

- Work has been done on the short sample analysis codes to update reporting systems to more easily compare data from other labs.

- Phases on Probe #4 were checked and verified against the standard Probe #3 Probe #4 is small enough to obtain cold measurements for the design D SSC magnets.

- Calibration of temperature sensors for the 17 m MTF stands has been completed.

- A ternary alloy dipole magnet was run at superfluid ambient pressure and its current surpassed the cable's measured perpendicular short sample current ($\rho_{eff} = 2 \times 10^{-12}$ -cm; 2K).

- Quench and isolation amplifier work continues for the SSC long coil tests.

4. Magnetic Measurements

Preparations for measuring 17 meter design D magnets at MTF continue. An existing stand and feed can for testing Tevatron dipoles has been removed and a new 17 meter test stand has been installed and aligned. The feed cans are being manufactured by the Accelerator Division cryogenics group. Modifications to the buss work to allow dc operation to greater than 7000 amps on the new test stand are nearly complete. A pair of Tevatron quench heater supplies have been modified to allow variable voltage operation required for test of quench properties of SSC magnets. Resistance thermometers were made and calibrated for installation by BNL inside the "dogbone" ends of the first single phase assembly. A current source and two amplifier channels for resistance thermometry were built and tested with one carbon-glass resistor and one germanium resistor inside the single phase return line of a Tevatron magnet. With the magnet powered, noise levels at the output of the amplifiers imply an equivalent resolution of about 5 mK at 4.5K.

Quench electronics associated with the quench pressure relief have been built and tested using a high pressure 60 psig test on a Tevatron dipole. To generate maximum heating and maximum pressures the dipole was run with a high ramp rate to the quench point. There were no serious repercussions of the high pressure on the MTF refrigerator. The tests were performed using 4 atm at 45 g/sec flow.

The writing of software for quench data collection and cryogenic monitoring is underway; work on code for magnetic measurements will begin shortly. Formats for writing quench data, harmonics data, current history, and cryogenic history have been established. Fittings have been made to allow calibration of the BNL Mole in Tevatron magnets.

5. Accelerator R&D

Theory SSC Effort Report

- A paper entitled "Energy Loss and Angular Characteristics of High Energy Electromagnetic Processes" was completed. It was submitted to Nucl. Instr. Methods. A mass production of the preprint is still in progress.

- Work on inelastic $pe^-$ and $\pi e^-$ continues (with S. Quian).

- Work on the "Shielding Manual" continues. Some of the programs connected with this have been released (to CERN and to D. Groom at CDG). Some preliminary results were communicated to T. Toohig with respect to some estimates of ground water activation.

SSC Generic Injector Design

In mid-October the Fermilab Accelerator Division was requested by the CDG to provide the injector design, along with accompanying written descriptions and cost estimates, for inclusion in the SSC Conceptual Design Report. The final drafts of both the text and accompanying cost estimate for the SSC injector were forwarded to the CDG during the month of March. With the release of the Conceptual Design Report the end of March, the work of the injector design group is essentially complete. The sole remaining activity of this group will be participation in the DOE review of the CDR scheduled the week of April 28.

6. Half-Cell Test Support

The tunnel and cryogenic facilities at ER are being completed for installation of HLM II. The floor and part of the coverings are complete. Pads are being prepared for magnet installation. Power and lighting facilities are only partially complete.

C. LBL.

1. Superconductor. During this report period, approximately 8,000 ft. of inner layer cable and 10,000 ft. of outer layer cable were completed. Most of this cable was made from strands with 18-23 μm filaments and was intended for use in long models 2 and 3 at BNL. All of this cable was within the mechanical specifications for SSC cable and exceeded the critical current specifications. However, some of the strands appeared to pop out from the inner layer cable made from one source of strand material. We demonstrated that this mechanical problem can be corrected with a post-cable anneal treatment and that this post-cable anneal does not seriously degrade the cable critical current. Consequently, we are working with BNL on post-cable annealing for this particular batch of cable before insulation and coil winding are commenced.

2. High Gradient Quads. We completed preliminary designs of high gradient quadrupoles for the CDR. The IR quad has two layers of cable of identical width to the 30 strand outer layer cable of the dipole. With a close-filling iron yoke, an operating gradient of 235 T/m is predicted. A similar analysis was made for the arc quadrupoles using self-supporting 10 mm wide collars; the design gradient is 212 T/m. A stress analysis study was done on the collars.

3. Analysis. Cross-sections cut from magnets MD-1 and MD-2 were analyzed. Several computer programs were developed to assist this analysis. Study of these results and improvements in the program PARTIALKEYSTONE have led to some design changes which should result in improved field quality in future dipole models.

The strands' X,Y coordinates from slices of magnets MD-1 and MD-2 were measured with a X-Y high resolution electromagnetic digitizing tablet (0.001" resolution and ± 0.010" absolute accuracy) using an enlarged (X5) photograph

of the cross-section. The data were analyzed with the STRANZn series of programs on the HP-1000, including plotting, location normalization, and multipole calculation. The results were then compared with magnetic measurements. The geometry generated of the measured strands was also compared with the design (ideal) geometry, and possible problem areas identified. Comparison of the two geometries indicates that the cable dimensions in the finished magnet are not uniform. Further investigation of this phenomenon is continuing.

The program PARTIALKEYSTONE was improved to better approximate the real current density of the conductor, and to accommodate variations in conductor dimension. Using this new version of PARTIALKEYSTONE, it was found that the effect of current density is to reduce the sextupole by -1.34 dipole units and the decapole by -0.037 dipole units (with negligible effect on higher multipoles).

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

   a) Completed assembly of MD-3.

   b) Modified MD-3 yoke assembly several times for warm end measurements.

   c) Completed 4 coils to be used in D14B-1.

   d) Completed first laminated yoke assembly.

   e) Completed new wedges for cross section NC6 to be used in D14B-2.

   f) Completed CNC machining of G10 end spacers for circular (Morgan) type coil ends for FY86 models.

During March, the design of the gages used for measuring coil pressure during assembly and testing was upgraded. The changes should make the pressure gages reliable and accurate.

5. Instrumentation and Measurements.

a. 1.8 K conditioning (non-quench training of MD-3, tested March 24-27, 1986)

In January, 1986, we showed through testing a matched pair of C5 cross section SSC dipole magnets that superfluid 1.8 K conditioning could eliminate magnet training through quenching in HeI at 4.4 K. These magnets, D-12C-7 and D-12C-8, have evolved to have excellent training behavior.

The improved cross section series have been started with a mechanical design name of MD-#. The MD series was originally intended for warm testing only, coil ends are not well supported, and old cable was used; nevertheless, we later decided to test MD-2 and MD-3 in He. The training of MD-2 in HeI was only fair; see February 1986 Monthly Report. MD-3 was conditioned (as was D-12C-8 earlier) at 1.8 K by ramping it to 7.2 tesla, without quenching. The temperature was then raised to 4.4 K in HeI and the quench current was determined. It was within 2 percent of its short sample (6.4 tesla). As a memory test, the magnet was then warmed to room temperature, recooled to 4.5 K in HeI, and retested. The quenches were at short sample values so there was no loss of memory for this magnet.

b. Room temperature magnetic measurements: Magnet MD-3 was measured warm March 10-15, 1986. The inner and outer layers were separately excited as well as the two layers in series. Axial scans were carried out in all configurations and both ends were analyzed.

D. TAC.

1. Correction Magnets. The superferric correction dipole magnet has not yet been tested because the test facility has been occupied with other tests. We are waiting for delivery of the superconduction wire to construct other magnets.

2. Quench Diodes. We have put considerable effort into quench diodes this month. Next month we will make a report.

3. Superferric Magnets. During the past month we have measured a one meter dipole constructed by Meyer Tool, Inc. of Chicago and a 28 meter dipole constructed by General Dynamics Corporation, San Diego, see Attachment 1.

## C. PROJECT COST DATA
(Index)


| SSC Program | Table | Figure |
|---|---|---|
| Central Design Group | C-1 | 1 |
| Brookhaven National Laboratory | C-2 | 2 |
| Fermi National Accelerator Laboratory | C-3 | 3 |
| Lawrence Berkeley Laboratory | C-4 | 4 |
| Texas Accelerator Center | C-5 | 5 |
| SSC Program Summary | C-6 | 6 |

TABLE C-1

CENTRAL DESIGN GROUP - SUPERCOLLIDER

MARCH 1986 COST REPORT (K$)

| | PROGRAM ELEMENT | LABOR | MAT'L & SERVICES | G & A | MONTH TOTAL | YEAR TO DATE | ANNUAL BUDGET |
|---|---|---|---|---|---|---|---|
| 1.1 | ADMINISTRATION | 103 | 137 | 104 | 344 | 1411 | 2710 |
| 1.2 | PROGRAM PLANNING & MANAGEMENT | 28 | 1 | 14 | 43 | 198 | 650 |
| 1.3 | ACCELERATOR R & D | 132 | 77 | 80 | 249 | 1098 | 4060 |
| 1.4 | CONVENTIONAL SYSTEMS DEVELOP. | 59 | 404 | 31 | 494 | 1763 | 2560 |
| | PROGRAM COSTS | 322 | 579 | 229 | 1130 | 4470 | 9980 |
| | COMMITTMENTS | | | | | 222 | |
| | CHANGE IN COMMITTMENTS (Delta) | | | | | -97 | |

TABLE C-2

BROOKHAVEN NATIONAL LABORATORY - SUPERCOLLIDER

MARCH 1986 COST REPORT (K$)

| | PROGRAM ELEMENT | LABOR | MAT'L & SERVICES | G & A | MONTH TOTAL | YEAR TO DATE | ANNUAL BUDGET |
|---|---|---|---|---|---|---|---|
| 2.1 | MAGNET FABRICATION | 122 | 89 | 71 | 288 | 1536 | 3020 |
| | PROGRAM COSTS | 122 | 89 | 71 | 288 | 1536 | 3020 |
| | COMMITTMENTS | | | | | 247 | |
| | CHANGE IN COMMITTMENTS (Delta) | | | | | -244 | |
| | EQUIPMENT | 15 | 2 | | 17 | 48 | 250 |

TABLE C-3

FERMI NATIONAL ACCELERATOR LABORATORY - SUPERCOLLIDER

MARCH 1986 COST REPORT (K$)

| | PROGRAM ELEMENT | LABOR | MAT'L & SERVICES | G & A | MONTH TOTAL | YEAR TO DATE | ANNUAL BUDGET |
|---|---|---|---|---|---|---|---|
| 3.1 | GENERAL | 0.8 | 5.1 | 2.2 | 8.1 | 93.3 | 140 |
| 3.2 | CRYOSTAT DESIGN & DEVELOPMENT | 37 | 8.2 | 17 | 62.2 | 388.3 | 960 |
| 3.3 | LONG MAGNET FABRICATION | 84.1 | 60.5 | 54.3 | 198.9 | 980.8 | 1300 |
| 3.4 | MAGNETIC MEASUREMENTS | 26 | 16.3 | 15.9 | 58.2 | 166.4 | 600 |
| 3.4A | CRYOGENIC SYSTEM | 0 | 12.1 | 4.5 | 16.6 | 16.6 | 42 |
| | PROGRAM COSTS | 147.9 | 102.2 | 93.9 | 344 | 1645.4 | 3042 |
| | COMMITMENTS | | | | | 174.9 | |
| | CHANGE IN COMMITTMENTS (Delta) | | | | | -4.7 | |
| | EQUIPMENT | 7.7 | 62 | | 69.7 | 170.2 | 550 |

TABLE C-4

LAWRENCE BERKELEY LABORATORY - SUPERCOLLIDER

MARCH 1986 COST REPORT (K$)

| | PROGRAM ELEMENT | LABOR | MAT'L & SERVICES | G & A | MONTH TOTAL | YEAR TO DATE | ANNUAL BUDGET |
|---|---|---|---|---|---|---|---|
| 4.1 | GENERAL | 7 | 0 | 4 | 11 | 50 | 120 |
| 4.2 | SUPERCONDUCTOR | 12 | 0 | 6 | 18 | 135 | 560 |
| 4.3 | HIGH GRADIENT IR QUADRUPOLES | 14 | 0 | 7 | 21 | 110 | 270 |
| 4.4 | MAGNET MODELS | 59 | 1 | 29 | 89 | 308 | 450 |
| | PROGRAM COSTS | 92 | 1 | 46 | 139 | 603 | 1400 |
| | COMMITMENTS | | | | | 306 | |
| | CHANGE IN COMMITTMENTS (Delta) | | | | | 0 | |

TABLE C-5

TEXAS ACCELERATOR CENTER - SUPERCOLLIDER

MARCH 1986 COST REPORT (K$)

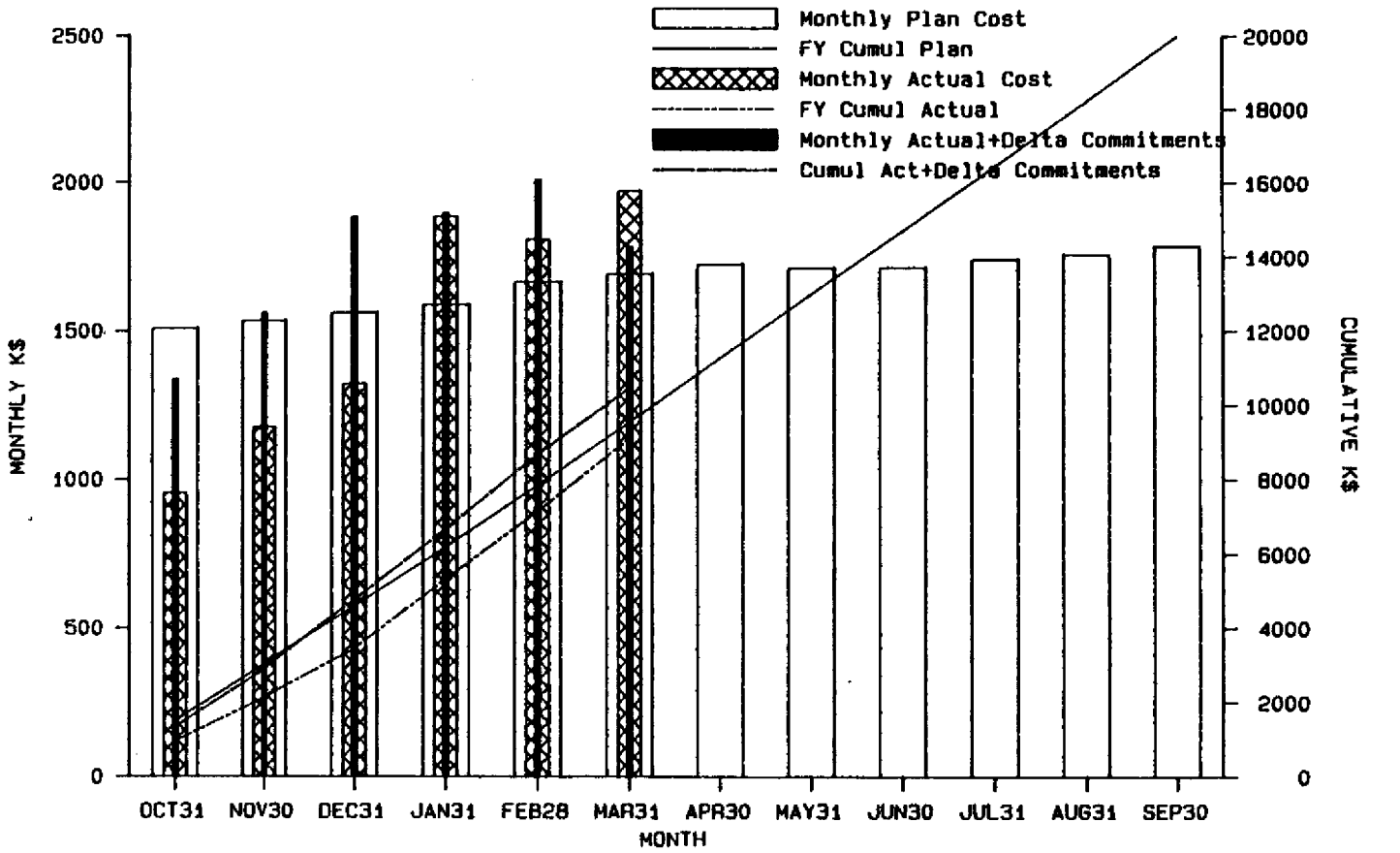
| | PROGRAM ELEMENT | LABOR | MAT'L & SERVICES | G & A | MONTH TOTAL | YEAR TO DATE | ANNUAL BUDGET |
|---|---|---|---|---|---|---|---|
| 5.1 | DIODE QUENCH PROTECTION | 9.5 | 1.8 | 2 | 12.3 | 62 | 550 |
| 5.2 | CORRECTION ELEMENTS | 8.6 | 0 | 3.5 | 12.1 | 157.6 | 1025 |
| 5.3 | ACCELERATOR PHYSICS | 2.2 | 0.5 | 0.9 | 4.6 | 56 | 275 |
| 5.4 | SUPERFERRIC MAGNET | 27.9 | 26.7 | -10.4 | 44.2 | 603 | 750 |
| | PROGRAM COSTS | 48.2 | 29 | -4 | 73.2 | 878.6 | 2600 |
| | COMMITMENTS | | | | | 402.8 | |
| | CHANGE IN COMMITTMENTS (Delta) | | | | | 155 | |

TABLE C-6

PROGRAM SUMMARY - SUPERCOLLIDER

MARCH 1986 COST REPORT (K$)

| | PROGRAM ELEMENT | LABOR | MAT'L & SERVICES | G & A | MONTH TOTAL | YEAR TO DATE | ANNUAL BUDGET |
|---|---|---|---|---|---|---|---|
| 1. | CDG PROGRAM | 322 | 579 | 229 | 1130 | 4470 | 9980 |
| 2. | BNL SSC PROGRAM | 122 | 89 | 71 | 282 | 1536 | 3020 |
| 3. | FNAL SSC PROGRAM | 148 | 102 | 94 | 344 | 1645 | 3042 |
| 4. | LBL SSC PROGRAM | 92 | 1 | 46 | 139 | 603 | 1400 |
| 5. | TAC SSC PROGRAM | 48 | 29 | -4 | 73 | 879 | 2600 |
| | TOTAL SSC PROGRAM COSTS | 732 | 800 | 436 | 1968 | 9133 | 20042 |
| | COMMITMENTS | | | | | 1353 | |
| | CHANGE IN COMMITTMENTS (Delta) | | | | | -191 | |




| | 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 | | | | | | |
| FY Cumul Actual | 955 | 2134 | 3458 | 5346 | 7158 | 9132 | | | | | | |
| Actual+Delta | 1336 | 1563 | 1887 | 1900 | 2014 | 1784 | | | | | | |
| Cumul Act+Delta | 1336 | 2900 | 4787 | 6686 | 8700 | 10484 | | | | | | |

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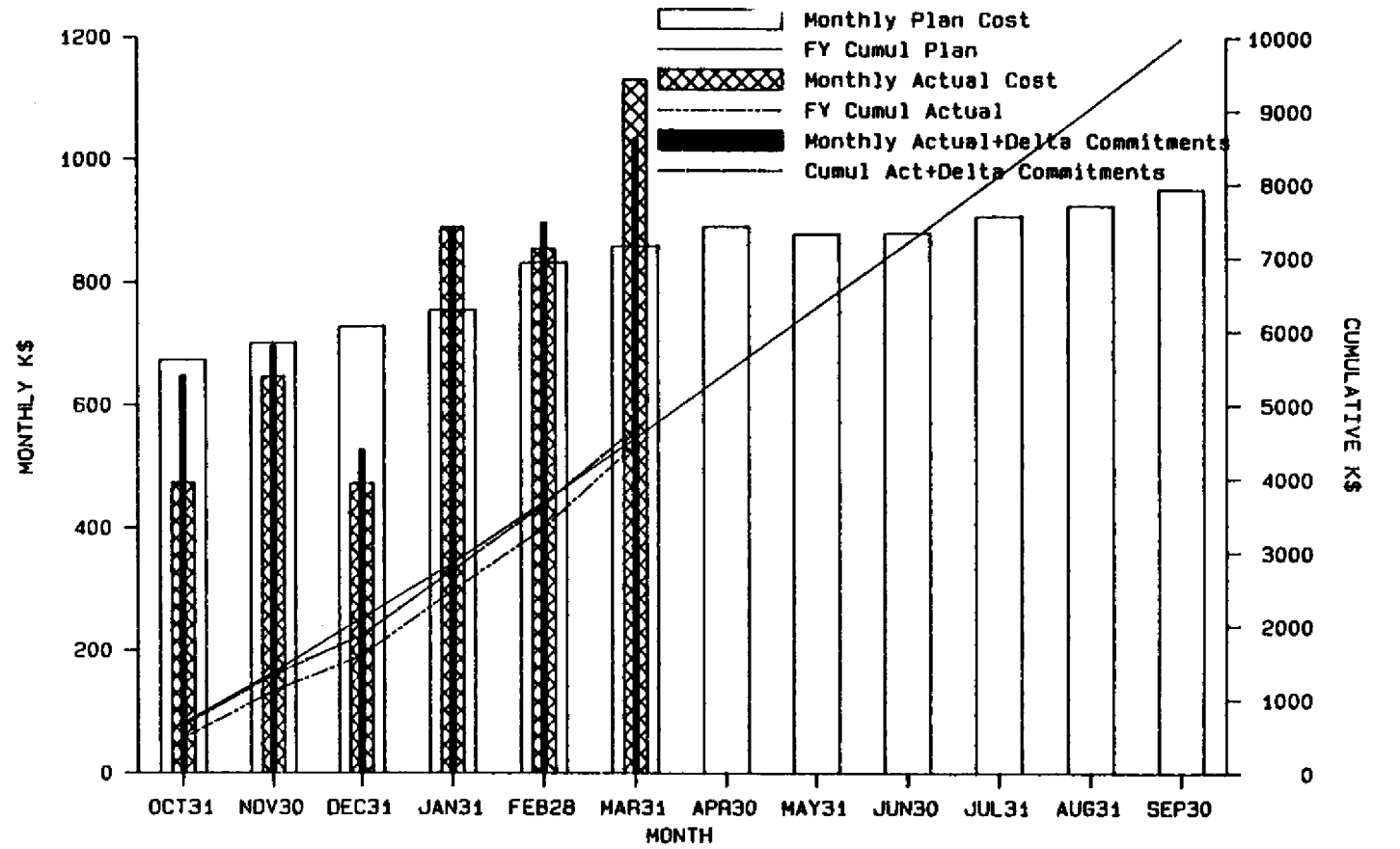
Figure 1




| | FISCAL YEAR 1986 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OCT31 | NOV30 | DEC31 | JAN31 | FEB28 | MAR31 | APR30 | MAY31 | JUN30 | JUL31 | AUG31 | SEP30 |
| Monthly Plan | 674 | 701 | 728 | 755 | 832 | 859 | 891 | 878 | 880 | 907 | 924 | 951 |
| FY Cumul Plan | 674 | 1375 | 2103 | 2858 | 3690 | 4549 | 5440 | 6318 | 7198 | 8105 | 9029 | 9980 |
| Monthly Actual | 474 | 647 | 473 | 890 | 855 | 1130 | | | | | | |
| FY Cumul Actual | 474 | 1121 | 1594 | 2484 | 3339 | 4469 | | | | | | |
| Actual+Delta | 648 | 696 | 527 | 890 | 897 | 1033 | | | | | | |
| Cumul Act+Delta | 648 | 1344 | 1871 | 2761 | 3658 | 4691 | | | | | | |

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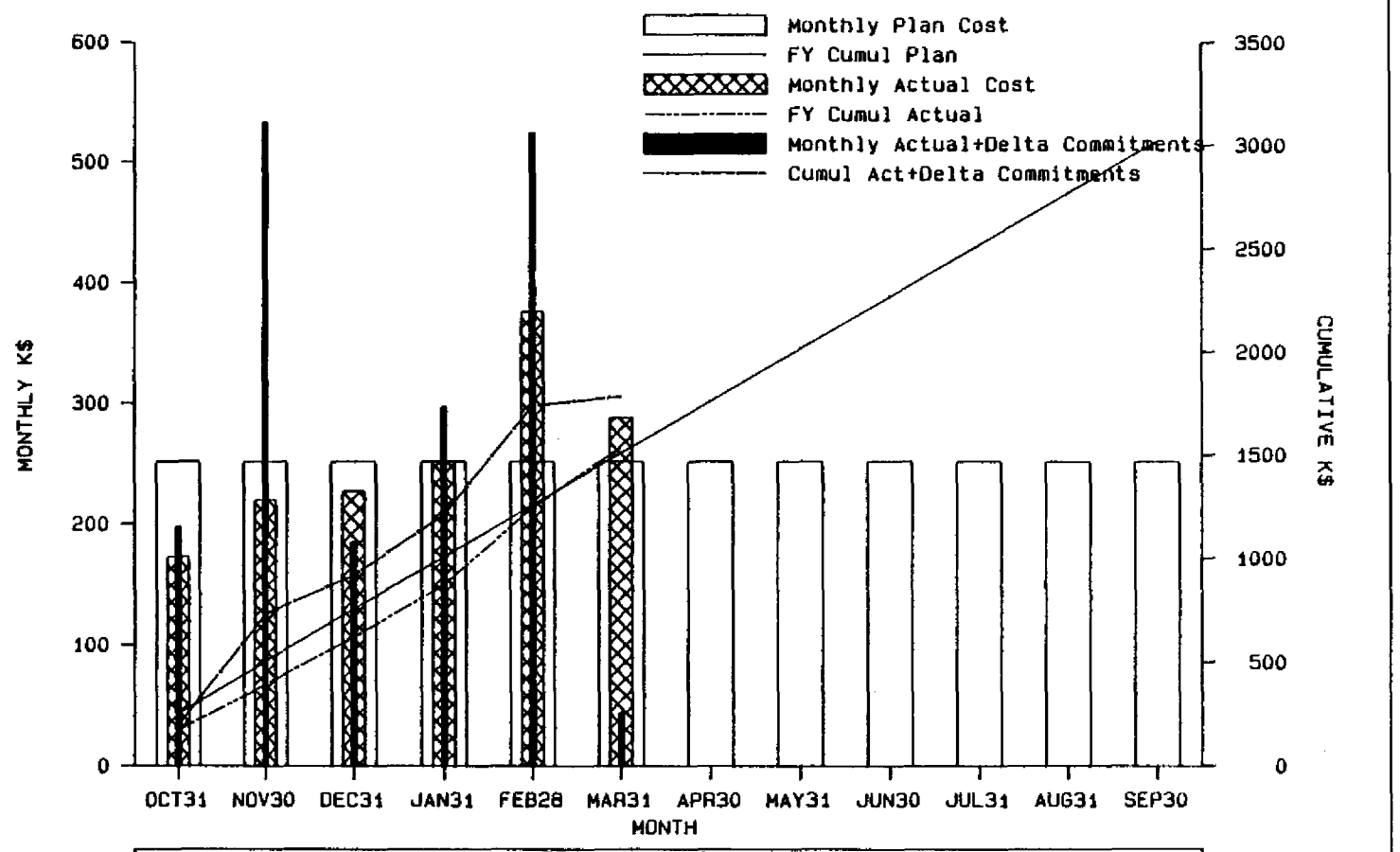
Figure 2




| | 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 | | | | | | |
| FY Cumul Actual | 173 | 393 | 620 | 872 | 1248 | 1536 | | | | | | |
| Actual+Delta | 198 | 534 | 185 | 297 | 525 | 44 | | | | | | |
| Cumul Act+Delta | 198 | 732 | 917 | 1214 | 1739 | 1783 | | | | | | |

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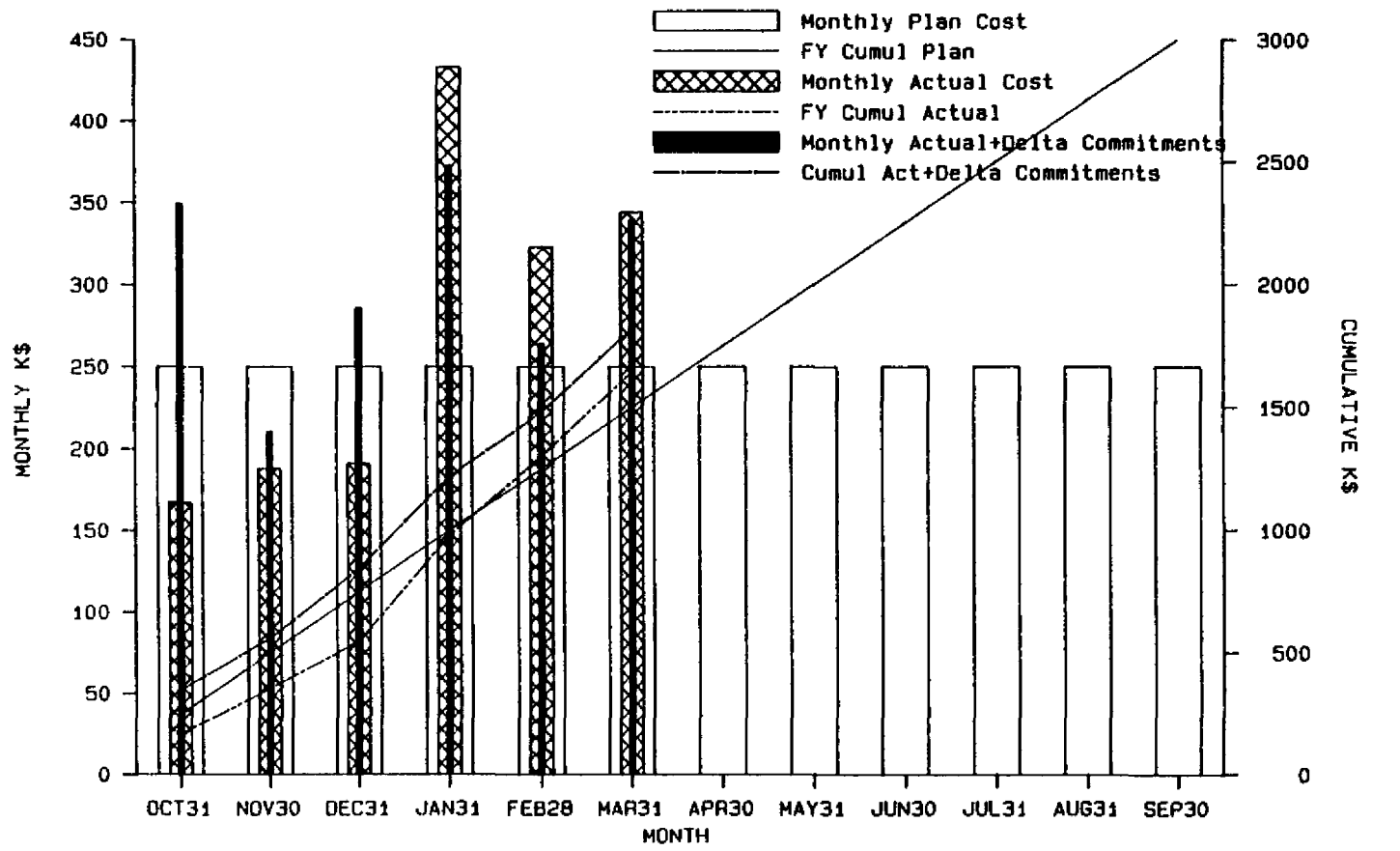
Figure 3




| | FISCAL YEAR 1986 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OCT31 | NOV30 | DEC31 | JAN31 | FEB28 | MAR31 | APR30 | MAY31 | JUN30 | JUL31 | AUG31 | SEP30 |
| Monthly Plan | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 |
| FY Cumul Plan | 250 | 500 | 750 | 1000 | 1250 | 1500 | 1750 | 2000 | 2250 | 2500 | 2750 | 3000 |
| Monthly Actual | 167 | 188 | 191 | 433 | 323 | 344 | | | | | | |
| FY Cumul Actual | 167 | 355 | 546 | 979 | 1301 | 1645 | | | | | | |
| Actual+Delta | 349 | 210 | 285 | 372 | 264 | 339 | | | | | | |
| Cumul Act+Delta | 349 | 560 | 845 | 1217 | 1481 | 1820 | | | | | | |

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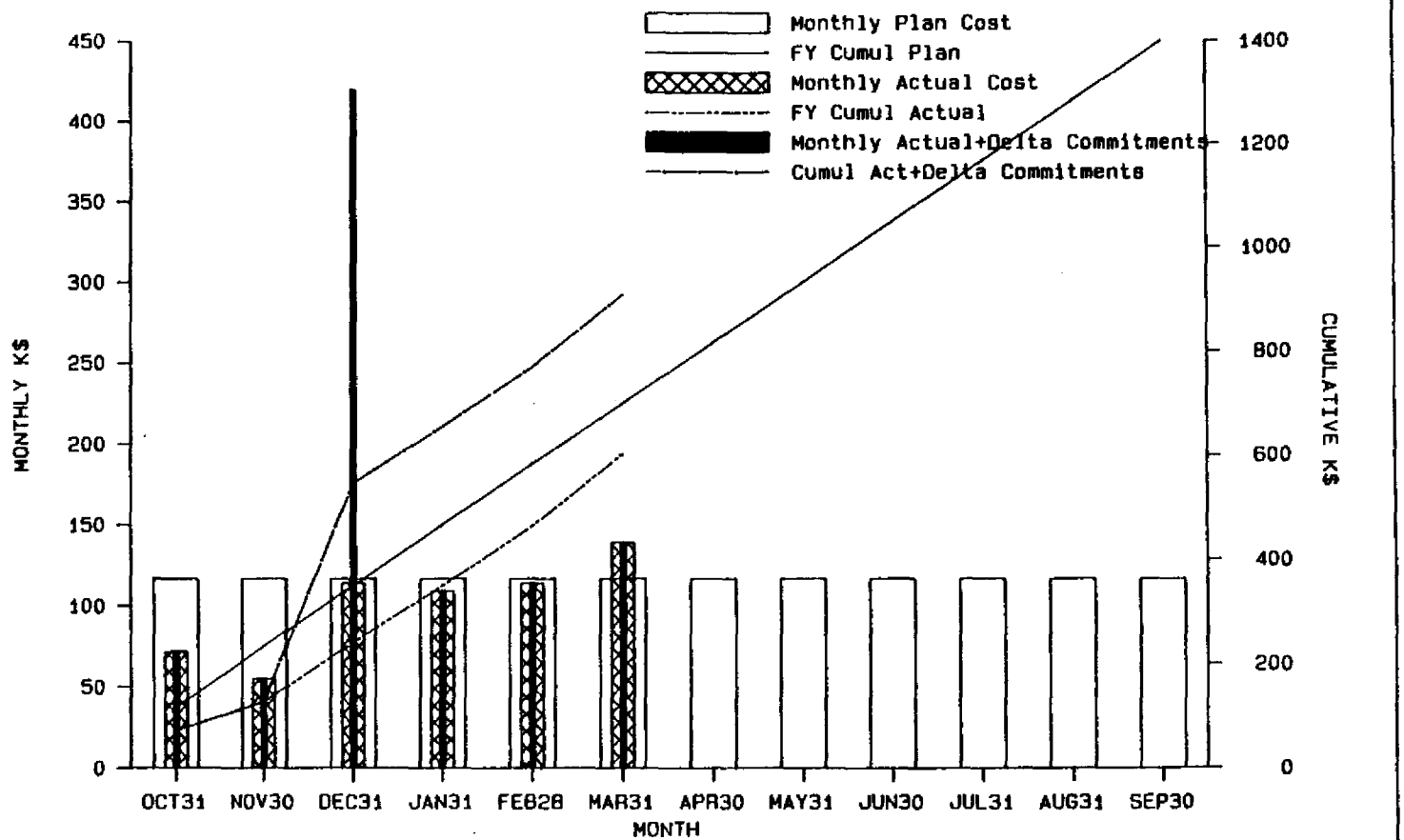
Figure 4




| | 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 | | | | | | |
| FY Cumul Actual | 72 | 127 | 241 | 350 | 464 | 603 | | | | | | |
| Actual+Delta | 72 | 55 | 420 | 109 | 114 | 139 | | | | | | |
| Cumul Act+Delta | 72 | 127 | 547 | 656 | 770 | 909 | | | | | | |

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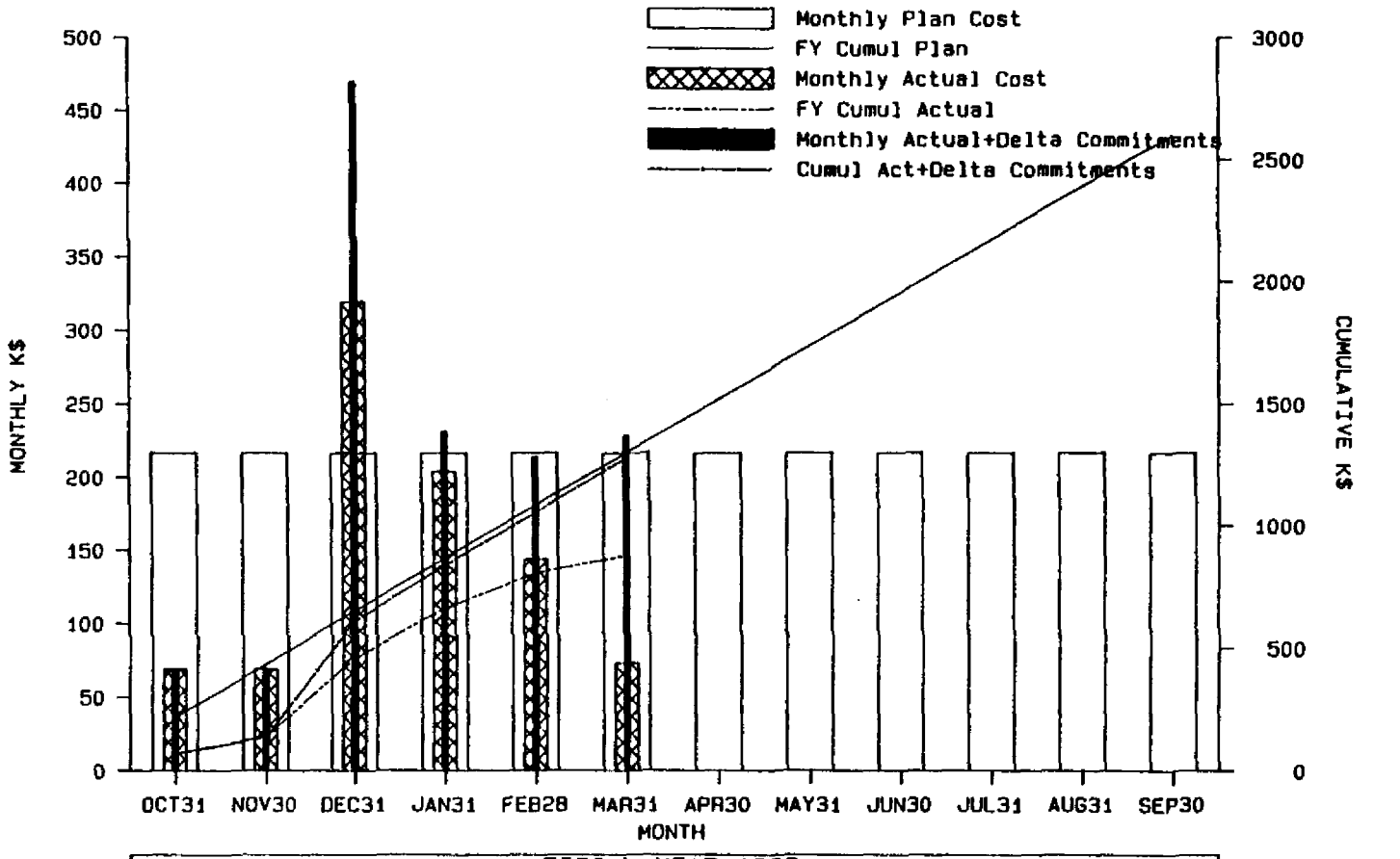
Figure 5




| | 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 | | | | | | |
| FY Cumul Actual | 69 | 138 | 458 | 662 | 805 | 879 | | | | | | |
| Actual+Delta | 69 | 68 | 470 | 231 | 214 | 228 | | | | | | |
| Cumul Act+Delta | 69 | 137 | 607 | 838 | 1052 | 1280 | | | | | | |

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Figure 6

MSIM
4/8-9/86

# TEXAS ACCELERATOR CENTER
# MAGNET PERFORMANCE DATA

* THIRD 28 METER DIPOLE RECEIVED FROM GENERAL DYNAMICS 4/3/86

* TAC HAS TESTED NINE (9) DIPOLE AND ONE QUADRUPOLE MAGNETS SINCE AUGUST 1985 (11 WERE TESTED BEFORE AUGUST 85)

* SUMMARY OF MAGNETS TESTED SINCE AUGUST 1985

| | | |
|---|---|---|
| * TAC 3 FOOT DIPOLE MAGNETS | | 4 |
| TAC 3 FOOT QUADRUPOLE MAGNET | 1 | |
| TAC 7 METER DIPOLE MAGNET | 1 | |
| INTERMAGNETICS GENERAL 3 FOOT MAGNETS | 2 | |
| MEYER TOOL 3 FOOT MAGNETS | 1 | |
| GENERAL DYNAMICS 28 METER DIPOLE MAGNETS | 1 | |
| TOTAL | 10 | |

* TO BE TESTED:

| | |
|---|---|
| TAC 1 METER DIPOLE CORRECTION MAGNET | 1 |
| GENERAL DYNAMICS 28 METER DIPOLE MAGNETS | 2* |

IN ADDITION TO STX 002 AND STX 003 GENERAL DYNAMICS STX 001 WILL BE RETESTED - UPPER BORE

* ALL MAGNETS HAVE EXCEEDED PEAK FIELD OF 3.2T WITH NO TRAINING EQUIVALENT OF GREATER THAN 3.4 T AT 4.6$^{o}$K

* MULTIPOLE SUMMARY

* $b_6$ (~ 4 UNITS) AT HIGH FIELD IS THE WORST CONDITION ENCOUNTERED. IT AGREES WITH PREDICTIONS AND WILL BE CORRECTED WITH A MINOR DESIGN CHANGE THAT REDUCES $b_6$ TO 0.3 UNITS.

* $a_1$ (~ 5 UNITS) AT LOW FIELD IS ATTRIBUTED TO COERCIVE FORCE WHICH WILL BE CONTROLLED THROUGH RESTRICTIONS ON 1008 CARBON STEEL CHEMISTRY (~ 3% SILICON).

MSIM
4/8-9/86

TEXAS ACCELERATOR CENTER
MAGNET PERFORMANCE DATA

| MAGNET | LENGTH | CURRENT (AMPS) | PEAK FIELD | TEMP (K) | REMARKS |
|---|---|---|---|---|---|
| IGC 1 | 3 FEET | 12,930 | 3.46 | 4.45-4.5 | NO TRAINING |
| TAC 9 | 3 FEET | 12,250 | 3.3 | 4.45-4.5 | QUENCHED IN LEADS |
| TAC 10' | 3 FEET | 12,997 | 3.46 | 4.45-4.5 | NO TRAINING |
| TAC 7'' | 3 FEET | 12,790 | 3.4 | 4.45-4.5 | NO TRAINING |
| TAC 11 | 3 FEET | 12,550 | 3.4 | 4.45-4.5 | NO TRAINING |
| MT 1 | 3 FEET | 12,750 | 3.4 | 4.45-4.5 | NO TRAINING |
| IGC 2 | 3 FEET | 13,100 | 3.46 | 4.45-4.5 | NO TRAINING |
| TAC 8 | 7 METER | 11,719 | 3.25 | 5 | NO TRAINING |
| STX 1 | 28 METER | 11,805 | 3.25 | ~ 5 | NO TRAINING |

MSIM
4/8-9/86

Table of Superferric magnet construction

| | MAGNET | LENGTH | #OF BORES | # OF CURRENTS | BUILT BY | TESTED |
|---|---|---|---|---|---|---|
| Nov. 84 | TAC1 | 3' | 1 | 2 | TAC | Y |
| Nov. 84 | TAC2 | 3' | 1 | 2 | TAC | Y |
| Apr. 85 | TAC3 | 7m | 2 | 2 | TAC | Y |
| Mar. 85 | TAC4 | 3' | 2 | 2 | TAC | Y |
| Apr. 85 | TAC5 | 3' | 1 | 3 | TAC | Y |
| Jul. 85 | GD1 | 3' | 1 | 3 | GD | Y |
| | TAC6 | 3' | 2 | 3 | TAC | N |
| Aug. 85 | TAC7 | 3' | 1 | 3 | TAC | Y |
| Aug. 85 | TAC9 | 3' | 1 | 3 | TAC | Y |
| Aug. 85 | TAC10 | 3' | 1 | 3 | TAC | Y |
| Aug. 85* | GD1' | 3' | 1 | 3 | TAC | Y |
| Aug. 85 | TAC7' | 3' | 1 | 3 | TAC | Y |
| Nov. 85 | TAC7'' | 3' | 1 | 3 | TAC | Y |
| Dec. 85 | TAC9' | 3' | 1 | 3 | TAC | Y |
| Nov. 85 | TAC10' | 3' | 1 | 3 | TAC | Y |
| Oct. 85 | TAC11 | 3' | 1 | 3 | TAC | Y |
| Jan. 86 | IGC1 | 3' | 1 | 3 | IGC | Y |
| Feb. 86 | IGC2 | 3' | 1 | 3 | IGC | Y |
| Mar. 86 | MT1 | 3' | 1 | 3 | MT | Y |
| Feb. 86 | TAC8 | 7m | 2 | 3 | TAC | 1 bore |
| Mar. 86 | STEX1 | 28m | 2 | 3 | GD | 1 bore |
| | STEX2 | 28m | 2 | 3 | GD | N |
| | STEX3 | 28m | 2 | 3 | GD | N |
| | IGC3 | 3' | 1 | 3 | IGC | N |
| | TACQ1 | 3' | 1 | 1 | TAC | N |
| | (a quadrupole magnet) | | | | | |
| | TACC1 | 1m | 1 | 1 | TAC | N |
| | (a correction dipole) | | | | | |

* The primes indicate that the magnet was taken apart and reassembled with different shims between the coils.

MAGNET: 'IGC001'

| CURRENTS (Amps) in | out | trim | B LD (Tesla) | HARMONICS (x0.0001) Bn/An 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 554. | 50. | 110. | 0.130 | 0.2 | -3.3 | -1.0 | -0.7 | -0.1 | -0.6 | 0.0 | -0.5 |
| | | | | -2.2 | -4.0 | 0.3 | -0.4 | 0.4 | -0.1 | 0.5 | -0.3 |
| 1941. | 51. | 746. | 0.466 | 0.0 | -0.3 | -0.2 | -0.6 | 0.1 | -0.6 | 0.0 | -1.1 |
| | | | | -2.4 | -1.6 | -0.6 | -0.3 | 0.2 | -0.2 | 0.5 | 0.4 |
| 4974. | 54. | 1996. | 1.188 | 0.2 | -0.4 | -0.1 | -0.4 | -0.2 | -0.9 | -1.0 | 0.5 |
| | | | | -2.4 | -1.0 | 0.1 | 0.0 | 0.3 | -0.1 | -0.2 | -0.4 |
| 6224. | 88. | 2347. | 1.474 | 0.2 | -0.1 | -0.3 | 0.7 | 0.1 | -0.2 | 0.4 | -0.1 |
| | | | | -2.8 | -0.4 | -0.6 | 0.2 | -0.6 | 0.0 | -0.8 | 0.2 |
| 8388. | 83. | 3198. | 1.961 | -0.3 | 0.1 | -0.5 | 1.8 | -0.4 | 0.0 | -0.5 | -0.7 |
| | | | | -3.3 | -0.6 | -0.3 | 0.6 | 0.4 | 0.5 | -0.4 | 0.6 |
| 9996. | 1503. | 3398. | 2.405 | -0.4 | -2.0 | -0.2 | 0.1 | 0.2 | -0.1 | 0.4 | 0.0 |
| | | | | -2.9 | -0.7 | 0.0 | -0.2 | 0.3 | -0.4 | 0.6 | -0.7 |
| 10950. | 6502. | 18. | 2.785 | 0.1 | -0.5 | 0.3 | -0.7 | 0.2 | 1.6 | -0.5 | 0.5 |
| | | | | -1.9 | -1.0 | 0.3 | -0.2 | 0.5 | 0.3 | -0.1 | 0.5 |
| 11647. | 11742. | -3478. | 3.079 | -1.4 | -0.2 | -1.0 | 0.5 | -0.7 | 3.9 | -0.2 | 1.5 |
| | | | | -0.3 | -1.5 | 0.6 | -0.2 | 0.1 | 0.0 | -0.5 | -0.5 |

IGC002

| Iin | Iout | Itrim | R0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 554 | 51 | 110 | 0.130 | 0.9 | -2.3 | -0.1 | -0.5 | 0.2 | -0.6 | 0.1 | 0.5 |
| | | | | 5.2 | 1.2 | 1.6 | 0.1 | 0.2 | -0.2 | 0.4 | -0.1 |
| 1939 | 50 | 745 | 0.467 | 0.1 | 0.6 | -0.9 | -0.7 | -0.1 | -0.4 | 0.1 | -0.3 |
| | | | | -0.5 | 0.1 | 0.3 | -0.3 | -0.2 | -0.4 | -0.2 | 0.2 |
| 4974 | 52 | 1996 | 1.190 | 0.3 | -0.3 | -0.3 | -0.3 | 0.0 | -0.6 | 0.4 | -0.2 |
| | | | | -1.3 | -0.2 | -0.3 | -0.2 | -0.3 | -0.3 | 0.4 | 0.0 |
| 6223 | 87 | 2348 | 1.477 | 0.2 | 0.6 | -0.3 | 1.2 | -0.2 | -0.4 | -0.4 | 0.4 |
| | | | | -1.6 | 0.0 | -0.1 | 0.2 | -0.2 | 0.1 | 0.2 | 0.4 |
| 8388 | 83 | 3198 | 1.964 | 0.1 | 0.3 | -0.4 | 1.5 | -0.1 | -0.4 | -0.4 | 0.7 |
| | | | | -1.6 | -0.7 | -0.1 | -0.3 | 0.2 | 0.1 | -0.3 | 0.3 |
| 9994 | 1502 | 3398 | 2.411 | -1.1 | -1.6 | -0.5 | -0.3 | 0.2 | -0.5 | 0.3 | 0.1 |
| | | | | -1.0 | -0.1 | -0.1 | -0.1 | -0.1 | -0.8 | -0.3 | -0.8 |
| 10947 | 6499 | 114 | 2.794 | -1.2 | 0.7 | -0.9 | -0.3 | -0.2 | 2.7 | -0.1 | 1.2 |
| | | | | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | -0.1 | 0.7 | 0.1 |
| 11646 | 11741 | -3478 | 3.088 | -1.1 | 0.4 | -0.3 | 0.6 | 0.1 | 3.6 | 0.3 | 1.1 |
| | | | | 0.6 | 1.2 | 0.2 | 0.5 | 0.8 | 0.4 | 0.3 | 0.2 |

MT 1

| | Iin | Iout | Itrim | BO | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 552.5 | 48.8 | 109.8 | 0.1298 | | | | | | |
| b | 1.0 | -3.7 | -0.3 | -1.5 | -0.2 | -0.1 | 0.1 | -0.2 | 0.4 | -0.2 |
| a | -9.4 | -3.9 | -2.4 | -0.5 | 0.1 | 0.1 | -0.2 | 0.1 | -0.2 | -0.4 |
| | 1939.7 | 48.8 | 745.5 | 0.4658 | | | | | | |
| b | -0.3 | 0.1 | -0.4 | -1.5 | -0.2 | -0.4 | -0.3 | -1.1 | 0.0 | -0.6 |
| a | -1.9 | -0.9 | -0.9 | -0.1 | -0.1 | 0.2 | -0.4 | 0.1 | -1.0 | 0.1 |
| | 4972.6 | 51.8 | 1995.8 | 1.1876 | | | | | | |
| b | 0.0 | -0.1 | -0.3 | -1.3 | 0.1 | -0.4 | 0.1 | 0.3 | 0.4 | 0.2 |
| a | 0.2 | 0.3 | -0.4 | 0.2 | -0.6 | 0.1 | -0.7 | -0.2 | -1.0 | -0.3 |
| | 6221.7 | 87.0 | 2346.6 | 1.4742 | | | | | | |
| b | 0.3 | 0.3 | -0.5 | 0.1 | -0.2 | -0.6 | -0.3 | -0.8 | -0.8 | -0.3 |
| a | 0.2 | 0.3 | -0.2 | 0.5 | 0.0 | 0.4 | -0.5 | 0.5 | -0.9 | 0.7 |
| | 8387.0 | 83.5 | 3197.4 | 1.9615 | | | | | | |
| b | 0.2 | 0.2 | -0.2 | 0.3 | 0.0 | -0.1 | 0.1 | -0.2 | 0.5 | -0.8 |
| a | 0.4 | 0.1 | -0.3 | 0.1 | -0.1 | -0.2 | 0.2 | 0.1 | -0.2 | 0.8 |
| | 9993.4 | 1502.1 | 3297.4 | 2.4048 | | | | | | |
| b | -0.1 | -2.6 | 0.2 | -1.7 | 0.6 | -0.4 | 1.0 | -0.3 | 1.9 | -0.1 |
| a | 0.2 | -0.2 | 0.1 | -0.1 | 0.3 | 0.3 | 0.4 | 0.6 | 1.0 | -0.2 |
| | 10949.8 | 6501.5 | 18.7 | 2.7827 | | | | | | |
| b | 0.0 | 0.2 | 0.0 | -0.7 | 0.3 | 2.1 | 0.1 | 1.0 | 0.1 | 0.8 |
| a | -0.9 | -0.2 | -0.6 | 0.2 | -0.2 | 0.0 | -0.5 | 0.5 | -0.7 | 0.4 |
| | 11644.6 | 11736.9 | -3477.5 | 3.0760 | | | | | | |
| b | 0.4 | 0.5 | 0.2 | 0.4 | 0.9 | 4.2 | 0.6 | 1.1 | 1.3 | 0.1 |
| a | -0.9 | 0.5 | 0.0 | 0.3 | 0.7 | 0.2 | 0.1 | -0.5 | 0.4 | -0.3 |

MSIM
4/8-9/86

The variation of measurements for 7 magnets of identical design.

| Iin (amps) | Iout (amps) | Itrim (amps) | B0 (Tesla) | bn (x.0001) n: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | an (x.0001) 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (The second line of each pair shows the sigma of the distribution.) | | | | | | | | | | | | | | | | | | | |
| 557. | 51. | 108. | 0.1314 | 0.5 | -1.8 | -0.3 | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 | -1.1 | -1.5 | -0.1 | -0.3 | -0.1 | -0.1 | -0.2 | -0.1 |
| 4. | 2. | 4. | 0.0015 | 0.3 | 2.4 | 0.4 | 1.1 | 0.3 | 0.5 | 0.5 | 0.4 | 4.8 | 2.0 | 1.3 | 0.2 | 0.3 | 0.3 | 0.6 | 0.3 |
| 1940. | 51. | 746. | 0.4678 | 0.1 | 0.6 | -0.5 | -0.8 | -0.2 | -0.6 | -0.1 | -0.7 | -0.6 | -0.4 | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 |
| 2. | 2. | 1. | 0.0017 | 0.4 | 0.9 | 0.3 | 0.4 | 0.2 | 0.2 | 0.4 | 1.0 | 1.5 | 0.8 | 0.6 | 0.3 | 0.2 | 0.5 | 0.5 | 0.4 |
| 4978. | 53. | 1997. | 1.1925 | 0.3 | 0.1 | -0.1 | -0.4 | -0.2 | -0.5 | -0.5 | -0.1 | -0.1 | 0.0 | 0.1 | 0.2 | 0.0 | 0.1 | -0.1 | 0.0 |
| 5. | 1. | 1. | 0.0041 | 0.3 | 0.7 | 0.2 | 0.6 | 0.2 | 0.4 | 0.7 | 0.8 | 1.5 | 0.6 | 0.4 | 0.3 | 0.5 | 0.4 | 0.4 | 0.3 |
| 6227. | 88. | 2349. | 1.4799 | 0.1 | 0.4 | -0.2 | 0.7 | -0.1 | -0.3 | 0.0 | -0.3 | -0.3 | -0.1 | 0.1 | 0.1 | -0.1 | 0.1 | -0.2 | 0.3 |
| 4. | 1. | 5. | 0.0061 | 0.3 | 0.6 | 0.4 | 0.6 | 0.3 | 0.3 | 0.3 | 0.7 | 1.7 | 0.4 | 0.5 | 0.2 | 0.4 | 0.2 | 0.5 | 0.4 |
| 8392. | 82. | 3198. | 1.9676 | 0.3 | 0.4 | 0.0 | 1.3 | 0.0 | 0.0 | -0.3 | -0.3 | -0.2 | -0.3 | 0.2 | 0.0 | 0.2 | 0.2 | -0.2 | 0.5 |
| 5. | 2. | 1. | 0.0073 | 0.5 | 0.7 | 0.4 | 0.5 | 0.4 | 0.5 | 0.4 | 0.5 | 1.7 | 0.5 | 0.4 | 0.4 | 0.2 | 0.4 | 0.4 | 0.4 |
| 9997. | 1441. | 3427. | 2.4076 | -0.2 | -1.2 | -0.1 | -0.3 | 0.1 | -0.3 | 0.3 | -0.4 | -0.2 | 0.0 | -0.1 | 0.1 | 0.0 | -0.2 | 0.1 | -0.2 |
| 3. | 163. | 77. | 0.0152 | 0.8 | 0.9 | 0.3 | 0.7 | 0.3 | 0.3 | 0.4 | 0.5 | 1.4 | 0.4 | 0.1 | 0.3 | 0.3 | 0.5 | 0.4 | 0.6 |
| 10951. | 6504. | 27. | 2.7932 | 0.1 | 0.2 | 0.1 | -0.6 | 0.1 | 2.0 | -0.2 | 0.6 | 0.4 | -0.2 | -0.2 | -0.1 | 0.0 | 0.2 | -0.3 | 0.3 |
| 3. | 3. | 32. | 0.0088 | 0.7 | 0.4 | 0.3 | 0.4 | 0.4 | 0.4 | 0.5 | 0.5 | 1.6 | 0.6 | 0.4 | 0.2 | 0.3 | 0.4 | 0.6 | 0.8 |
| 11645. | 11743. | -3424. | 3.0915 | -0.5 | 0.3 | -0.2 | 0.1 | 0.4 | 4.0 | 0.3 | 1.1 | 1.4 | 0.3 | 0.0 | 0.3 | 0.4 | 0.3 | 0.2 | 0.1 |
| 3. | 3. | 143. | 0.0153 | 0.6 | 0.7 | 0.5 | 0.6 | 0.6 | 0.4 | 0.4 | 0.5 | 2.1 | 1.2 | 0.5 | 0.4 | 0.4 | 0.3 | 0.4 | 0.6 |

Longitudinal variation of multipoles (x.0001)
in the 28m dipole STEX1

| Z(feet) | B0(Tesla) | b1 | a1 | b2 | a2 | b3 | a3 | b4 | b6 |
|---|---|---|---|---|---|---|---|---|---|
| 4 | 1.543 | 0.1 | 1.3 | -0.3 | 0.0 | 0.0 | 0.6 | 3.7 | 2.0 |
| 8 | 1.551 | -0.5 | 2.5 | -0.4 | -0.4 | -0.1 | 0.6 | 3.4 | 1.7 |
| 12 | 1.543 | -0.6 | 1.9 | -1.0 | 0.8 | 0.0 | 1.2 | 3.3 | 1.7 |
| 16 | 1.549 | -0.6 | 1.5 | -1.2 | 0.4 | 0.0 | 0.8 | 3.1 | 1.9 |
| 20 | 1.546 | -0.4 | 2.4 | -1.4 | -1.1 | -0.3 | 0.8 | 3.1 | 2.0 |
| 24 | 1.548 | -0.5 | 2.3 | -0.4 | -0.2 | 0.0 | 0.6 | 3.3 | 1.8 |
| 28 | 1.536 | -0.7 | 0.7 | -0.9 | -0.3 | -0.4 | 0.4 | 3.5 | 2.0 |
| 32 | 1.536 | 0.0 | 0.8 | -1.0 | 0.0 | -0.2 | 0.1 | 3.0 | 1.9 |
| 36 | 1.531 | -0.3 | 2.6 | -0.8 | 0.2 | -0.1 | 0.9 | 3.1 | 2.0 |
| 40 | 1.545 | -0.5 | 3.9 | -0.2 | -0.3 | 0.4 | 0.9 | 3.2 | 1.8 |
| . | | | | | | | | | |
| . | | | | | | | | | |
| . | | | | | | | | | |
| 76 | 1.550 | 0.0 | 3.5 | -0.9 | -0.5 | 0.3 | 1.8 | 2.6 | 1.6 |
| 80 | 1.552 | 0.1 | 0.7 | -0.7 | -0.1 | 0.0 | 0.3 | 2.7 | 1.7 |
| 84 | 1.548 | 0.0 | 2.3 | -0.1 | -0.6 | -0.1 | 1.0 | 3.0 | 1.5 |
| 88 | 1.546 | 0.3 | 2.0 | -0.7 | -1.4 | -0.3 | 0.9 | 2.8 | 1.7 |
| <> | 1.545 | -0.3 | 2.0 | -0.7 | -0.3 | -0.1 | 0.8 | 3.1 | 1.8 |
| sigma | 0.006 | 0.2 | 1.0 | 0.4 | 0.6 | 0.2 | 0.4 | 0.3 | 0.2 |

(The gap in this table was due to bad splices in the warm finger obstructing the probe. These will be corrected for our next measurements.)

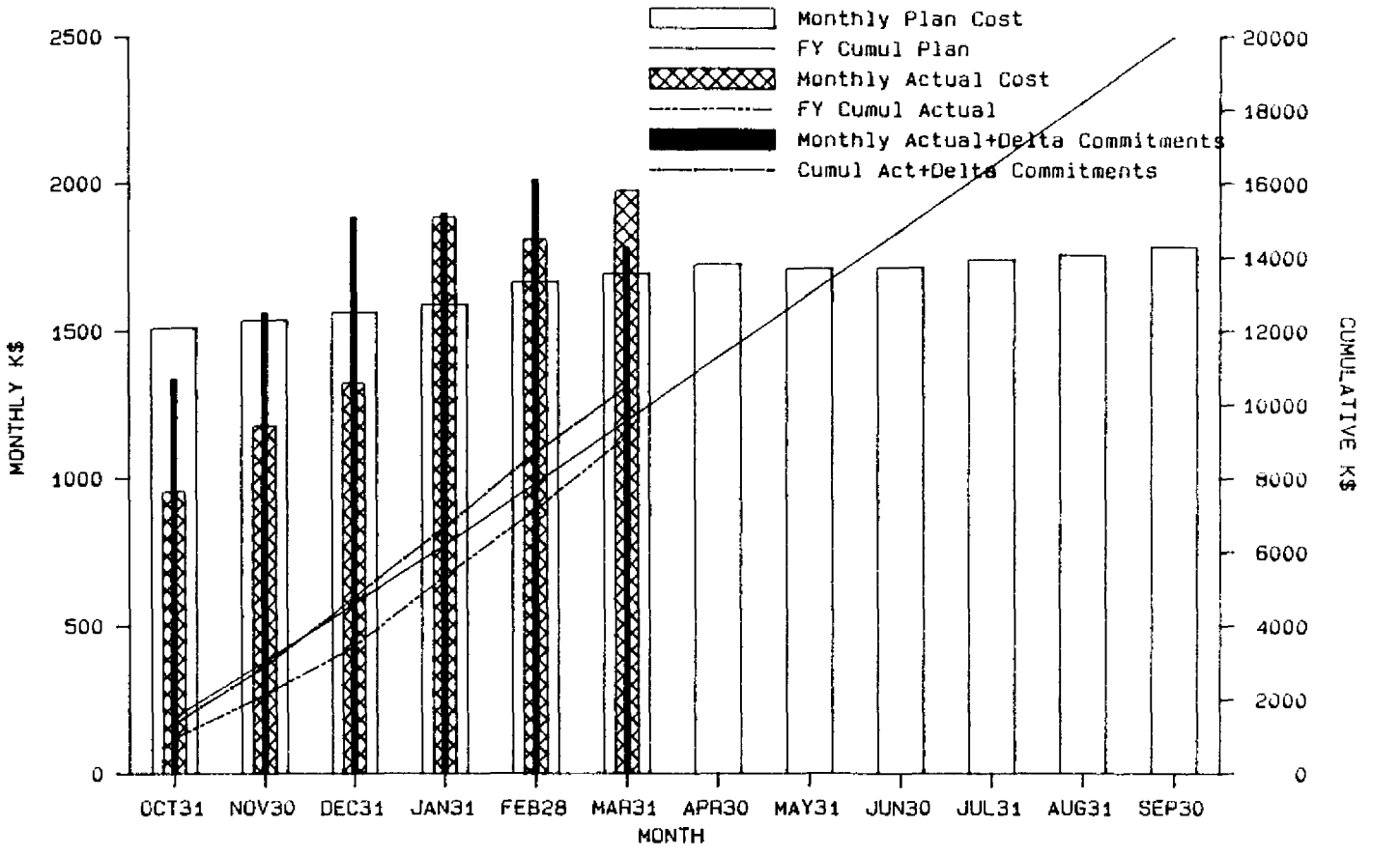
This magnet is of an earlier design of conducter placement. The currents were roughly adjusted to zero the sextupole in the first position. The decapole could also have been zeroed, but would have taken longer. The other points were measured using the same currents as used for the first point.

TEXAS ACCELERATOR CENTER
FY 86 Cost Report

Report Period: Mar. 1986

| Program Tasks | Material | Labor | G&A | Month Total | Year Total | Annual Budget |
|---|---|---|---|---|---|---|
| 01) Diode Quench Protection | 1.8 | 8.5 | 2.0 | 12.3 | 62.1 | 550.0 |
| 02) Correction Elements | 0.0 | 8.6 | 3.5 | 12.1 | 157.7 | 1025.0 |
| 03) Accelerator Physics | 0.5 | 3.2 | 0.9 | 4.6 | 56.0 | 275.0 |
| 04) Superferric Magnets | 26.7 | 27.9 | -10.4 | 44.3 | 603.1 | 750.0 |
| Program Cost Total: | 29.1 | 48.1 | -3.9 | 73.3 | 878.8 | 2600.0 |
| Additional Commitments: (As of 03/01/86) | 60.6 | | 125.7 | 186.3 | 402.8 | |

NOTE: This report reflects a correction made due to an error in the Dec. 1985 records.




| | 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 | | | | | | |
| FY Cumul Actual | 955 | 2134 | 3458 | 5346 | 7158 | 9132 | | | | | | |
| Actual+Delta | 1336 | 1563 | 1887 | 1900 | 2014 | 1784 | | | | | | |
| Cumul Act+Delta | 1336 | 2900 | 4787 | 6686 | 8700 | 10484 | | | | | | |

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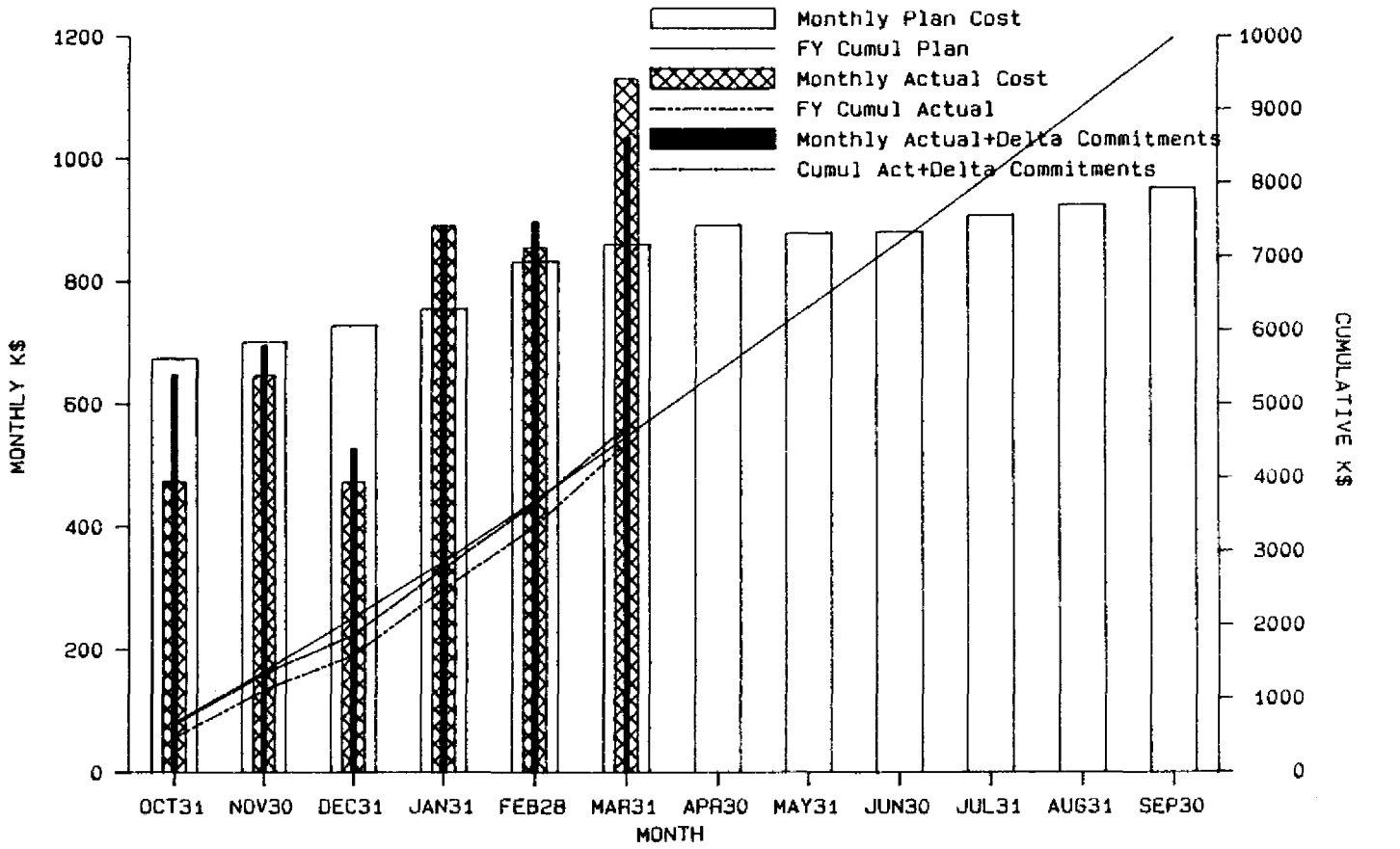
Figure 1




| | FISCAL YEAR 1986 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OCT31 | NOV30 | DEC31 | JAN31 | FEB28 | MAR31 | APR30 | MAY31 | JUN30 | JUL31 | AUG31 | SEP30 |
| Monthly Plan | 674 | 701 | 728 | 755 | 832 | 859 | 891 | 878 | 880 | 907 | 924 | 951 |
| FY Cumul Plan | 674 | 1375 | 2103 | 2858 | 3690 | 4549 | 5440 | 6318 | 7198 | 8105 | 9029 | 9980 |
| Monthly Actual | 474 | 647 | 473 | 890 | 855 | 1130 | | | | | | |
| FY Cumul Actual | 474 | 1121 | 1594 | 2484 | 3339 | 4469 | | | | | | |
| Actual+Delta | 648 | 696 | 527 | 890 | 897 | 1033 | | | | | | |
| Cumul Act+Delta | 648 | 1344 | 1871 | 2761 | 3658 | 4691 | | | | | | |

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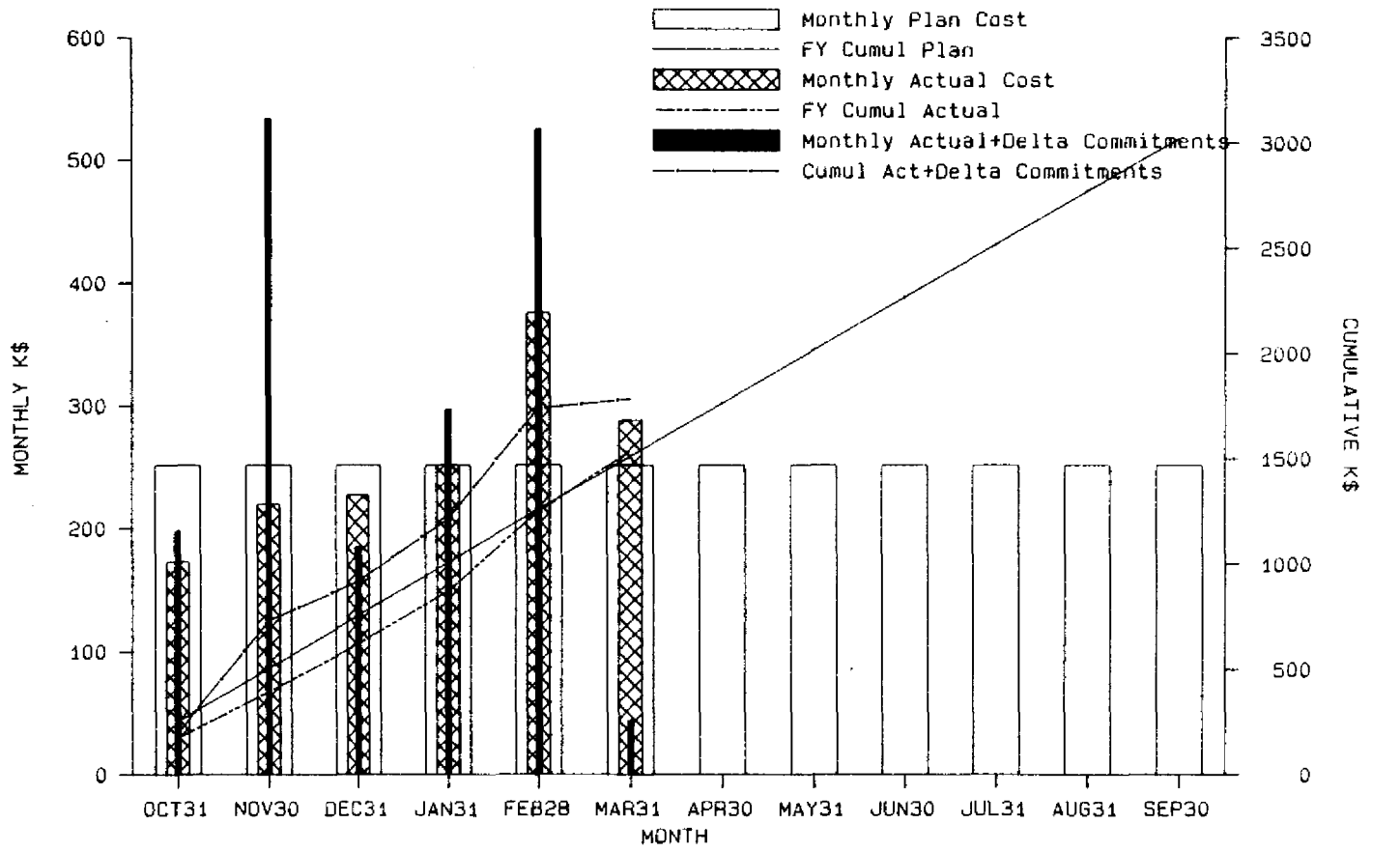
Figure 2




| | 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 | | | | | | |
| FY Cumul Actual | 173 | 393 | 620 | 872 | 1248 | 1536 | | | | | | |
| Actual+Delta | 198 | 534 | 185 | 297 | 525 | 44 | | | | | | |
| Cumul Act+Delta | 198 | 732 | 917 | 1214 | 1739 | 1783 | | | | | | |

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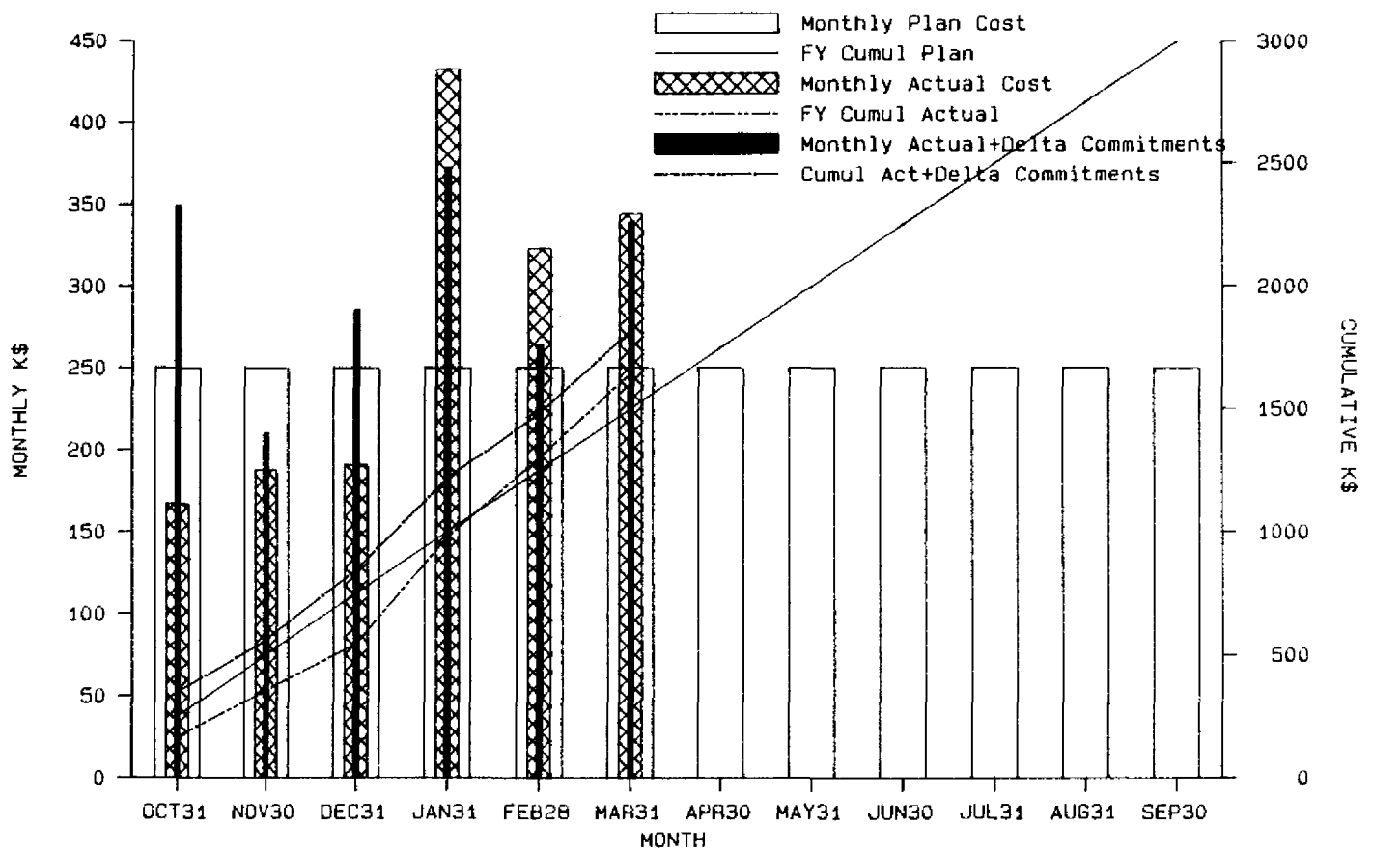
Figure 3




| | FISCAL YEAR 1986 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OCT31 | NOV30 | DEC31 | JAN31 | FEB28 | MAR31 | APR30 | MAY31 | JUN30 | JUL31 | AUG31 | SEP30 |
| Monthly Plan | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 |
| FY Cumul Plan | 250 | 500 | 750 | 1000 | 1250 | 1500 | 1750 | 2000 | 2250 | 2500 | 2750 | 3000 |
| Monthly Actual | 167 | 188 | 191 | 433 | 323 | 344 | | | | | | |
| FY Cumul Actual | 167 | 355 | 546 | 979 | 1301 | 1645 | | | | | | |
| Actual+Delta | 349 | 210 | 285 | 372 | 264 | 339 | | | | | | |
| Cumul Act+Delta | 349 | 560 | 845 | 1217 | 1481 | 1820 | | | | | | |

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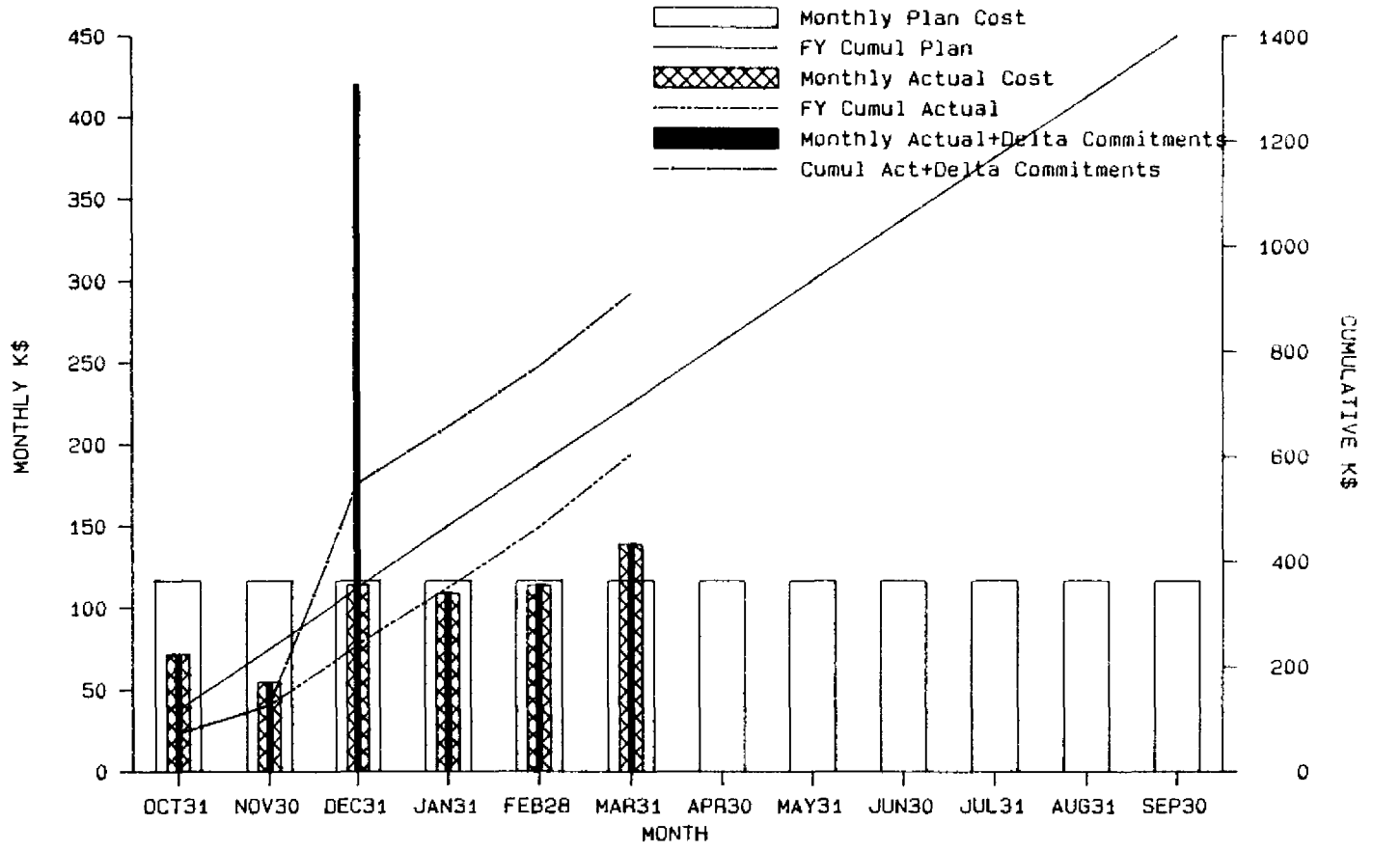
Figure 4




| | 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 | | | | | | |
| FY Cumul Actual | 72 | 127 | 241 | 350 | 464 | 603 | | | | | | |
| Actual+Delta | 72 | 55 | 420 | 109 | 114 | 139 | | | | | | |
| Cumul Act+Delta | 72 | 127 | 547 | 656 | 770 | 909 | | | | | | |

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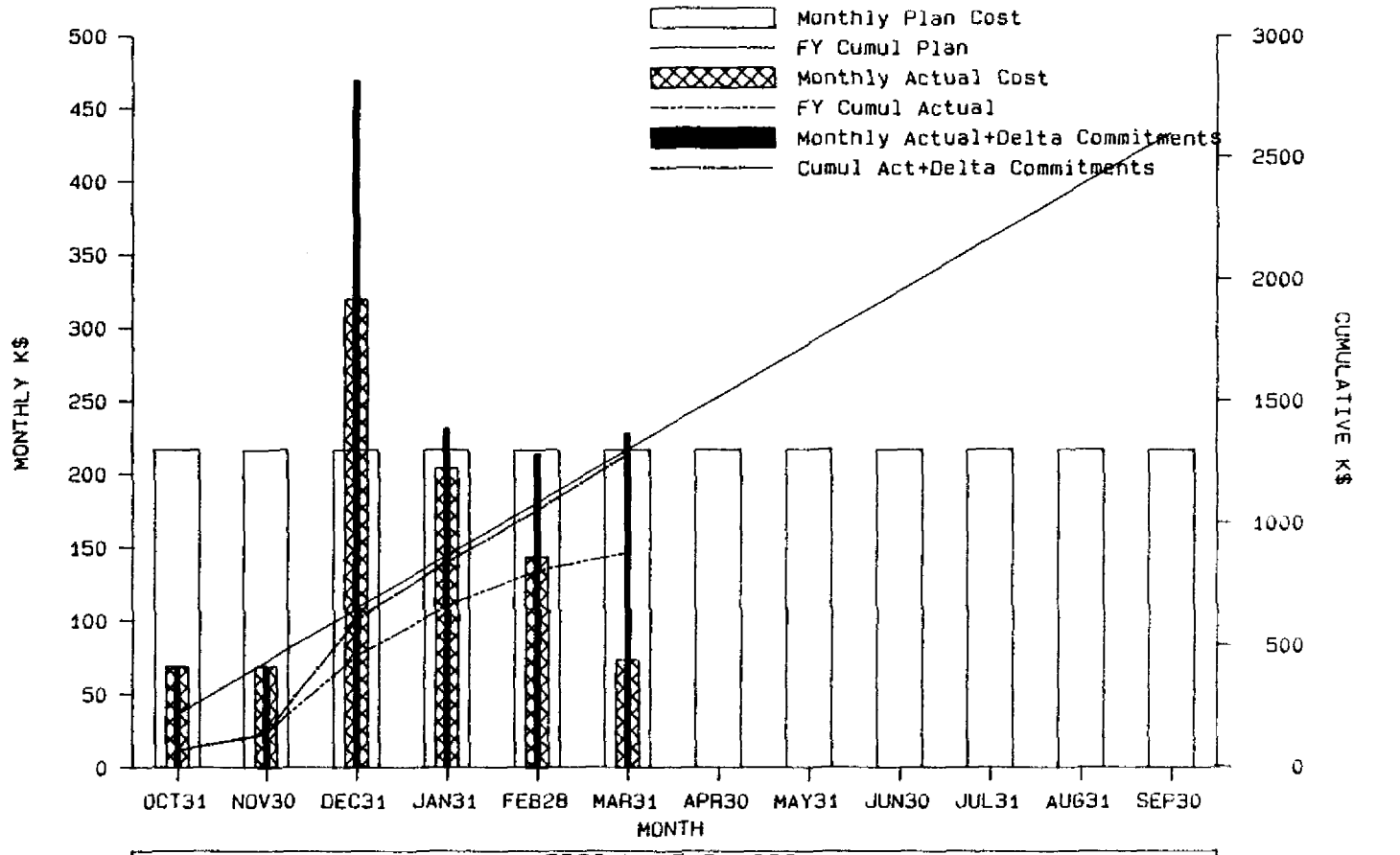
Figure 5




| | 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 | | | | | | |
| FY Cumul Actual | 69 | 138 | 458 | 662 | 805 | 879 | | | | | | |
| Actual+Delta | 69 | 68 | 470 | 231 | 214 | 228 | | | | | | |
| Cumul Act+Delta | 69 | 137 | 607 | 838 | 1052 | 1280 | | | | | | |

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Figure 6