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Superconducting Super Collider Laboratory

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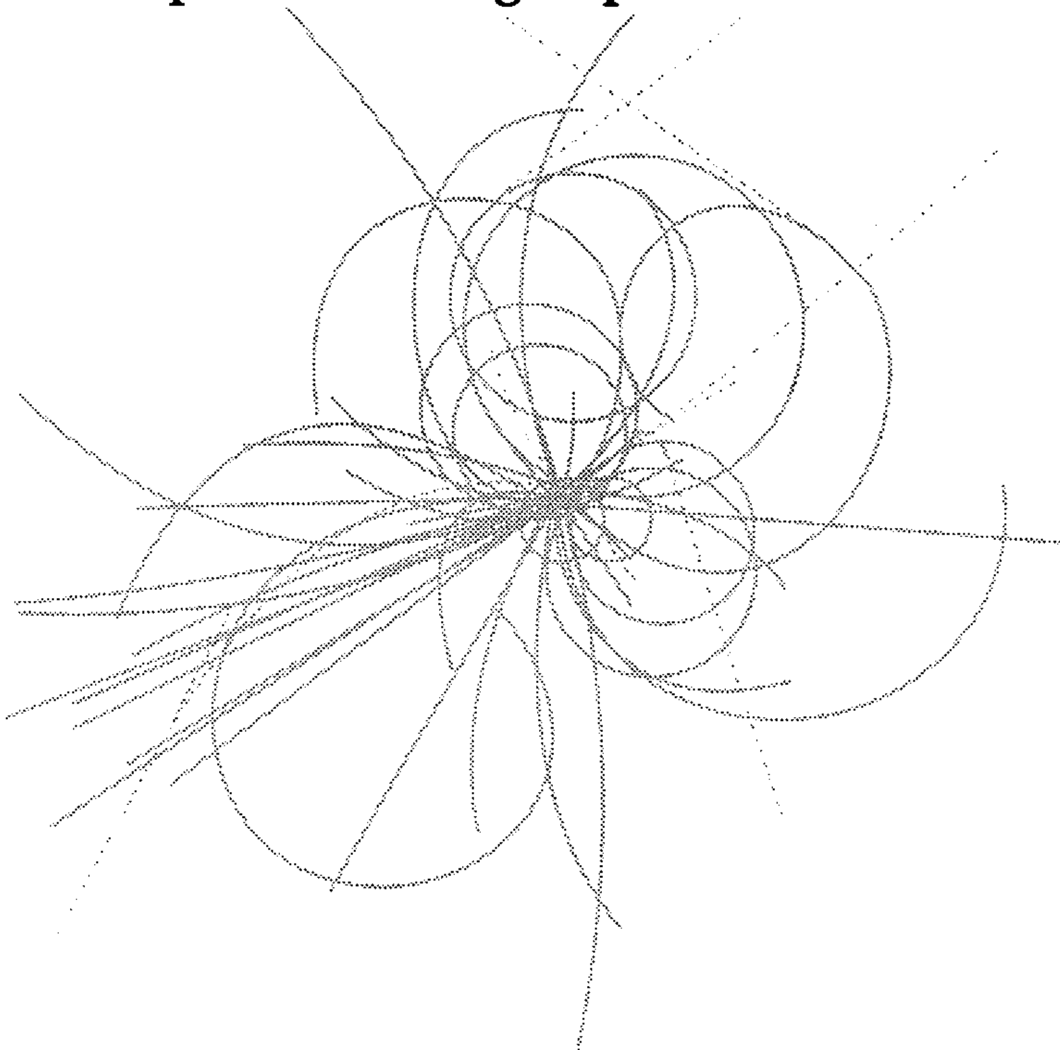

SSC Monthly Report

April 1985

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SSC MONTHLY REPORT

APRIL 1985

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SSC MONTHLY REPORT

APRIL 1985

A. Project Summary

- The SSC Site Parameters Document was sent to DOE on April 15, meeting a major project milestone. Copies are expected to be available for distribution from the CDG next month.

- A Workshop on Power Supplies and Quench Protection was held at LBL, April 1-5. There were 11 attendees from 7 institutions who started work on various issues related to power supplies and quench protection. There will be a preliminary report in June.

- An Aperture Task Force review meeting was held at LBL April 22-23 and attended by 47 participants from 9 institutions.

- The Task Force on Commissioning and Operations held their final meeting on April 12. A preliminary report is scheduled for next month and a final report in July.

- Magnet cost estimating contracts were signed with the Convair Division of General Dynamics Corporation and with Westinghouse Corp.

- A Technical Magnet Review Panel has been appointed as a critical part of the basic magnet type selection. In addition, a Magnet Selection Advisory Panel, composed of senior physicists, scientific managers, and industrial consultants, will soon be appointed.

- The second DOE Quarterly Review of the SSC program was held April 29.

- A meeting was held with CH and RTK on April 10 to discuss A/E plans and proposals pertinent to final contract negotiation.

- BNL. The coils for the first two 4.5 m long model dipoles of 4.0 cm aperture (Reference Design D) were wound and cured. All yoke blocks for both magnets were fabricated as well, and collars for the first magnet were received from the vendor.

- The fourth 4.5 m long 2-in-1 dipole of 3.2 cm aperture was tested with good results.

- Design details for the full-length (16.6 m) dipole of 4.0 m aperture underwent various revisions, partly in a continuous effort to ensure cost effectiveness. The full-length coil winder is nearing completion, and other assembly tooling is on schedule.

- New fine filament NbTi samples exhibit excellent current densities and magnetization behavior in good agreement with the "critical state" model.

- The compressor system for the 25 kW refrigerator underwent successful acceptance tests.

- Fermilab. Development activity focused on cryostat model tests. Both the 6 meter magnetic model and the 12 meter heat leak model were under test. Although the data are now being analyzed, preliminary indications are that both models behave as predicted.

- The sixth dry wound 5 cm dipole is nearly complete. A few winding problems have been encountered in learning the assembly techniques; however, the last two magnets wound have come out well.

- Accelerator physics efforts included experiments carried out on the Tevatron to study intentionally introduced field non-uniformity.

- The program costs for this month are higher than projected due to an accelerated effort to provide detailed information for the magnet style selection process.

- LBL. Magnet D12C-2, a one-meter model with the Reference Design D 40 mm bore and nitronic 40 steel collars, was tested and reached 6.0 Tesla on the second quench. Magnet D12C-3 was completed and coils for magnet D12C-4 were started.

- Cable was produced at the LBL facility with an improved Turkshead roller design that resulted in much closer control at keystone angle. This design will be used in the next New England Wire Company production run.

- Analysis of field errors produced by manufacturing tolerances was further improved. The HP-1000 system was upgraded to allow much faster computation speed.

- TAC. Efforts concentrated on magnet measurements. Measurements were made of both the quench velocity in the cable and the magnetic field multipoles. The results of the final measurements compare reasonably well with the Energy Doubler data evaluated at one half the inner coil radius (1.9 cm).

- The measurement of the quench velocity as a function of field compares well with predicted values. The most difficult quench--that is, the one that produces the highest temperature in the cable--is when an outer coil quenches.

- Difficulties with the measurement system have been studied, modifications are being made, and magnetic measurements can resume within a month.

B. Project Report

I. Central Design Group

Magnet Program. Detailed planning continued toward the achievement of the next major milestone of the SSC program, the Magnet Style Selection.

As a critical part of the basic magnet type selection, a Technical Magnet Review Panel has been appointed. Their charge is as follows:

> 1) Review magnet and cable development programs at BNL, Fermilab, LBL, and TAC.
>
> 2) Write a report evaluating the technical status of dipole and quadrupole magnet design and development work for the one-in-one and two-in-one low-field and high-field magnet styles. For each style, enumerate the R/D remaining before each style can prudently be carried to the full scale prototype stage. This enumeration should include an estimate of the time and manpower effort needed to complete the pre-prototype R&D. The report should include a detailed account of model tests for the various designs.
>
> 3) Evaluate and report on the status of superconducting cable development and enumerate further development objectives which could reasonably be expected to be complete in time to have a beneficial impact on SSC magnet cost, reliability, and ease of operation. The report should be complete by the end of July.

Members of this review panel are A. Tollestrup, chairman, Fermilab; F. R. Huson, TAC; R. Lundy, Fermilab; P. Reardon, BNL; C. Taylor, LBL; H. Hirabayashi, KEK; R. Watt, SLAC; and R. Yourd, CDG.

Soon to be appointed will be a Magnet Selection Advisory Panel to be composed of senior physicists, scientific managers, and some industrial consultants.

Contracts have been signed with the Convair Division of General Dynamics Corporation and with Westinghouse Electric Corporation to provide cost estimates for magnet designs C and D. The Laboratory programs will provide detailed cost estimates for magnet designs A, B, C, and D. This cost information for dipole magnet design is expected to be completed on or before

July 1. Revised estimates for conventional facility systems appropriate to the various magnet designs will also be completed July 1.

Cost estimates for quadrupoles, spool pieces, cryogenic systems, installation, and other accelerator systems are planned for completion by July 15. Technical reports from the Theory Group, the Low Temperature Operations Task Force, the Operations and Commissioning Task Force, the Power Supply and Operations Task Force, and current information frm the photodesorption experiment are planned for completion in July.

The above cost information, systems technical reports, and Magnet Review Panel evaluation will be provided to the SSC Director and the Magnet Selection Advisory Committee about August 1. The selection of the SSC magnet style is projected for September 1 (±15 days).

Conventional Systems. After receiving numerous comments from DOE in Washington and Chicago on the draft Siting Parameters Document, additional technical work was undertaken with the engineering firms, CER Corp. and their subcontractor, Parsons Brinckerhoff. The work centered on clarifying the information items that are being recommended to DOE for consideration. Numerical information was reviewed and modified as necessary. Following revision, the document was sent to DOE on April 15, meeting one of the major milestone dates of this phase of the SSC. It is expected that copies will be available for distribution from the CDG early next month.

The plans for design work, including scheduling and cost estimating of the conventional facilities of the SSC, were advanced during the month. A more detailed plan was developed that identified specific topics to be addressed during the next several years. These plans must be combined with those of the technical systems in order to have an integrated approach to the design and construction of the SSC. These plans will also guide the work of the new

A/E firm, RTK. Preliminary meetings were held with RTK in order to inform them of the scope of work that is contemplated.

Accelerator Theory and Computation. An Aperture Task Force review meeting was held at LBL on April 22-23 to summarize the aperture evaluation work up to that time. Each of the task force groups are preparing an interim technical report. In addition, several technical reports by individuals were contributed for a total of 11 reports.

Discussed in the meeting were the following topics of particular importance: 1) the recommendation by the aperture criterion group to emphasize the "linear aperture" evaluation; 2) the proposal of the first tentative set of magnet errors for both the cosine theta and the superferric magnet designs; 3) preliminary results from tracking with multipole errors; 4) the proposal of a "brick wall" effect for the evaluation of field error tolerance; 5) scaling of dynamic aperture with cell length has indicated that shorter cell length would be better.

Accelerator Systems. A Workshop on Power Supplies and Quench Protection was held at LBL April 1-5. Attendees were G. Cottingham and A. Prodell, BNL; D. Hartill, Cornell; W. Hassenzahl, LBL; K. Koepke and G. Tool, Fermilab; H. Kraus, INEL; P. Limon, CDG; G. Lopez, T. Tamanaka and J. Zeigler, TAC. They began work on various issues related to power supplies and quench protection. There will be a preliminary report in June and a final report one month later. The issues that are being studied in detail are:

- The behavior of the multiple power supplies of the superferric design, particularly taking into account the strongly coupled coil configuration.

- The capability of attaining the required power supply regulation. It appears that a regulation of $\Delta I/I \simeq 10^{-5}$ will be necessary to maintain the tune within an acceptable range.

- An investigation of the expected transmission line behavior of the power supply and magnet system.

- Reaching agreement about the input parameters that should be used for the quench propagation calculations.

- A study of various questions having to do with passive quench protection, such as the maximum permissible magnet length, the required sensitivity of detection schemes, and the quench propagation velocities.

- The pressure rise in cryostats during a quench especially in the high field magnets.

The final meeting on the Task Force on Commissioning and Operations was held. A preliminary report will be issued next month. The preliminary conclusions are as follows:

- Machines with reasonable operational characteristics can be built with any of the magnet types now under development.

- There are real differences among the magnet types that result in variances in operational behavior and flexibility and operating costs.

- One-in-one magnet types are preferred over two-in-one types for their greater flexibility, ease of operation and commissioning, and a number of design details of the complete machine. These factors are considered more important than having fewer cryostats, the major advantage of two-in-one types.

- Over/under magnet configurations are preferred to side-by-side configurations, when considering one-in-one types, because of better use of tunnel space and easier installation and replacement. There are also more options for configuring the injection and abort functions for either two-in-one or one-in-one magnet types.

- There is no obvious choice to be made at this time between low field and high-field magnet types. From the designs presently available, it appears that the low-field design results in a machine that is 5% to 10% more costly to operate than a ring of high-field magnets. However, there are other issues, such as synchrotron radiation and collective effects, which may be more important than the operating cost, and have yet to be completely evaluated.

The status of the Photodesorption Experiment at BNL is the following: The front end of the beam line is set up and aligned; light has been seen at the entrance into the experiment, and the alignment looks good. Calibration of the mass spectrometers is being done at Fermilab. In addition, the warm beam tube and the electronics have been shipped from Fermilab.

II. Laboratory Programs

A. BNL.

1. General

a. Analytical Studies. Optimization studies continued on the C5 coil design for the Reference Design D dipole. One interesting configuration was studied which has two more turns per quadrant than C5. This version called PK15 has a total of 38 turns in each half coil with a transfer fraction of 10.68 G/A compared with 10.35 G/A for the C5 design. Thus, it is slightly less efficient (approx. 2%) in the use of superconductor; however, the dipole field is purer and in particular the b_8 harmonic is reduced significantly as shown in the table below.

	b_2	b_4	b_6	b_8	b_{10}	b_{12}
C5	0.42	0.00	0.16	0.84	-0.03	-0.04
PK15	-0.05	-0.16	-0.03	0.15	0.19	0.05

b. Miscellaneous. Magnet Division personnel started and completed the first cost estimate of Magnet Design D. Magnet components (e.g., wedges, yoke laminations, insulators) were forwarded to LBL and Fermilab for use in their respective model magnet programs. The month saw considerable interaction with laboratories and industrial concerns. Discussions took place at BNL with representatives from General Dynamics on automation of SSC magnet assembly and with BBC personnel on SSC cryostat development. BNL personnel visited Fermilab, and vice versa, for discussions of a cryostat design and cost estimate. Finally, members of the CDG visited BNL to urge that the full-length magnet schedule be accelerated.

2. Model Magnets

a. 3.2 cm Aperture x 4.5 and 16.6 m Long Magnets. Inspection and testing of completed Nb_3Sn coils continued in the R&D group. Thus far, four inner coils have been tested; they all exhibit some degradation at the end of the straight section in the innermost turn.

b. <u>4.0 cm Aperture x 4.5 Long Magnets</u>.

- Four inner and four outer coils were completed by the end of April. For the inner coils, typically 8-9 kpsi was required for closing the molding fixture, and approximately 16 kpsi for the outer coils.

- All yoke module blocks required for the first two yokes have been completed.

- The transducers for the first magnet have been gauged, wired, and calibrated.

- The G10 tapered and collar spacers and coil and supports are nearing completion. Coil transition insulation is also in the fabrication stage.

- The first pair of inner and outer coils have been joined together with coil-to-coil solder connections completed.

- An experiment to determine the transverse thermal contraction of the collared coils was completed, and a technical note summarizing the results is in preparation.

- Collars for the first magnet were received from the vendor, H & J Tool & Die Co.

3. Tooling and Facilities

a. <u>Coil Fabrication Tooling</u>.

- As is evident from the discussion under Section 2.b above, both the 4.5 m coil winding, as well as coil curing fixtures, became operational in April.

- Design of the 16.6 m long coil winder is approximately 90% completed.

- Considerable progress was made on aspects of the coil tooling essential to achieving the required field quality. In particular, stress transducers were installed in the curing fixture. Initial results show excellent correlation between curing stress and hydraulic pressure. Provisions have been made for entering strain gauge data from the curing fixture into the HP86 computer.

b. <u>Coil and Yoke Assembly</u>.

- Design drawings of a press for testing a single collar module for shim size determination were released for fabrication, and the press was completed in the Heavy Duty Shops.
- Tooling for assembly of the 16.6 m yoke was released to the Shops.
- Changes were made in the design of the base of the press, incorporating "T"-slots. The platen was redesigned, and the detailed design of the "T" bars completed. Machining of the platen in the Heavy Duty Shops was completed by the end of April.
- A technique was finalized for assembling the 16.6 m yoke and helium containment vessel.
- Designs for flexible electrical interconnections and quench protection diode assemblies are still under study. A model of a flexible joint of the rolling type was subjected to fatigue tests, with no discernible degradation after 10,000 cycles.

c. <u>Bore Tube and Trim Coil Tooling</u>.

- The first conventionally wound trim coil-bore tube assembly was completed and is being prepared for inclusion in the first 4.0 cm aperture magnet.
- Proposals for bore tube plating were reviewed, and Task I has been awarded to two vendors.
- Considerable progress was made in the Multiwire trim coil area; the substrate transporter was installed at the vendor; multiwire samples with 0.008 in. diameter superconductor in a sextupole pattern, mounted on a bore tube, were delivered by the manufacturer; tooling for assembling coils onto the bore tube is also progressing.
- Tooling design for a full-length bore tube strong back has been released to the Shop for fabrication.

d. <u>Magnet Test Facilities</u>.

- Design of a room temperature second generation version of the traveling probe ("MOLE") was started. Meanwhile, revisions in the first generation high-field mole are continuing. Studies of gravity sensors have confirmed that a double sensor will provide the resolution required for precision field meaasurments.

- A vertical coil insertion/extraction fixture was released to the Shops.

- The engineering phase of the horizontal test facility is now under way.

4. Superconductor

a. Wire Procurement. An order was placed with IGC for special processing of NbTi wire suitable for inner coils in magnets of Reference Design D type, but with a revised copper-to-superconductor ratio (1.5:1 vs. the present ratio of 1.3:1) to serve as backup material in case magnets wound from 1.3:1 material should exhibit unstable performance. A minimum of 300 pounds of usable wire was ordered, or a minimum acceptable length at final wire size (diameter 0.0318 in.) of 2500 ft.

b. Cable Procurement. As noted in last month's report, a Request for Quotation was distributed to seven superconductor manufacturers in the U. S., Europe, and Japan on proposals for producing inner and outer cable for Reference Design D model magnets with filament size $\leq$ 5 micron diameter and $J_c > 2400$ A/mm^2. Sufficient cable for winding two 4.5 m long dipoles was requested, with delivery in December 1985. By April 15, the deadline for the RFQ, six replies had been received, including one joint proposal. The various proposals being evaluated are from Furukawa, Supercon/VAC, BBC, IGC, and MCA.

c. Coil Manufacturing. As of the end of April, four inner and four outer coils for 4.5 m long model magnets of Reference Design D type have been wound and cured, i.e., sufficient for two magnets.

d. Research. New wire samples have been received from Furukawa, MCA, and IGC with filament diameters ranging down to approximately 3 mu m. The samples exhibit excellent J_c values down to the smallest filament sizes. From magnetization measurements on some of these samples, it is concluded that down to filament diameters approximately 5 mu m, the "critical state" model is adequate in describing the scaling of magnetization with the product J_c. Moreover, direct magnetization measurements at low fields can be used to predict the changes in magnitude of the magnetization sextupole in magnets as the filament diameter is varied.

The short sample measurements on inner cable samples continued with measurements at Fermilab on the same conductor showing similar results. Use of the new high-pressure sample clamping fixture considerably improved the training behavior and yielded more consistent current-voltage curves. Nevertheless, the observed voltage behavior at low currents is still not understood.

5. Tests and Measurements

The fourth two-in-one SSC R&D magnet was successfully tested during April. Like its predecessors, the magnet has an aperture of 3.2 cm and is 4.5 m long. It was made with a different coil cross section in order to minimize the sextupole and decapole terms so that a reliable measurement of the quadrupole term due to cross talk between the bores can be made. The mag- net went to its short sample, 5.4T, without training. The sextupole and decapole were small enough so that a good measurement of the quadrupole can be made. The quadrupole terms have been measured with equal excitations of the two bores. Data taking for unequal excitation of the bores continues.

6. Power Supplies, Quench Protection, Electrical Systems

Magnet Division personnel participated in a SSC Workshop at LBL during April 1-5, where the possibility of a passive SSC magnet quench protection system was discussed. A possible approach, based on a 4-diode quench protection scheme, is presented in BNL Magnet Division Note 129-9 (SSC-MD-97).

7. Cryogenic Systems

Continued operation of cryogenic systems for magnet testing (Bldg. 902) and short sample testing (Bldg. 960) continued. The liquefier at Bldg. 960 was down for one week to investigate a high pressure drop in the heat exchanger train which is limiting liquid helium production. It was found that the charcoal used in the purifiers was pulverized into dust and that was blocking heat exchanger passages. The 80K absorber has been removed and large quantities of charcoal dust blown from the 80K to 20K heat exchanger. Results from this action are being evaluated to determine the need for further action.

We have begun a preliminary cost/benefit study of the 80K refrigeration level for SSC. Refrigeration at this temperature is used to cool magnet heat shields and, in some designs which use liquid nitrogen, as a precoolant for the helium refrigeration cycle. Different methods to produce and distribute this refrigeration are being studied.

The helium compressor system for the 25 kW refrigerator was operated for its acceptance test. The start-up was very smooth and the plant reached its design efficiency. The refrigerator will be used to supply cooldown refrigeration for the SSC long string test. Attention will now be focused on the refrigerator to prepare for its acceptance test in July.

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Both the 4.5 m coil winding, as well as coil curing fixtures, became operational this month. Design of the 16.6 m long coil winder is approximately 90Δ complete, and progress was made on aspects of the coil tooling essential for achieving the required field quality. In particular, stress transducers were installed in the curing fixture. Initial results show excellent correlation beetween curing stress and hydraulic pressure.

The first conventionally wound trim coil-bore tube assembly was completed and is being prepared for inclusion in the first 4.0 cm aperture magnet.

By the middle of the month, six replies had been received, including one joint proposal, for the request for quotation for procurement of superconducting cable for Reference Design D magnets that had been sent to vendors in the U. S., Europe, and Japan. The various proposals being evaluated are from Furukawa, Supercon/VAC, BBC, IGC, and MCA.

Four inner and four outer coils for 4.5 m long model magnets of Reference Design D type have been wound and cured (sufficient for two magnets). New wire samples have been received from Furukawa, MCA, and IGC which exhibit excellent J_c-values down to the smallest filament sizes.

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B. FNAL.

1. Cryostat Development

a. Magnetic Effects Model. The magnetic effects model installation was completed, and the model was cooled down and operated using the laboratory refrigeration system and the initial phase of the test program was carried out. The test sequence evaluated the response of cryostat components to symmetrical magnet coil quenches at various levels of current. The mechanical and thermal response of the 10K thermal radiation shield to the forces due to eddy currents induced by the quenches was measured.

The model will be warmed up and the coil decentered by the prescribed amount. Following decentering, the model will be cooled down and operated to measure the effects of decentering forces between the coil and the steel vacuum vessel. The following evaluation will be the cryostat response to the asymmetric quenching of the coil assembly.

b. Heat Leak Model. The heat leak model was cooled down and operated for the purpose of the heat leak measurements. The heat leaks to 4.5, 10, and 80K were measured. The test data is being analyzed.

2. Suspension R&D

Work continued on the conversion of the heat leak suspension dewar for the measurement of multilayer insulation (MLI) systems and their application techniques. Minor difficulty was encountered with the insulating vacuum with the research dewar. The heat meter was calibrated in the 0-3W range at liquid helium temperature. The conversion of the lower end of the vessel for measurement with MLI was completed. MLI measurements will begin in May.

The measurement of the creep of shrink fit joints between FRP tubes and metal end connection continues. Representative joints corresponding to that employed in the no-iron dipole are evaluated. The measurement is at a temperature of 105°F corresponding to the design criteria storage temperature. The measurements are being conducted in air.

3. Cryostat Design

Work continues on the conceptual design for a cold-iron magnet. Various geometries of piping and shields have been considered. A result of the study is that the minimum practical diameter for the vacuum vessel is of the order of 21 inches. The initial phase of a cost sensitivity study for vacuum vessel diameters, thicknesses, and materials is complete.

Evaluation of suspension systems continues. A detailed review was initiated for tension member and arch type systems. A parallel review will be initiated for post type systems.

The second revision of the SSC Design D Cryostat Design Criteria was issued April 26.

A contract for materials evaluation for the Design D Cryostat was awarded to the National Bureau of Standards at Boulder. NBS will provide input in the areas of criteria material properties, creep of FRP materials, radiation resistance of materials, and the use of titanium alloys for low temperature applications.

Work was also initiated on cryostat costs for the Design D magnet. The initial costs have been developed for the cryostat by Fermilab and are being developed for the 10 phase assembly by BNL. The initial cost estimate will be issued early next month and the final cost estimate will be completed in June.

4. Conductor Development

Cable short samples were measured using 5 to 15 cm long hairpin testing geometry. It was found that in order to get a resistive transition, some of the lower Cu/SC volume ratio samples had to be stabilized either with copper or stainless steel foil at current densities in excess of 2200A/mm^2. The higher copper-to-superconductor ratio cables (i.e., inner and outer of Design B and the 10 kA, 10T NbTi cable) were able to obtain a resistive transition at current densities as high as 2550A/mm^2 $\rho_{eff} \simeq 2\text{-}4 \times 10^{-12}$ Ω-cm 5.0T. The Design B prototype cables current densities were > 20Δ higher than the original 2200A/mm^2 used in the calculations.

5. Magnet Models

a. 12 Meter Thermal Model. Assembly was completed on April 3 and turned over to the Engineering Lab for cooldown.

b. 5 cm 824 Dipole Dry Winding. SG-1001 was completed on March 29 and SG-1002 was completed on April 4; both had severe turn-to-turn shorts. SG-1001 was autopsied with results concluding the cause of the turn-to-turn problem stemmed from bunching of the kapton insulation between the inner and outer coil layers. The insulation has been redesigned to prevent bunching as the collars are closed. SG-1002 is being potted in preparation for sectioning. Cross sections will be quite helpful in understanding what goes on when a dry wound coil is collared, i.e., slip planes, conductor placement, etc., in both the body and the ends. SG-1003 was completed and sent to the Magnet Test Facility on April 15. This magnet incorporates the redesigned intercoil insulation which seems to work successfully. Warm measurement of this magnet saw a large normal sextupole moment arising suspicion of magnetic material within the collar structure. Permeability measurements of collar keys and rods proved negative; however, the stainless steel shim used at the coil keys (both inner and outer) was found to be sightly magnetic. Magnet SG-1004 was completed and sent to the Magnet Test Facility on April 25. A high resistance short between upper and lower coils (>5 μΩ @ 0.8 kV) was found after collaring and repaired. Partial uncollaring at one end revealed the parting plane insulation was not cut to the correct width in a localized area. SG-1005 is in process with expected completion by the end of the month.

c. 5 cm 824 Dipole, Wet Winding. The first inner wet wound coil was completed on April 25 with very satisfactory results. Winding and curing will continue with expected completion of the first wet wound magnet the first week of May. The wet wound magnets are the same in all respects as the dry wound with the exception of the addition of 0.1 mil "B" stage epoxy on the kapton cable insulation.

d. 4 cm Design D (Dry Winding). Winding will begin on May 1. All parts are on hand with the exception of outer coil saddles (Fermilab parts) and collars (BNL parts).

e. Cable Measurements. Both BNL and Fermilab cable measurement machines will be mechanically operational by the end of the month. Two to three additional weeks are necessary for wiring and interfacing to the computer.

f. Traveling Collar Press. The collar press is operational for collaring 1-meter models. SG-1006 will be collared utilizing this press. Work continues to demonstrate its application on long magnets using a dummy long length collared coil assembly.

6. Accelerator Physics

A magnet aperture/field quality criterion was presented at a meeting of the Aperture Task Force at the Central Design Group headquarters. The criterion places emphasis on the interpretable beam behavior. An analysis of Tevatron operating experience was presented as background material in support of the criterion.

Experiments were carried out on the Tevatron to study the dynamical effects of intentionally introduced magnetic field nonlinearities--sextupole magnets in this case. The principal goal of this first study period was to verify that the hardware and diagnostic programs were working properly. Observations of a third-integer resonance in one degree of freedom were in good agreement with predictions. As a spinoff of this activity, the phase space plots that can now be made routinely in the control room will likely be a useful tool for Tevatron operation. An account of this work has been submitted for publication in Particle Accelerators.

a. Shielding. Hadron and muon shielding requirements were reviewed at the request of personnel working on the site criteria. Muon flux calculations were performed to estimate the muon intensity in the neighborhood of an interaction region arising from collisions at a nearby interaction region in the clustered layout. Detailed shielding calculations continue, using the FPS164 attached processor.

b. Cryogenic Progress. Efforts were devoted to contributing to the Operations and Commissioning Task Force held at the CDG. Studies that were agreed to in the January 1985 workshop were carried out and write-ups were prepared. C. Rode reviewed warmup and cooldown for various magnet types. An important aspect of this work was to review the data for different cryogenic systems in order to make sure that they were being compared on a fully equal basis. P. VanderArend studied steady-state operations for different magnet types. W. Fowler summarized the studies and prepared a draft summary report.

The conclusion of the work to date is that there are no insurmountable cryogenic problems associated with any of the proposed magnet types. The studies yielded a long list of comments and areas for future work.

c. Beam-Tube Vacuum Experiment. The cryostat for the vacuum experiment to be conducted by H. Jostlein and D. Trbojevic in conjunction with BNL at the NSLS is under construction by the cryogenic group at Fermilab (C. Rode, R. Andrews, et al.). The detector for neutrals will be a pair of Balzers QMS311 quadrupole mass spectrometers with cross-beam ion sources.

C. LBL.

1. Magnet Models.

a. D12C3. The fabrication and assembly of D12C3 was completed. Fabrication and assembly work on a flush type (non-flared coil end) dipole magnet continued during this reporting period. The initial design and fabrication of D12C4 was also started this month.

During the month the following tasks were completed: fabrication of collar keys; N. C. machining of G-10 coil end saddles; fabrication of coil end insulators; forming of Kapton coil insulation; fabrication and calibration of collar position indicators; assembly and calibration of coil load cells in collar packs; winding and curing of two inner and two outer coils; mechanical measuring of coil while under a loading of 10,000 psi; installation of coils and insulation of assembly mandrel; completion of end assembly including installing voltage taps; collaring coil with 25 mm aluminum collars; installing coil/collar assembly in yoke blocks; installing lead end splice plates, completing lead splices and instrumentation wiring.

The fabrication and assembly of D12C3 was achieved without any difficulty. Particular emphasis was placed on trying to increase the coil preload in the area where the inner coil first turn meets the end tear drops. Initial test results on D12C2 indicate that most of the quenches originated at this point in the coil assembly. D12C3 was mechanically complete by the end of April and ready for testing in the Bldg. 58 cryostat.

b. D12C4. The following tasks were completed this month: inner coil conductor cabled at the LBL facility; moulding of the coil end wedges; insulating of copper coil wedges received from BNL; design of inner and outer coil layer tear drops for both lead and return ends. D12C4 will utilize punched Nitronic 40 collars supplied by BNL. The present schedule calls for the completion of the magnet in mid-June.

2. Superconductor

a. Cabling R&D. One recurring problem in the attempts to produce cable to the stringent SSC specifications has been the variability in cable keystone angle. It has been concluded that this variability was due to worn parts in the Turksheads being utilized at New England Electric Wire. However, more recent tests showed that variations could also arise with new Turkshead components from differences in assembly techniques. In order to eliminate this additional source of variability, we have proposed a different configuration of the Turkshead rolls and have demonstrated that the new configuration allows reproducible keystone angles to be achieved. In the new configuration, the top and bottom rolls are ground to the width of the cable being produced. In operation, the side rolls are moved into contact with the top and bottom rolls. The top and bottom rolls are then adjusted to produce the desire cable thickness In the old set-up procedure, one side roll contacted the upper roll and the other side roll contacted the bottom roll. This allowed a large lateral load to be applied to the top and bottom rolls and this unbalanced load would tilt these rolls and change the keystone angle. The new configuration allows equal force to be applied to both sides of the top and bottom rolls. This configuration has been used to manufacture approzimately 8000 ft of cable with virtually no variation in the keystone angle. This change has been discussed with New England Electric Wire, and this new approach will be used on the next production run.

b. Fine Filament R&D. The raw materials necessary for preparing two billets for the hydrostatic extrusion experiment have arrived. These include copper cans, copper tubes, and NbTi rods. The NbTi rods will be clad with copper and loaded into the copper cans; the cans will be fitted with end caps and electron-beam welded under vacuum.

3. Analysis

a. POISSON Computer Program. A paper was presented at the Particle Accelerator Conference in Vancouver, British Columbia, covering the addition of elliptical region boundaries and the simulation of an infinite outer iron-free and current-free region.

Magnetization effects for a number of cases were calculated; more cases are to be considered.

b. Cryogenics. A note was written summarizing heat transfer considerations for a helium-II system for the SSC, including removal of heat generated by synchrotron radiation and sizing of the low-pressure heat exchanger.

c. Effect of Random Manufacturing Errors on Field Quality. A paper was presented at the Particle Accelerator Conference covering the estimation of magnetic field aberrations for the various circular-aperture SSC reference designs by extrapolation from SSC and Tevatron experience.

A preliminary note was issued covering the sensitivities of field aberrations to a variety of manufacturing errors for the circular-aperture SSC reference designs. This will serve as an aid to the establishment of manufacturing tolerances. This will be refined and re-issued in the following ways:

- The wedge-shaped spacers in each layer will be included in the analysis, as will the inclination of the near-radial block sides. (Previously, each layer was considered to be a single, radial-sided current block.)

- As an aid to the diagnosis of the causes of magnetic field errors measured on magnets, the sensitivities of field aberrations to various mechanical errors will be presented. (In the previous work, the signs of the field errors and various symmetries became lost in the process of determing root-mean-square errors.)

d. HP-1000 Computer System. The new A900 minicomputer was installed, along with the vendor's software for the operating system and utilities, and integrated into the HP-1000 network. POISSON and some of its ancillary programs were ported to the A900.

The data-acquisition system for the magnet-testing facility was upgraded.

e. Magnet Cross Section Design Program (BNL). A version of R. Fernow's program, MAG2PL, was ported to the A900, and some testing and debugging performed, along with porting the optimizing code MINUIT. Additional work will be required.

4. Instrumentation and Measurements

Initial testing for SSC model dipole D12C-2 began this month. This one meter long magnet is the first model that incorporates all the elements of the C-5 cross section for the 4 cm diameter aperture D magnet with stainless steel collars.

Training was excellent in HeI at 4.4K with the first quench at 5.5 Tesla and the second at 6.0 Tesla. It was observed from the strain gauge measurements that the inner layer was unloaded at the pole before maximum field was reached. The magnetic field quality is very good with a b_2 (sextupole) error of only 6 units (10^{-4} of the dipole at 1 cm radius) in the center section and an integral b_2 at injection field is only some 0.5 unit and the corrected b_2 is less than 2 units up to 4 Tesla central field.

Refrigeration malfunction forced a temporary shutdown after the early tests described above. Complete testing, including 1.8K operation in HeII, will be done late next month after refrigerator repair.

D. TAC.

1. General

During April, efforts concentrated on the various measurements of magnets. Measurements were made of both the quench velocity in the superconducting cable and of the magnetic multipoles of the field. The magnetic field measurements compare reasonably well with the Energy Doubler data evaluated at one half the inner coil radius (1.9 cm). Part of the width of the distribution of the data is due to systematic errors caused by the measurement probe.

Quench velocity was measured as a function of field. The measured values compare well with predicted values and are used in calculation of quenches in the magnet. The most difficult quench--that is, the one that produces the highest temperature in the cable--is when an outer coil quenches. The collected data give the various current variations during a quench and the maximum temperatures in each of the coils.

2. Short Magnets

Three difficulties were encountered with the TAC measurement system. First, the bearings on the probe were not adequate to guide the probe evenly, and a systematic wobble in the probe occurred. Second, the speed of the probe varies with time, and third, the ripple in the power supply is larger than desired. In addition a modification to the positioning of the probe in the magnets during measurements is necessary. The present probe is 1.5 cm in diameter and thus measures the magnetic field out to a radius of 0.75 cm (multiples are quoted at a radius of 1 cm). The probe will therefore be modified so that it can be offset by 4 mm horizontally so that the field can be sampled beyond 1 cm radius. It will take about one month to make the modifications to the measurement system and return to magnetic measurements.

The quench propagation velocity was measured in one of the one meter magnets. Various voltage taps were placed in the magnet so that the time the cable went normal at a particular position could be recorded. These measurements agree well with predicted values of quench propagation.

3. Theory and Design

We have modified the layout of the refrigeration system in the large ring. From discussions at the Operations and Commissioning Task Force, it became apparent that 24 refrigerators were more expensive to operate than 12 refrigerators. Since the number of refrigerators is determined more by the total heat load, it is possible to reduce the number of refrigerators to 12. This design change has been implemented and modifications to the various design parts of the magnet will be made where necessary.

The lattice for the superferric SSC has also been changed. The half cell length has been reduced from 150 to 115 meters; therefore, the 115 meter unit of this design is composed of three 35 meter dipole units, a 4.7 meter quadrupole, 4.3 meters of spool piece, and a 1.0 meter tap for magnet connections. These modifications will be transmitted to the CDG in a forthcoming report.

C. Project Cost Data

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TABLE C-1
CENTRAL DESIGN GROUP - SUPERCOLLIDER

APRIL 1985 COST REPORT (K$)

	PROGRAM ELEMENT	LABOR	MAT'L & SERVICES	G & A	MONTH TOTAL	YEAR TO DATE	ANNUAL BUDGET
1.1	ADMINISTRATION	95	236	37	368	1225	2015
1.2	PROGRAM PLANNING & MANAGEMENT	34	12	22	68	167	400
1.3	ACCELERATOR R & D	37	85	55	177	554	1730
1.4	CONVENTIONAL SYSTEMS DEVELOP.	6	0	3	9	122	1180
	CDG TOTAL COSTS	172	333	117	622	2068	5325
	ESTIMATED COMMITTMENTS					368	

TABLE C-2
BROOKHAVEN NATIONAL LABORATORY - SUPERCOLLIDER

APRIL 1985 COST REPORT (K$)

	PROGRAM ELEMENT	LABOR	MAT'L & SERVICES	G & A	MONTH TOTAL	YEAR TO DATE	ANNUAL BUDGET
2.1	GENERAL	20	29	20	69	422	800
2.2	MAGNET MODELS	89	50	59	198	1290	2200
2.3	TOOLING	27	24	22	73	541	800
2.4	MAGNET MEASUREMENT & DEVEL.	19	11	13	43	279	400
2.5	POWER SUPPLIES & QUENCH PROT.	15	3	8	26	232	280
2.6	CRYOGENIC TESTING	27	5	16	48	321	500
	BNL SSC PROGRAM	197	122	138	457	3085	4980
2.7	SUPERCONDUCTOR DEVELOPMENT	26	20	19	65	482	900
2.8	CRYOGENIC SYSTEMS DEVELOPMENT	36	7	22	65	428	770
	BNL ACCELERATOR RELATED PROG.	62	27	41	130	910	1670
	BNL TOTAL	259	149	179	587	3995	6650
	ADDITIONAL COMMITMENTS					342	
	EQUIPMENT						475

TABLE C-3
FERMI NATIONAL ACCELERATOR LABORATORY - SUPERCOLLIDER

APRIL 1985 COST REPORT (K$)

	PROGRAM ELEMENT	LABOR	MAT'L & SERVICES	G & A	MONTH TOTAL	YEAR TO DATE	ANNUAL BUDGET
3.1	GENERAL	3.4	6.3	3.6	13.3	109.2	340
3.2	MAGNET MODELS	69.1	331.6	145.8	546.5	2196.4	3225
3.3	FACILITY DEVELOPMENT	4.4	12.2	6	22.6	214.3	340
	FNAL SSC PROGRAM	76.9	350.1	155.4	582.4	2519.9	3905
3.4	SUPERCONDUCTOR DEVELOPMENT	21.4	5.1	9.6	36.1	114.4	400
3.5	CRYOSTAT DEVELOPMENT	94.3	32.2	46	172.5	1088.6	890
3.6	ACCELERATOR PHYSICS	32.7	37.2	25.3	95.2	425.7	830
	FNAL ACCELERATOR RELATED PROG.	148.4	74.5	80.9	303.8	1628.7	2120
	FNAL TOTAL	225.3	424.6	236.3	886.2	4148.6	6025
	ADDITIONAL COMMITMENTS					240.6	
	EQUIPMENT						25

TABLE C-4
LAWRENCE BERKELEY LABORATORY - SUPERCOLLIDER

APRIL 1985 COST REPORT (K$)

	PROGRAM ELEMENT	LABOR	MAT'L & SERVICES	G & A	MONTH TOTAL	YEAR TO DATE	ANNUAL BUDGET
4.1	GENERAL	2	2	2	7	81	115
4.2	MAGNET MODELS	14	2	8	23	221	395
4.3	ANALYSIS	7	2	5	14	89	125
4.4	INSTRUMENTATION/MEASUREMENTS	4	2	3	9	73	155
	LBL SSC PROGRAM	27	8	18	53	464	790
4.5	ACCELERATOR THEORY	40	4	22	66	538	800
4.6	SUPERCONDUCTOR DEVELOPMENT	3	6	4	12	170	410
	LBL ACCELERATOR RELATED PROG.	43	10	26	78	708	1210
	LBL TOTAL	70	18	44	131	1172	2000
	ADDITIONAL COMMITMENTS					149	

TABLE C-5
TEXAS ACCELERATOR CENTER - SUPERCOLLIDER

APRIL 1985 COST REPORT (K$)

	PROGRAM ELEMENT	LABOR	MAT'L & SERVICES	G & A	EQUIP	MONTH TOTAL	YEAR TO DATE	ANNUAL BUDGET
5.1	GENERAL	0	130.1	15.3		145.4	438	825
5.2	SHORT MAGNET MODELS	19.1	23.3	7.6		50	770.5	1150
5.3	LONG MAGNET MODELS*	19.1	0	0		19.1	123.4	1660
5.4	TOOLING	0	0	0		0	0	630
5.5	THEORETICAL ANALYSIS	19.1	0	0		19.1	74.8	130
5.6	FACILITY DEVELOPMENT	0	0	0	8.3	8.3	233.9	605
	TAC SSC PROGRAM	57.3	153.4	22.9	8.3	241.9	1640.6	5000

*Does not include 1062 K$ obligation to General Dynamics Corp. for fabrication of long magnets

TABLE C-6
PROGRAM SUMMARY - SUPERCOLLIDER

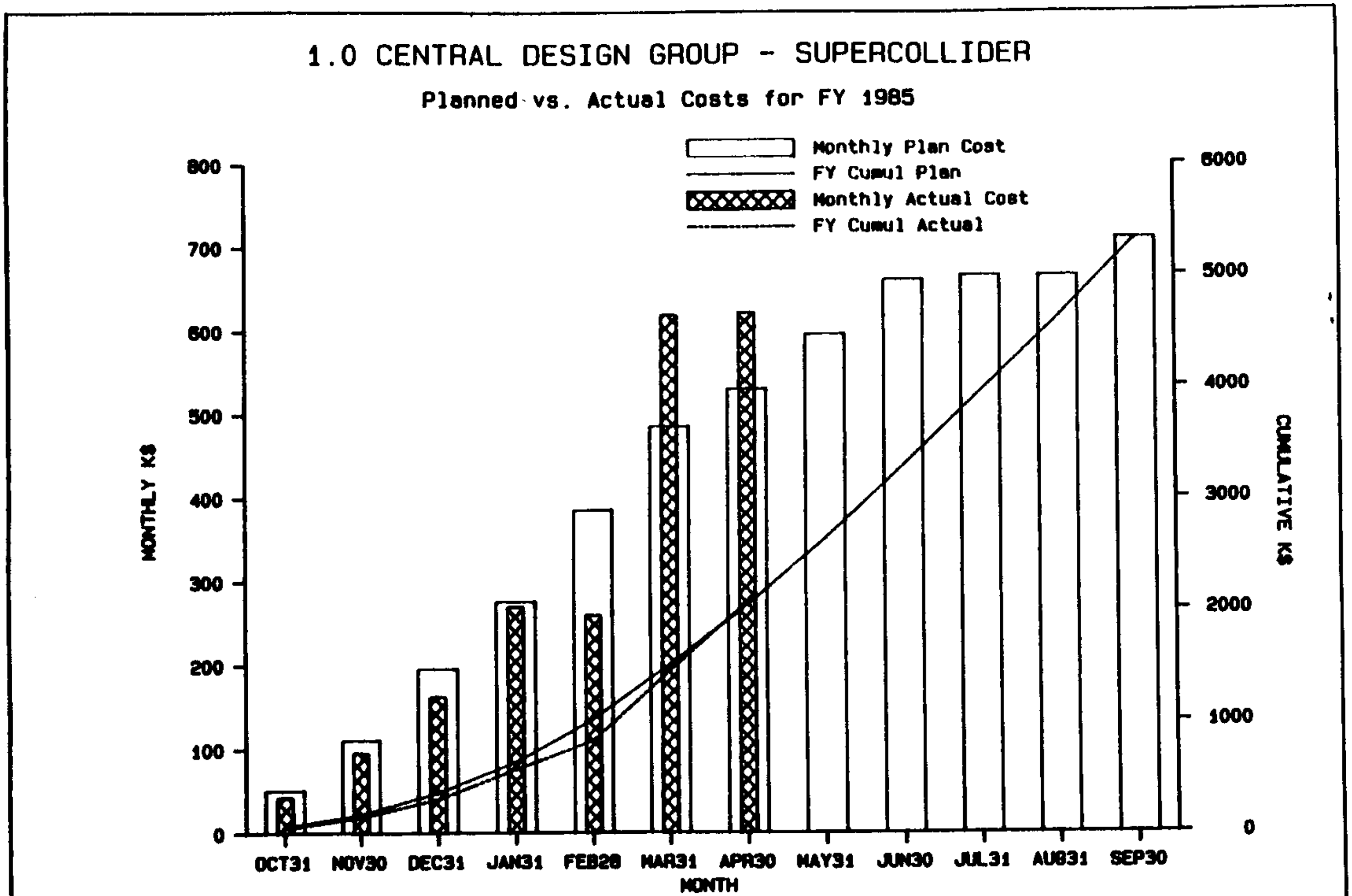
APRIL 1985 COST REPORT (K$)

	PROGRAM ELEMENT	LABOR	MAT'L & SERVICES	G & A	EQUIP	MONTH TOTAL	YEAR TO DATE	ANNUAL BUDGET
1.	CDG PROGRAM	172	333	117		622	2068	5325
2.	BNL SSC PROGRAM	197	122	138		457	3085	4980
3.	FNAL SSC PROGRAM	76.9	350.1	155.4		582.4	2519.9	3905
4.	LBL SSC PROGRAM	27	8	18		53	464	790
5.	TAC SSC PROGRAM	57.3	153.4	22.9	8.3	241.9	1640.6	5000
	TOTAL SSC PROGRAM	530.2	966.5	451.3	8.3	1956.3	9777.5	20000

TABLE C-7
SSC RELATED ACCELERATOR PROGRAM SUMMARY

APRIL 1985 COST REPORT (K$)

	PROGRAM ELEMENT	LABOR	MAT'L & SERVICES	G & A	EQUIP	MONTH TOTAL	YEAR TO DATE	ANNUAL BUDGET
1.	BNL SSC PROGRAM	62	27	41		130	910	1670
2.	FNAL SSC PROGRAM	148.4	74.5	80.9		303.8	1628.7	2120
3.	LBL SSC PROGRAM	43	10	26		79	708	1210
	TOTAL SSC RELATED ACCEL PROG	253.4	111.5	147.9	0	512.8	3246.7	5000



	FISCAL YEAR 1985											
	OCT31	NOV30	DEC31	JAN31	FEB28	MAR31	APR30	MAY31	JUN30	JUL31	AUG31	SEP30
Monthly Plan	50	110	195	275	385	485	530	595	660	665	665	710
FY Cumul Plan	50	160	355	630	1015	1500	2030	2625	3285	3950	4615	5325
Monthly Actual	42	95	162	269	259	619	622					
FY Cumul Actual	42	137	299	568	827	1446	2068					

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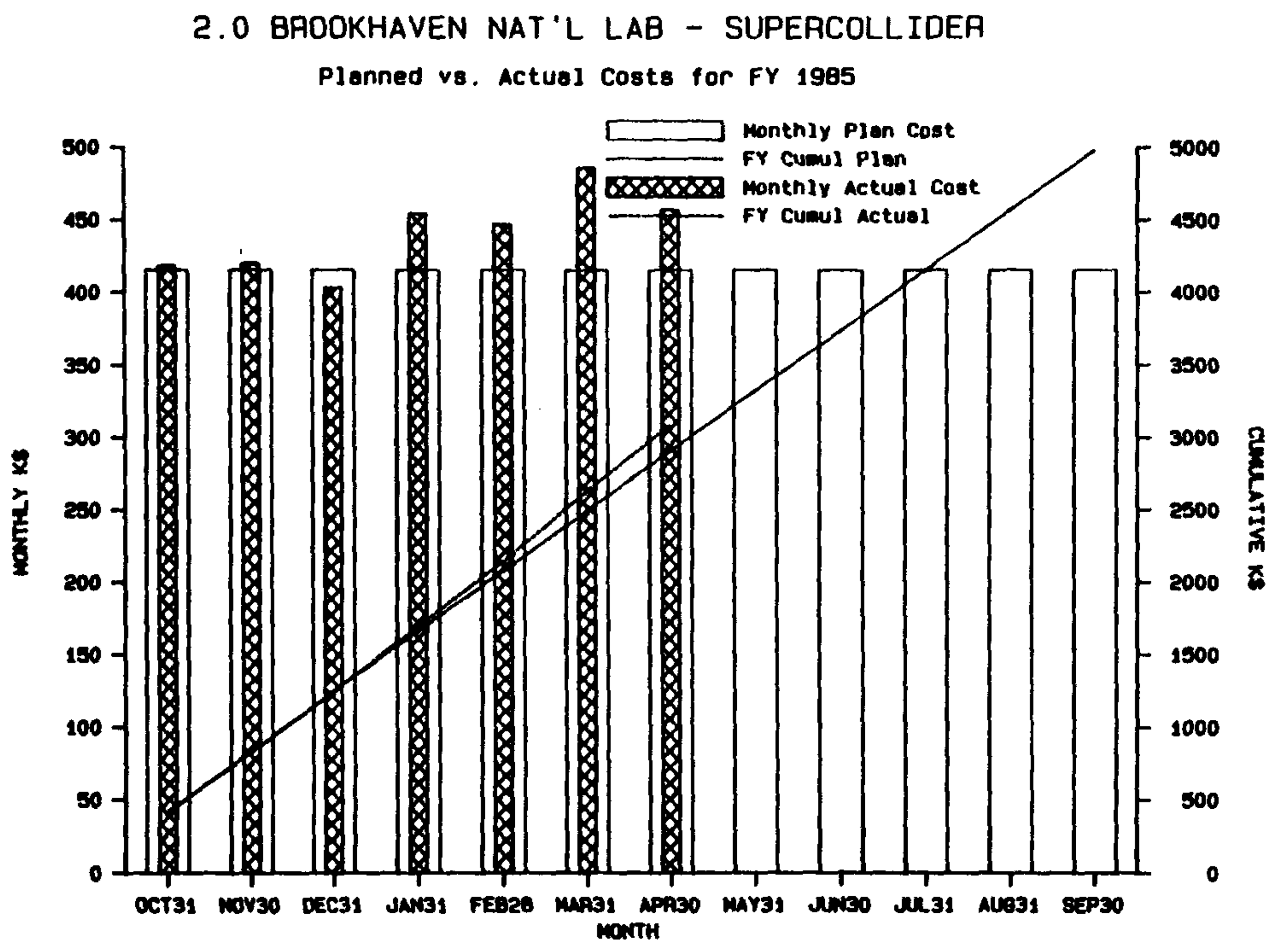
29-MAY-85

Figure 1



	FISCAL YEAR 1985											
	OCT31	NOV30	DEC31	JAN31	FEB28	MAR31	APR30	MAY31	JUN30	JUL31	AUG31	SEP30
Monthly Plan	415	415	415	415	415	415	415	415	415	415	415	415
FY Cumul Plan	415	830	1245	1660	2075	2490	2905	3320	3735	4150	4565	4980
Monthly Actual	418	420	403	454	447	486	457					
FY Cumul Actual	418	838	1241	1695	2142	2628	3085					

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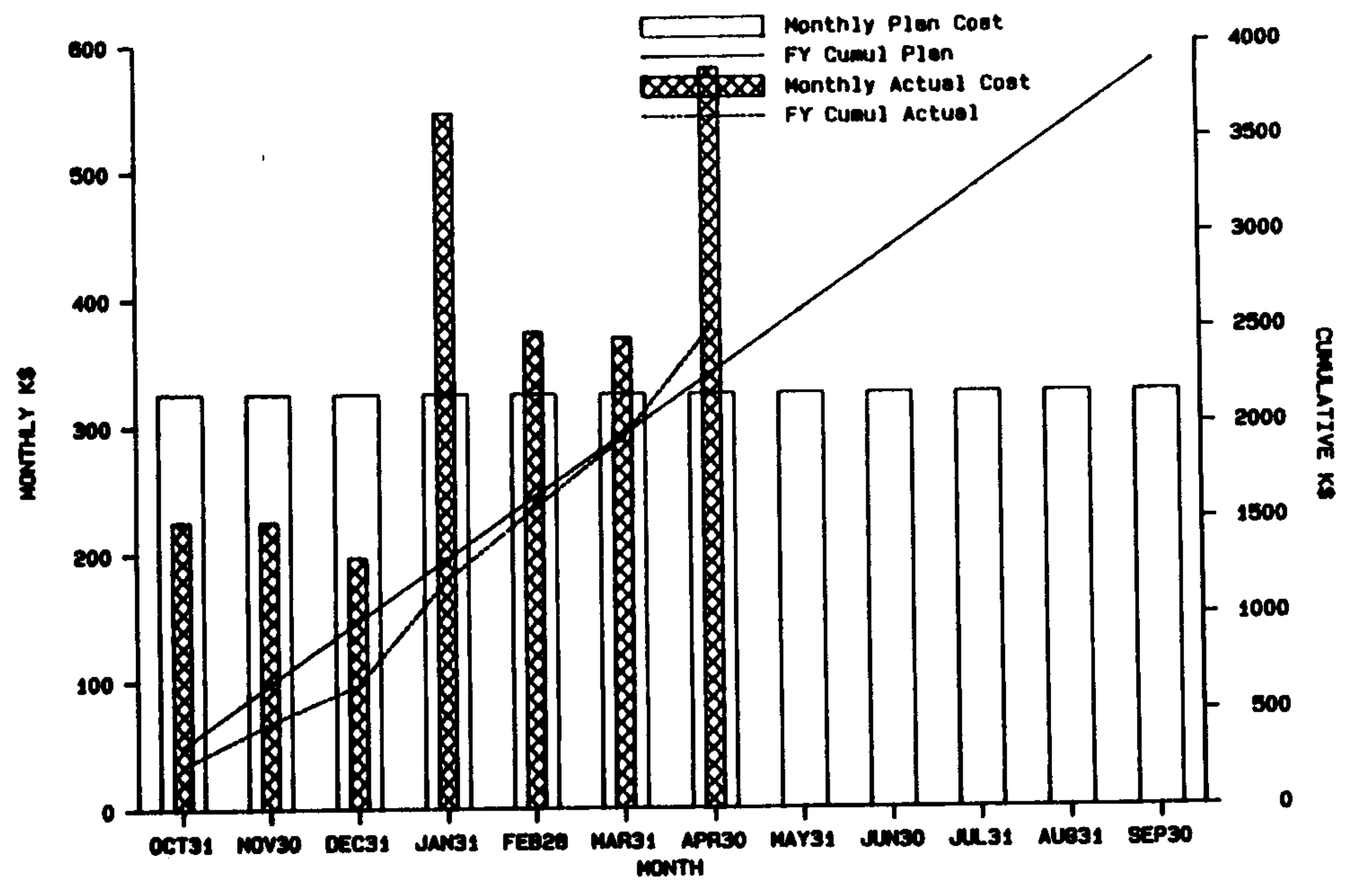
Figure 2

3.0 FERMI NAT'L ACCEL LAB - SUPERCOLLIDER

Planned vs. Actual Costs for FY 1985



	FISCAL YEAR 1985											
	OCT31	NOV30	DEC31	JAN31	FEB28	MAR31	APR30	MAY31	JUN30	JUL31	AUG31	SEP30
Monthly Plan	325	325	325	325	325	325	325	325	325	325	325	325
FY Cumul Plan	325	651	976	1302	1627	1953	2278	2603	2929	3254	3580	3905
Monthly Actual	225	225	197	547	374	370	582					
FY Cumul Actual	225	450	647	1194	1568	1938	2520					

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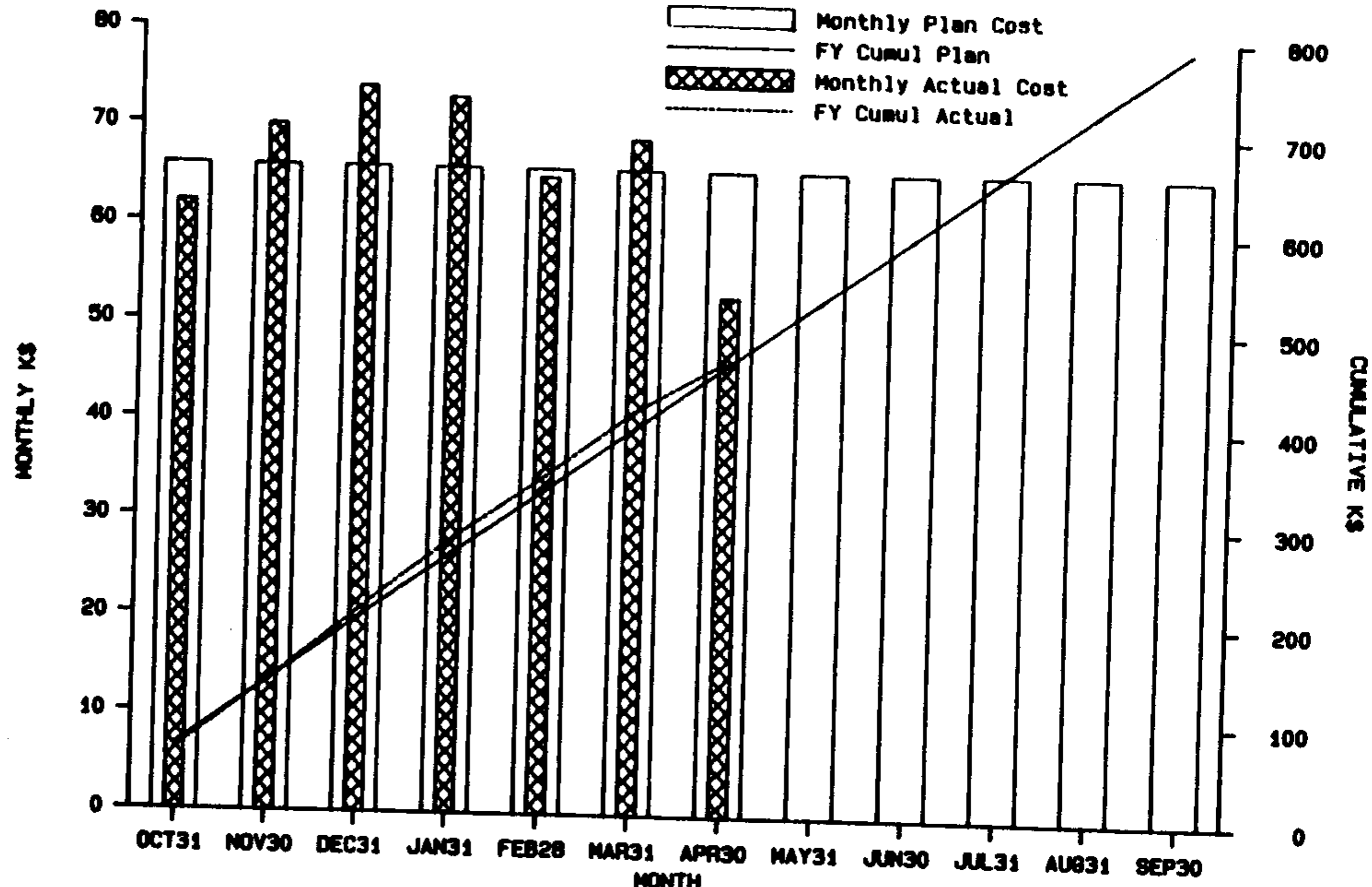
29-MAY-85

Figure 3

4.0 LAWRENCE BERKELEY LAB - SUPERCOLLIDER

Planned vs. Actual Costs for FY 1985



	FISCAL YEAR 1985											
	OCT31	NOV30	DEC31	JAN31	FEB28	MAR31	APR30	MAY31	JUN30	JUL31	AUG31	SEP30
Monthly Plan	66	66	66	66	66	66	66	66	66	66	66	66
FY Cumul Plan	66	132	198	263	329	395	461	527	592	658	724	790
Monthly Actual	62	70	74	73	65	69	53					
FY Cumul Actual	62	132	206	279	344	413	466					

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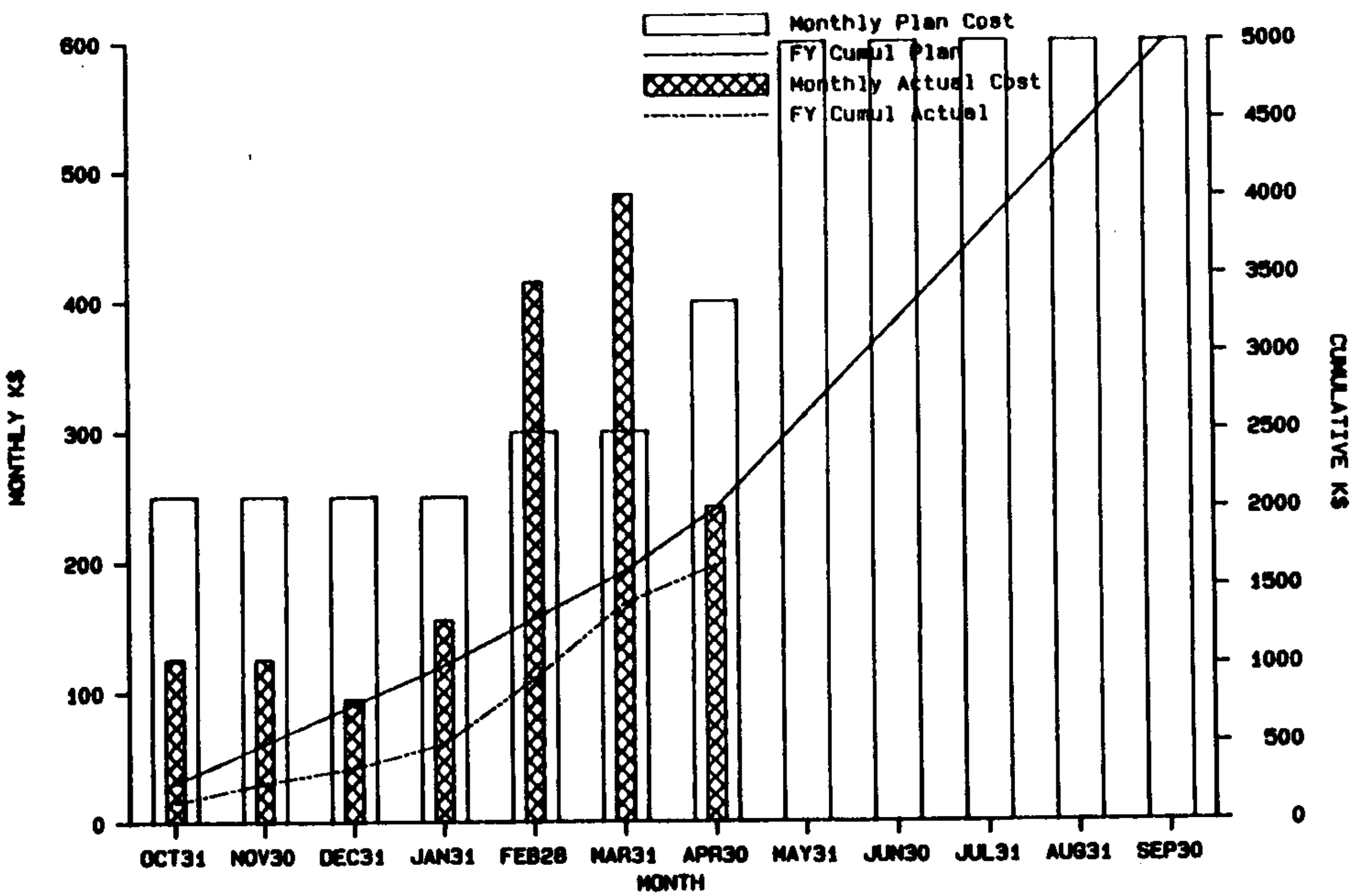
3:41 pm
29-MAY-85

Figure 4

5.0 TEXAS ACCELERATOR CENTER - SUPERCOLLIDER

Planned vs. Actual Costs for FY 1985



	FISCAL YEAR 1985											
	OCT31	NOV30	DEC31	JAN31	FEB28	MAR31	APR30	MAY31	JUN30	JUL31	AUG31	SEP30
Monthly Plan	250	250	250	250	300	300	400	600	600	600	600	600
FY Cumul Plan	250	500	750	1000	1300	1600	2000	2600	3200	3800	4400	5000
Monthly Actual	125	125	94	155	416	483	242					
FY Cumul Actual	125	250	345	500	916	1399	1641					

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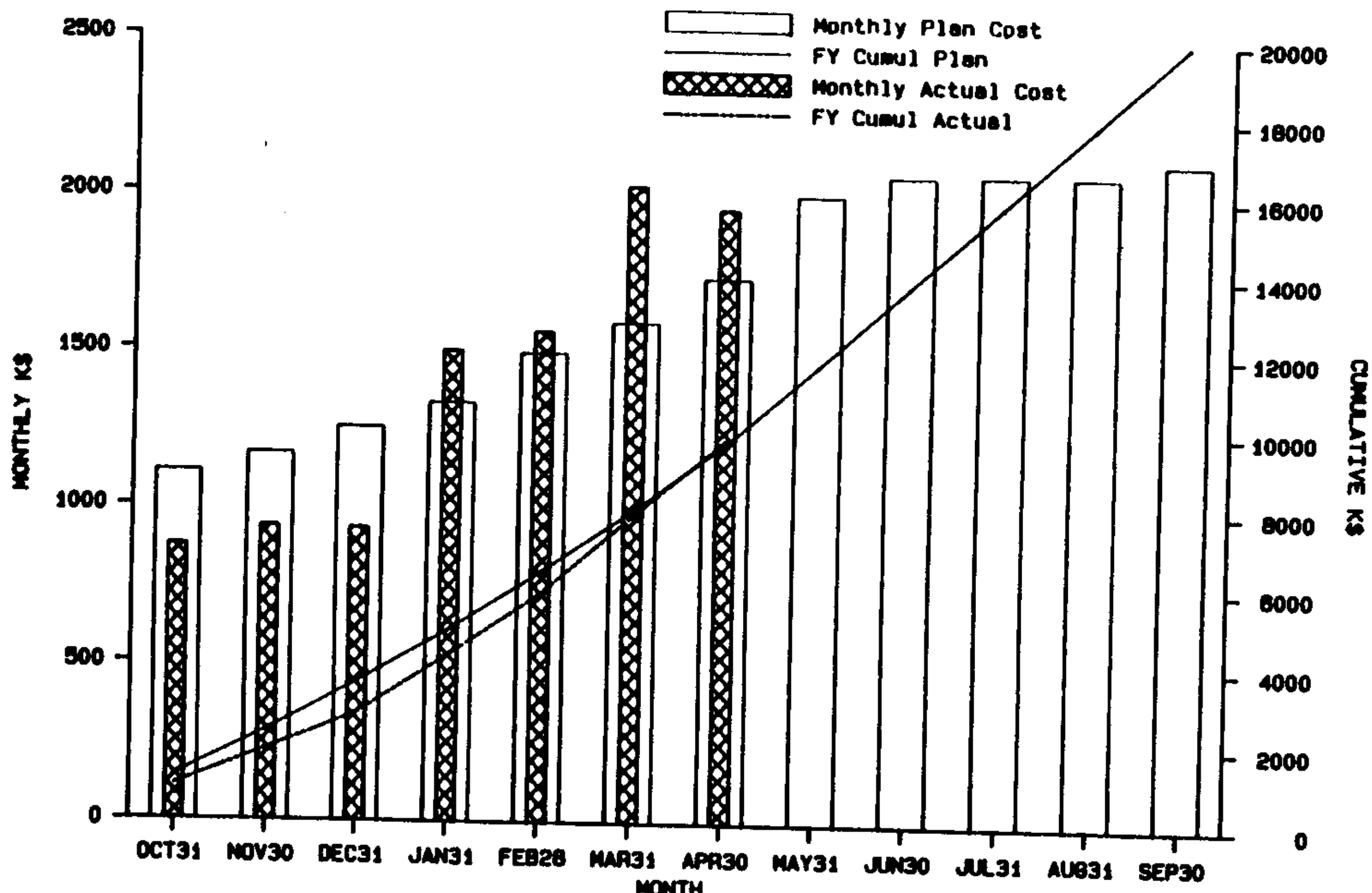
29-MAY-85

Figure 5

0.0 PROGRAM SUMMARY - SUPERCOLLIDER

Planned vs. Actual Costs for FY 1985



	FISCAL YEAR 1985											
	OCT31	NOV30	DEC31	JAN31	FEB28	MAR31	APR30	MAY31	JUN30	JUL31	AUG31	SEP30
Monthly Plan	1106	1166	1251	1331	1491	1591	1736	2001	2066	2071	2071	2116
FY Cumul Plan	1106	2273	3524	4855	6346	7936	9674	11675	13741	15812	17884	20000
Monthly Actual	872	935	930	1498	1561	2026	1956					
FY Cumul Actual	872	1807	2738	4236	5797	7823	9780					

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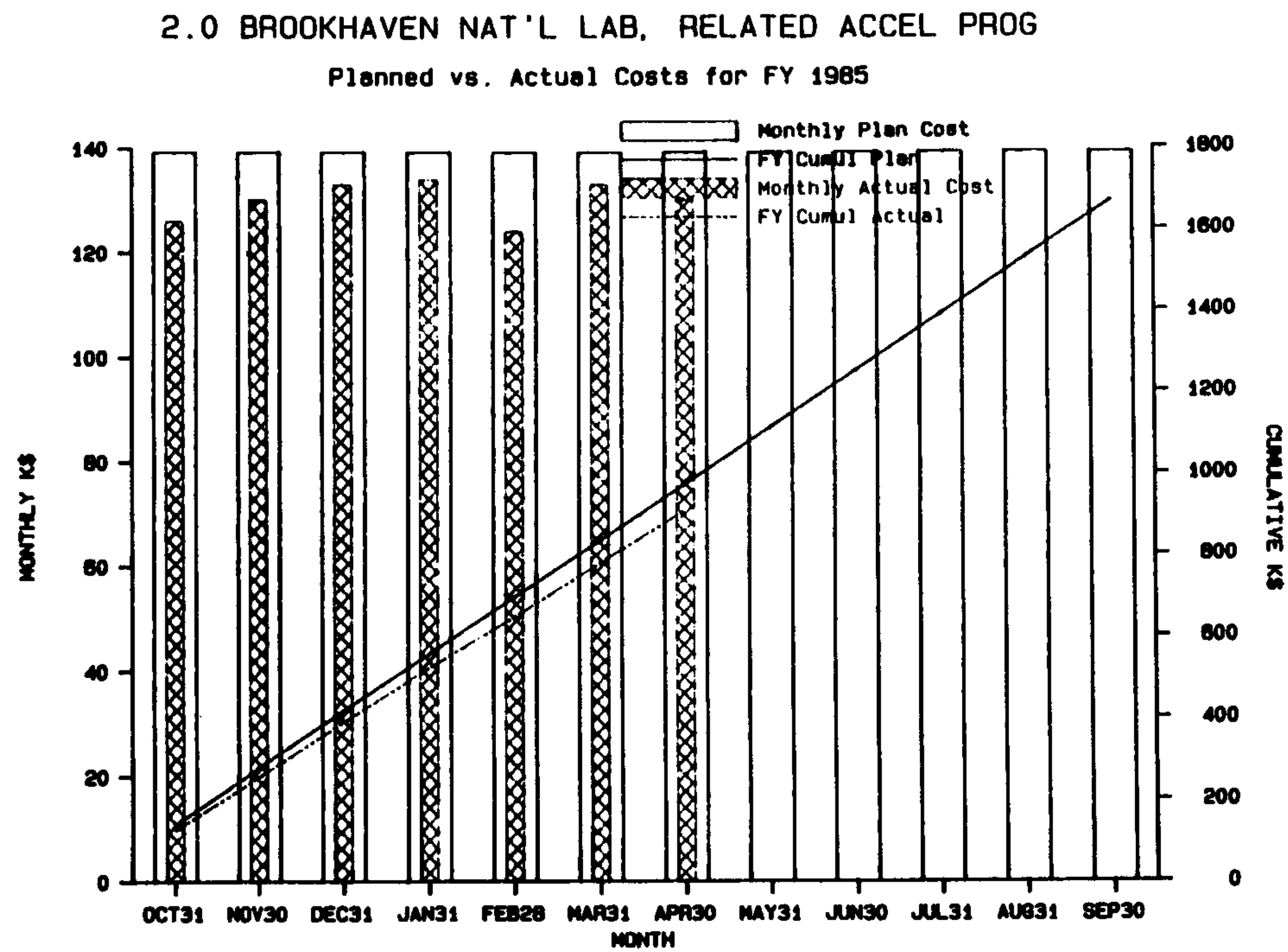
3:38 pm
29-MAY-85

Figure 6



	FISCAL YEAR 1985											
	OCT31	NOV30	DEC31	JAN31	FEB28	MAR31	APR30	MAY31	JUN30	JUL31	AUG31	SEP30
Monthly Plan	139	139	139	139	139	139	139	139	139	139	139	139
FY Cumul Plan	139	278	418	557	696	835	974	1113	1253	1392	1531	1670
Monthly Actual	126	130	133	134	124	133	130					
FY Cumul Actual	126	256	389	523	647	780	910					

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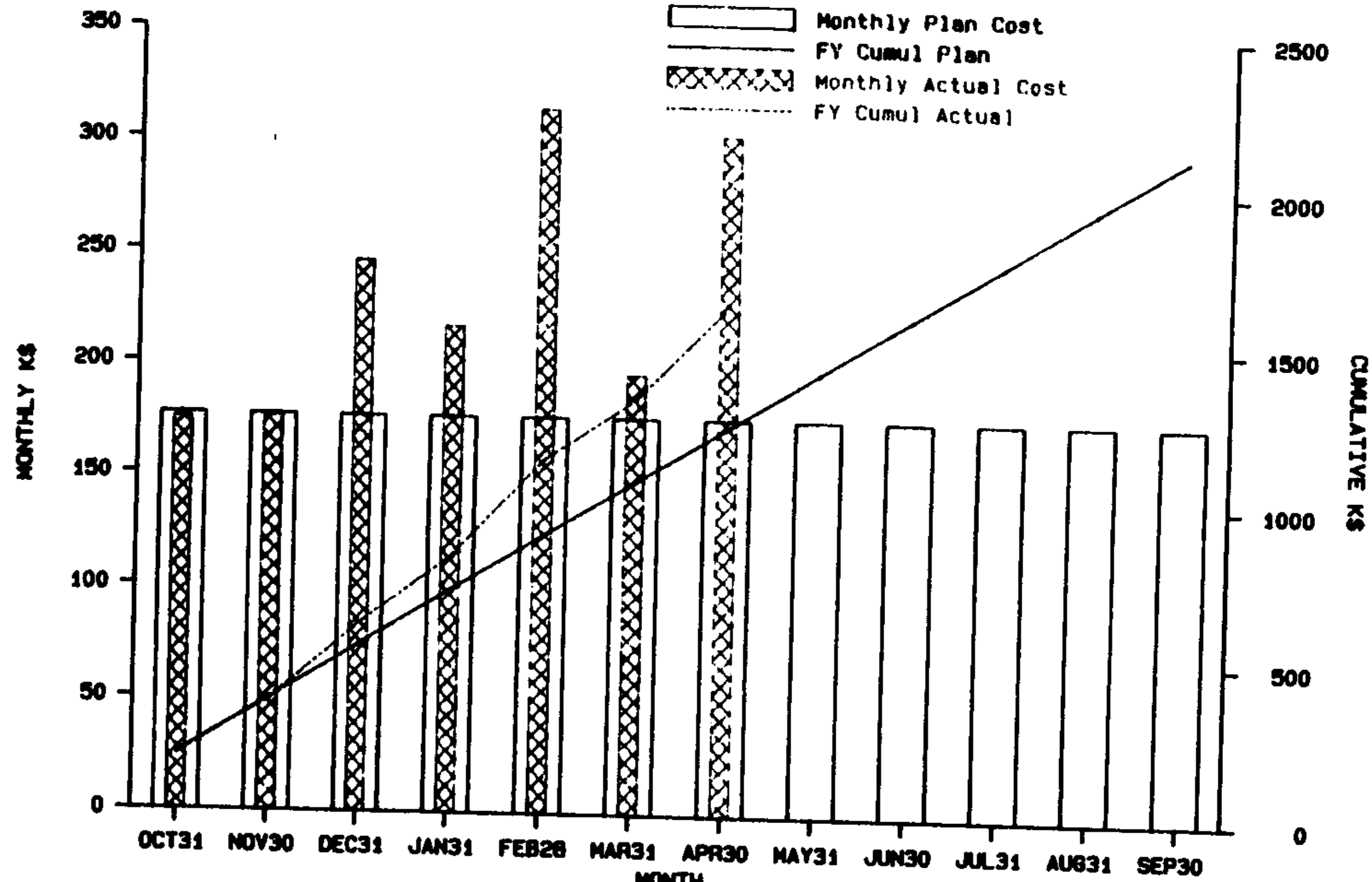
Figure 7

3.0 FERMI NAT'L ACCEL LAB. RELATED ACCEL PROG

Planned vs. Actual Costs for FY 1985



	FISCAL YEAR 1985											
	OCT31	NOV30	DEC31	JAN31	FEB28	MAR31	APR30	MAY31	JUN30	JUL31	AUG31	SEP30
Monthly Plan	177	177	177	177	177	177	177	177	177	177	177	177
FY Cumul Plan	177	353	530	707	883	1060	1237	1413	1590	1767	1943	2120
Monthly Actual	175	176	246	217	315	196	304					
FY Cumul Actual	175	351	597	814	1129	1325	1629					

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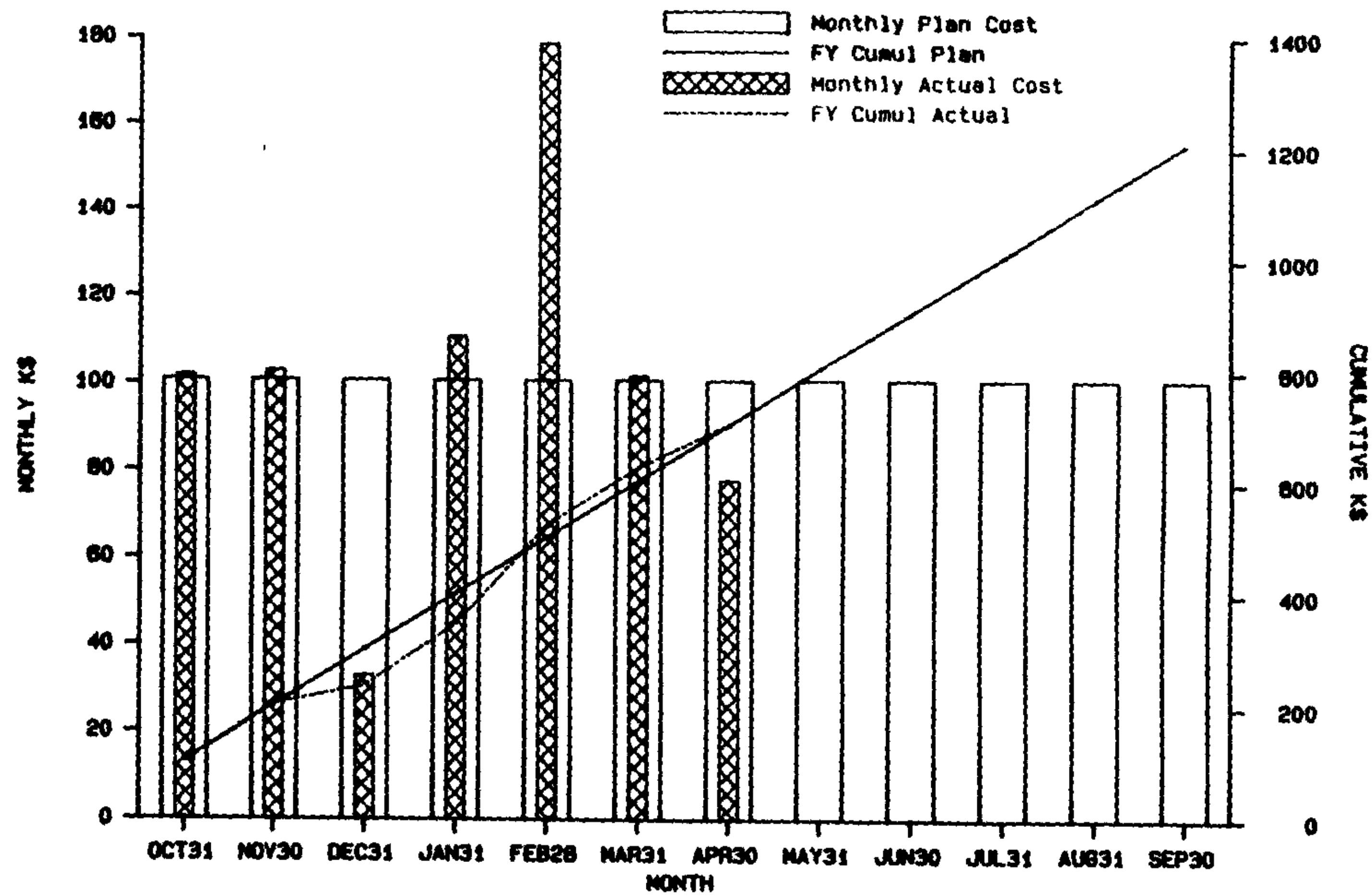
29-MAY-85

Figure 8

4.0 LAWRENCE BERKELEY LAB. RELATED ACCEL PROG

Planned vs. Actual Costs for FY 1985



	FISCAL YEAR 1985											
	OCT31	NOV30	DEC31	JAN31	FEB28	MAR31	APR30	MAY31	JUN30	JUL31	AUG31	SEP30
Monthly Plan	101	101	101	101	101	101	101	101	101	101	101	101
FY Cumul Plan	101	202	303	403	504	605	706	807	907	1008	1109	1210
Monthly Actual	102	103	33	111	179	102	78					
FY Cumul Actual	102	205	238	349	528	630	708					

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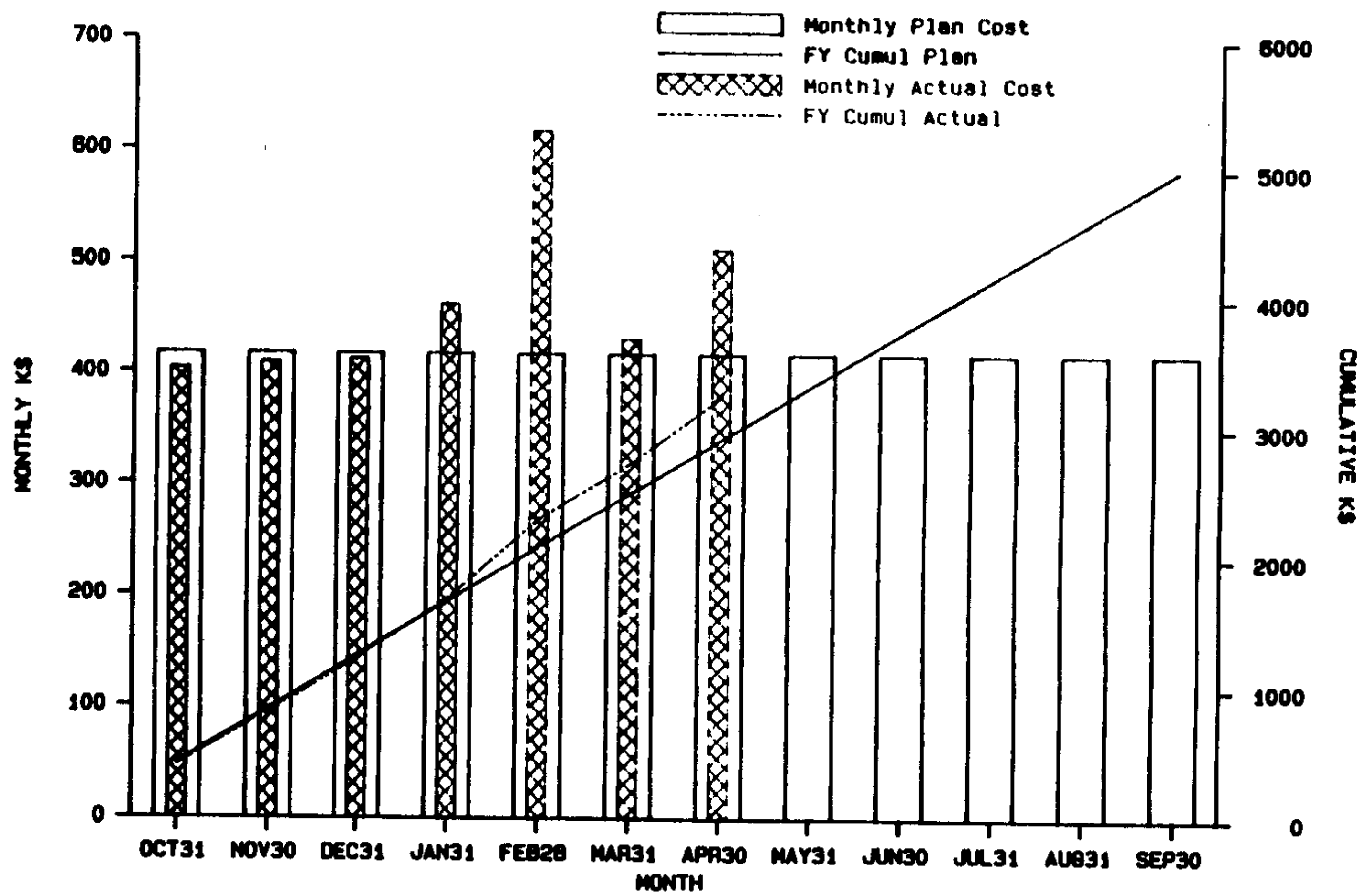
29-MAY-85

Figure 9

0.0 SSC RELATED ACCELERATOR PROGRAM SUMMARY

Planned vs. Actual Costs for FY 1985



	FISCAL YEAR 1985											
	OCT31	NOV30	DEC31	JAN31	FEB28	MAR31	APR30	MAY31	JUN30	JUL31	AUG31	SEP30
Monthly Plan	417	417	417	417	417	417	417	417	417	417	417	417
FY Cumul Plan	417	833	1250	1667	2083	2500	2917	3333	3750	4167	4583	5000
Monthly Actual	403	409	412	462	618	431	512					
FY Cumul Actual	403	812	1224	1686	2304	2735	3247					

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(JSZ)
3:42 pm
29-MAY-85

Figure 10