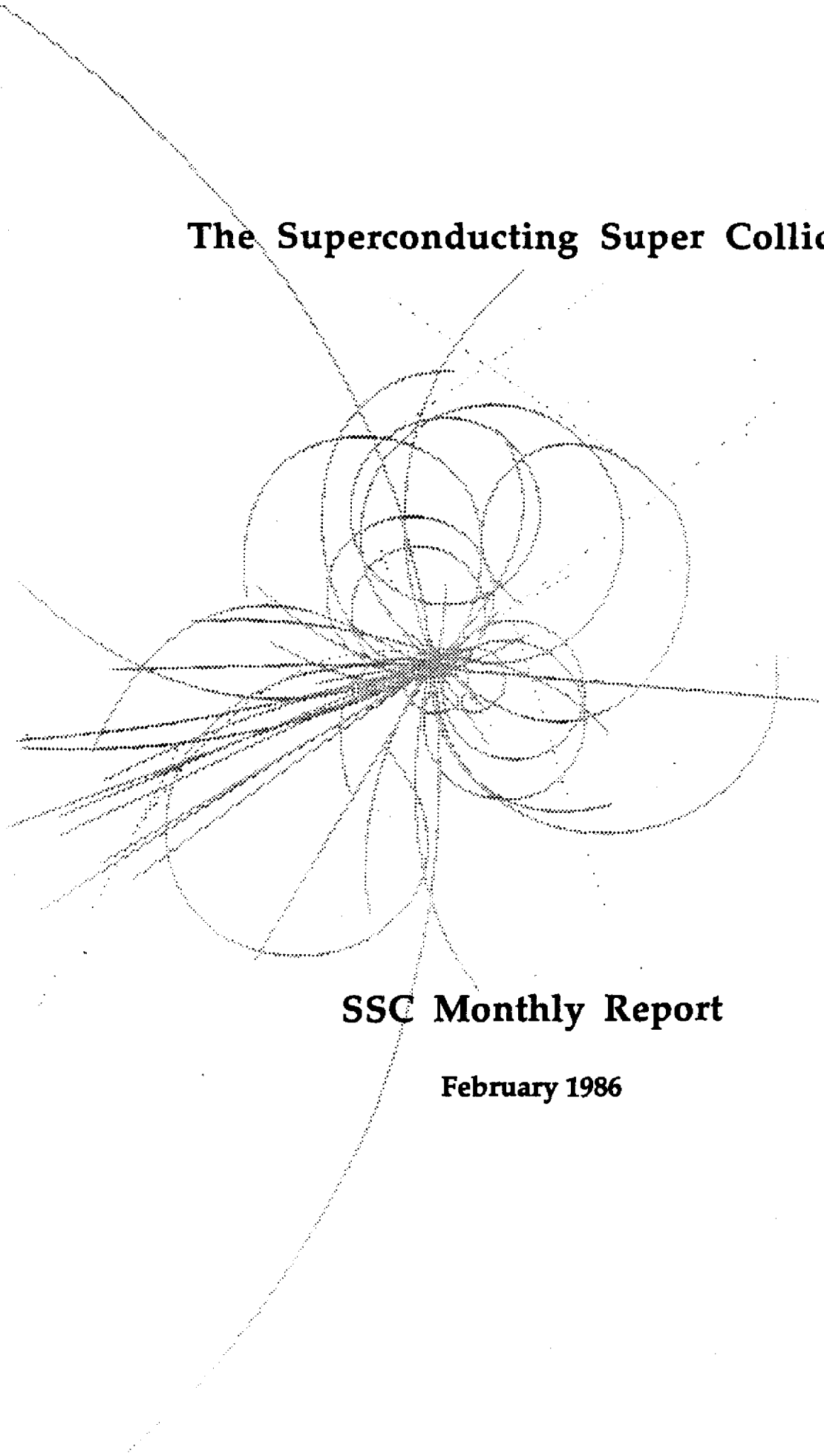
SSC-66

The Superconducting Super Collider



SSC Monthly Report

February 1986

SSC MONTHLY REPORT

FEBRUARY 1986

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SSC MONTHLY REPORT

FEBRUARY 1986

A. Project Summary

Central Design Group (CDG)

- The conceptual design work continues at a rapid pace. Drafts of all chapters, including illustrations, were prepared for a mailing March 3.

- The large number of SSC magnets requires that their testing and training must be accomplished as efficiently as possible. The training curves for the eight model magnets fabricated by BNL and for ten model magnets fabricated by LBL were examined. There are several viable alternatives within cost and schedule constraints to test and train magnets either at 4.35K or 2K. These options will be developed further, but a final decision will be made after development tests at lower temperature are completed at both BNL and LBL.

- A Magnet Systems Integration meeting was held on February 6 and 7 at Fermilab. Considerable time was devoted to finalizing the procedure for the first long magnet test at both the MTF and at the Half Cell Test Facility at Fermilab. At the end of the meeting, test protocol was published. In addition, the quadrupole configuration was presented by LBL and adopted as the basis for the conceptual design. Other promising options will be considered at a later date.

- The first issue of **The Lattice** was published and distributed.

- A DOE review of the TAC effort on R&D for the SSC took place in February.

- Fermilab is proceding satisfactorily on the construction of the E4 test area for the Half-Cell Test. It appears that they are on schedule, and the test area will not be a critical path item in the Half-Cell Test.

- RTK devoted considerable time to the preparation of several cost estimates, schedule examples, and text preparation. On two different occasions cost estimates were prepared for the three example sites that are being developed by RTK. Attempts were made to integrate all the cost elements, although segments of the injector were still included as approximations. As the estimates developed, adjustments were made in the WBS to cover the scope of the work.

- A considerable amount of attention was devoted to studying the emerging cost estimates. Efforts were made to "track" the costs for Site A, as an increasing amount of detail developed. With the provision of preliminary estimates for B and C, it was possible to look for internal consistency.

- The head-on beam-beam interaction causes a tune shift of 0.8×10^{-3} per crossing, which is rather small. The long-range beam-beam interaction contributes a tune shift of 1.8×10^{-3}. These tune shifts are for small amplitude particles. The amplitude dependence of these tune shifts was studied in February.

- Effects of orbit distortion were studied in more detail. The expected magnet misalignment and strength errors are simulated, and the resulting orbit distortion is corrected by the proposed orbit correction scheme. Multipole field errors of the dipole magnets are included in the simulation. The rms orbit distortion after correction is about 0.4 mm and the rms corrector strength is 7 μrad, both in good agreement with previous analytical estimates. The dynamic aperture with orbit distortion is found to be 12 mm, basically the same as the case without orbit distortion. The aperture shrinks by about 10% when orbit distortion is doubled.

Brookhaven National Laboratory (BNL)

- Major effort continued to be focused on completing all aspects of the coil tooling for the long dipoles, culminating in the successful winding and curing of the first 17 m coils. In addition, work is continuing on the cost estimate and narrative contributions for the Conceptual Design Report. Another coordination meeting between the various collaborating parties was held, this time at Fermilab.

Fermi National Accelerator Laboratory (FNAL)

- Steady progress has been made on the assembly of the Heat Leak Model (HLM II). One of the strong motivations for the HLM II was to shake out the design, tooling, and assembly procedures for the "D" cryostat. That exercise was very beneficial since a number of problem areas have been identified and corresponding design refinements made. Materials and tooling will be ready for the April delivery of the first cold mass assembly. A safety review of the cryostat is underway.

- Cryostat R&D issues pursued during February included further study and refinement of the support post, dynamical stress analysis of the magnet/cryostat system, and the study of automatic welding techniques for the cryostat.

- Preparations continue on the ER enclosure for the model magnet string test. The buildings will be far enough along so that the tests on the HLM II can be started around the first of April.

- Conceptual design of the injector was completed. Costing and write up for the SSC Conceptual Design Report for all the injector systems, as well as the cryostat magnet assembly and installation, are essentially complete.

Lawrence Berkeley Laboratory (LBL)

- LBL has continued model tests to investigate collar behavior and, at the same time, to make field uniformity measurements of the new 4-wedge cross section (NC515). Measured prestress loss in the collaring process is predicted closely by finite element analysis for both Al and stainless steel collars. Further prestress loss on cool-down appears to produce much greater measured prestress loss for stainless steel than for aluminum; this is being investigated further, both experimentally and with analytical modeling.

- Collars for the new cross section were ordered. Careful inspection of cross sections cut from model magnets has been initiated (autopsy program) and measured field compared with that predicted from the mechanical inspection.

- A length of prototype fine filament cable showed that strands retained their extremely high critical current, 30% greater than the CDR design goal. Initial cable made from fine filament strand seems to have a poorer "flatness" than earlier cable; experimentation has begun on methods to improve this. Experiments to improve piece lengths are being conducted on commercial production of fine filament strands.

Texas Accelerator Center (TAC)

- TAC has completed construction of the first prototype superferric dipole correction magnet. It will be tested next month. Field calculations and design are still being done on the cosine theta magnet.

- A high priority has been put on preparing diodes for a test in the Texas A&M reactor. This test will be at liquid nitrogen temperature and will test radiation damage and our test set-up. An attached summary on the quench diode project follows the TAC section of this report.

- One 1-m superferric dipole assembled at IGC in New York and one 7-m superferric dipole assembled at TAC were tested this month. Both magnets performed as expected. This was the second successful magnet from IGC. The measurements of the skew quadrupole through the 7-m magnet averages to 0.9 units.

B. Project Report

I. Central Design Group

Magnet Program. The major activity of the Magnet Division continued to be in finalizing the Conceptual Design Report. A rough draft of the report was prepared, and the technical baseline was expanded, particularly for the quadrupole and special magnets. There are 1356 quadrupoles and approximately 500 special magnets. The cost estimate for the magnet system is 90% complete.

The large number of SSC magnets requires that their testing and training must be accomplished as efficiently as possible. The training curves for the eight model magnets fabricated by BNL and for ten model magnets fabricated by LBL were examined. Statistical analysis indicated that three training quenches should be considered to reduce the probability of subsequent quenches in the tunnel to an acceptably low number during 6.6 tesla operation. Although it might be possible to improve the magnet design sufficiently to eliminate training quenches (and we will be looking at some improvements in this area), it is prudent to plan for training requiring a certain number of quenches.

One possible method for eliminating training is to pre-condition the magnet at a reduced temperature. At reduced temperatures, below the 4.35K operating temperature, the higher critical current allows the magnet to be driven well above the normal operating current, field, and forces, yet remain below its critical field. At reduced temperatures the first quench is likely to occur well above 6.6 T; therefore, it is possible that at such a temperature the magnet can be energized to, say, 7 T or 7.5 T without quenching. Subsequently at 4.35K the magnet will not train. This approach offers a way to eliminate training by low temperature conditioning, which can be done on individual magnets or on a string of magnets. A one meter model was recently

trained at 1.8K without quenches at LBL. Thus, the method looks promising; however, it needs to be statistically proven under a wider range of operating conditions. An R&D program is planned to provide the necessary data base for a timely decision.

Identification of the methods and sequence of magnet training has implication in reliability, operating levels, and both time and dollar costs. The following options have been examined:

1. Training magnets in a fabrication facility
2. Training magnets at the HEP labs
3. Training magnets on site
4. Training magnets in the tunnel.

Each of the above options can be implemented either at 4.35K or at 2K. Option No. 1 embodies the possibility of returning a defective magnet to the factory floor for immediate correction and feedback on production quality. It does, however, require duplication in cryogenic and measuring equipment and additional trained staff. Option No. 2 requires the least equipment investment but ~20M cost of transportation offsets the reduced on-site equipment requirement. Option No. 3 requires occupancy at the site in the second quarter of FY90 and installation of one of the planned SSC refrigerator buildings shortly thereafter. This option appears to be a minimum cost and low risk scenario. The cost of refrigerator and additional production testing equipment should be less than $20M. Option No. 4 requires interfacing with tunnel construction and early installation of one of the corresponding SSC cryogenic systems. It presents more complex installation logistics, and the magnet system will experience more training quenches because of the linear geometry of the magnets under test. It is the least attractive method, whether done at 4.35K or 2K.

In summary, there are several viable alternatives within cost and schedule constraints to test and train magnets either at 4.35K or 2K. These

options will be developed further, but a final decision will be made after development tests at lower temperature are completed at both LBL and BNL.

Analysis of data from the existing accelerators is continuing and preliminary results indicate that availability of the goals established for the SSC are realistic, but design improvements for some systems will be required to meet the SSC availability/reliability goals.

A Magnet Systems Integration meeting was held on February 6 and 7 at Fermilab. The agenda was as follows:

Day I

	Plenary Session	
9:00 a.m.	Opening Remarks	P. Mantsch
9:15	CDG News & Views	V. Karpenko
	Long Magnet Model Program Status and Schedule	
9:45	Cold Mass Status/Schedule	W. Schneider
10:15	Cryostat Status/Schedule	N. Engler
10:45	MTF Plans	J. Strait
11:00	Half Cell Test Objectives	P. Limon
11:15	Half Cell Test Plans	J. Theilacker
12:30	Working Lunch	
	Tour of Cryostat Production Area	
1:30	Parallel Sessions	
	A Model Design & Production Questions	N. Engler/W. Schneider
	B MTF and Half Cell Testing Questions	J. Strait/E. Willen/J. R. Orr
4:00	Plenary Session (Summary)	
	Model Design & Production (Session A)	N. Engler
	Testing (Session B)	J. Strait

Day II

8:30	Conceptual Design Report	V. Karpenko et al.
	CDG Input	
	Dipole Design Issues	
	Quadrupole and Spool Design	
10:45	Cost Status	N. Engler/C. Goodzeit
11:15	Industrialization Plans	V. Karpenko
12:00	Lunch	
	Parallel Sessions	
1:00	R&D Workshops (TBD)	V. Karpenko/C. Taylor
4:00	Closing	
	Summary	
	Action Items	

Presentations on the status of the 17 m magnet fabrication and test program indicated that schedule slippage might occur if extra effort is not applied to fabrication of some of the BNL tooling components. A decision was made to continue to fabricate these components at the vendor's plant but to start in parallel fabrication of additional components at LBL shops.

Considerable time was devoted to finalizing the procedure for the first long magnet test at both the MTF and at the Half Cell Test Facility at Fermilab. At the end of the meeting test protocol was published.

During this meeting the quadrupole configuration was presented by LBL and was adopted as the basis for the conceptual design. Other promising options will be considered at a later date. Incorporation of the mounting stand into the vacuum vessel was also selected for the conceptual design. This concept proposed by Fermilab eliminated the special magnet stand in the tunnel and simplified magnet installation and alignment while maintaining the 70 cm center-to-center vertical spacing between two magnet rings. The next meeting is scheduled for March 11 and 12 at BNL.

Conventional Systems. RTK devoted considerable time to the preparation of several cost estimates, schedule examples, and text preparation. On two different occasions cost estimates were prepared for the three example sites that are being developed by RTK. Attempts were made to integrate all the cost elements, although segments of the injector were still included as approximations. As the estimates developed, adjustments were made in the WBS to cover the scope of the work. RTK provided copies of their cost estimate at sixth level on a magnetic disc. This allowed for checking of level structure, completeness, and ability to roll-up the cost numbers by an alternative approach. In parallel with this work RTK provided one schedule example for an initial exercise in integrating the technical and conventional systems in an

overall schedule. At month's end, several problems had been identified and worked on by the entire team.

A series of editorial meetings were held at RTK to prepare and in some cases, clarify their text for the appendix to the CDR. Meanwhile a draft version of Chapter 6 for the CDR was being prepared at the CDG. Copies of the respective portions were exchanged in order to express the design considerations in as clear a manner as possible. RTK has prepared up to sixty drawings, and illustrations to use in their report. Some of these clarified the design in the injector areas, and with the injection lines from accelerator to accelerator. A progress meeting was held with DOE in which RTK and the Conventional Systems group of the CDG presented the status of the design including the report writing.

At the CDG a considerable amount of attention was devoted to studying the emerging cost estimates. Efforts were made to "track" the costs for Site A, as an increasing amount of detail developed in time. With the provision of preliminary estimates for B and C, it was possible to look for internal consistency. This set the stage for some initial discussions on costs for AE/CM services, and allowances for contingency. A meeting was arranged with RTK to discuss a schedule example. The methodology was explored by the use of a PERT diagram. Preparations are being made to use the cost estimate and schedule to develop a funding profile.

Accelerator Systems. The main efforts for the month were in Conceptual Design Report progress and R&D activities. Plans were also generated for post-CDR activities.

All of the CDR text having to do with the technical systems of the collider rings has been completed. Editing and clean-up is proceeding; all the cost estimates for the technical systems of the collider rings have been

completed. They are being checked for consistency and double counting with one another, and with other systems; some redesign has been done in order to be consistent with the results of various calculations regarding reliability. This has had a major impact in text and cost on the Controls System and the correction element power supplies.

A DOE review of the TAC effort on R&D for the SSC took place in February. Approximately three weeks earlier than that, a review was held by the CDG, not reported on in the January Monthly Report. As a result of the January review, some shortcomings were pointed out to TAC management by the CDG, and it was clear by the time of the DOE review that TAC management had started to take steps to correct these deficiencies. It appears that milestones are clearly understood by all parties, and progress will be closely monitored. The most likely cause of conflict in meeting milestones will be delays in testing the remaining superferric magnets, because that effort occupies manpower required to accomplish other tasks.

Fermilab is proceding satisfactorily on the construction of the E4 test area for the Half-Cell Test. It appears that they are on schedule, and the test area will not be a critical path item in the Half-Cell Test. It does appear, however, that the CDG has been somewhat lax in setting forth the exact nature of the test procedures with the Magnet Division, and with Fermilab, BNL, and LBL. A Magnet System Integration meeting that was held at Fermilab in February was devoted to a large extent to addressing those issues, and considerable progress was made. More attention must be paid to complete communication among the participating R&D centers in the future with regard to the Half-Cell Test.

Some of the most important activities that will have to take place in the months after the CDR is completed have been identified. A budget for

accomplishing these activities has been estimated through FY 1987, and in some cases for even longer periods.

A. Magnet Related R&D
   1. Operation of the Half-Cell Test
   2. Design and construction of the Accelerated Life Test
   3. Feedback into magnet design, construction, testing, and quality control
   4. Quench protection issues, calculation, and design, including bypass diode tests
   5. Correction element and spool piece design
   6. Vacuum desorption and beam tube surface impedence measurements

B. Cryogenics
   1. Interface with the Half-Cell Tests
   2. Prototype refrigerator calculations and design
   3. Prototype refrigerator - writing performance specifications

C. Reliability
   1. Calculations of various component, subsystem, and overall reliability
      a. Continuation of present modeling work
      b. New models and improvments to present model
      c. Design and cost impact of results
      d. Inclusion of radiation effects

D. Beam Loss
   1. Calculations
      a. Muon and other experimental and environmental background
      b. Radiation induced quench studies
      c. Effects on electronics and bypass diodes
   2. Measurements
      a. Refinement of Tevatron Measurements
      b. (Beam sensitivity of SSC magnets) ?

<u>Accelerator Theory and Computation</u>. A horizontal planar layout is preferred for the SSC. The planar aspect simplifies the beam dynamics. The horizontal orientation simplifies surveying, alignment, and cryogenic considerations. Nevertheless, for some potential sites, a more complex tunnel configuration that follows the geology more closely may allow sufficient savings to become favorable. As one such example, a folded tunnel configuration (with clustered IRs) has been worked out. The folding is made around two hinge sections. Each hinge consists of six cells around the center of the long arc and is a section of unit transformation. The ring is folded by properly choosing

the roll angle and the folding angle of the hinges in coordination with the folding angle of the ring. The ring fold angle is taken to be one degree in the example. The perturbation of particle motion inside the hinge sections is found to be tolerable.

Effects of orbit distortion are studied in more detail. The expected magnet misalignment and strength errors are simulated, and the resulting orbit distortion is corrected by the proposed orbit correction scheme. Multipole field errors of the dipole magnets are included in the simulation. The rms orbit distortion after correction is about 0.4 mm and the rms corrector strength is 7 μrad, both in good agreement with previous analytical estimates. The dynamic aperture with orbit distortion is found to be 12 mm, basically the same as the case without orbit distortion. The aperture shrinks by about 10% when orbit distortion is doubled.

During colliding beam operation, the luminosity changes with time through changes in the beam intensity and emittance. The beam intensity changes because of collision events, residual gas scattering and Touschek scattering. The emittance changes because of synchrotron radiation damping, intrabeam scattering, and elastic collision events. The interplay among these effects and their integrated effect on the luminosity were calculated. It was found that in a normal operation, the luminosity increases with time during the first day of operation until it is doubled at the end of the first day. It then starts to decrease. At the end of the second day of operation, the luminosity remains about $10^{33} cm^{-2} s^{-1}$.

The head-on beam-beam interaction causes a tune shift of 0.8×10^{-3} per crossing, which is rather small. The long-range beam-beam interaction contributes a tune shift of 1.8×10^{-3}. These tune shifts are for small amplitude particles. The amplitude dependence of these tune shifts were

studied this month. The long-range effect is rather linear in the sense that the spread in tune shift for particles with moderate amplitudes is small compared with that due to the head-on interaction. For large amplitudes, both interactions need to be considered. With proper choice of the unperturbed tunes, the tune spread caused by both types of beam-beam interactions can be accommodated without operating near significant resonances.

When a beam is injected with a betatron amplitude error or with an energy offset, its effective emittance will increase by filamentation as it circulates around the ring with nonlinear error fields. To counteract this, the motion of the injected beam needs to be damped by a feedback system. This process has been simulated. It was found that, with a feedback system that provides damping in 50 turns at 1 TeV, the increase in emittance is rather small. On the other hand, if the beam is injected with too large an amplitude (corresponding to a failed injector kicker-module, for example), the emittance will double. When this happens, the beam will not be suitable for luminosity runs and will have to be aborted.

II. Laboratory Programs

A. BNL.

1. Model Magnets. Preparations for the first long dipole assembly are continuing. The following is a list of the major accomplishments and on-going activities in this area:

- Two 17 m inner coils were wound and cured at ~ 8 kpsi. One 17 m outer coil was wound and cured at 10 kpsi.
- The program for the inner coil curing cycle was finished. The corresponding outer coil program is still under development.
- Data on the iron density in the yoke blocks for LLN-001 and LLN-002 were analyzed. Results were found to be within the more conservative tolerances. A report is in press.
- The SSC data base traveler is complete, except for the portions pertaining to yoke shell assembly and shipping. These are essentially complete and are being incorporated into the traveler.

The following R&D activities are being pursued:

- The full bridge strain gauge circuit is in preparation, with the initial results to be incorporated in LLN-001.
- The flat cable coil-collar assembly test was completed. Stress losses correlate roughly with those for the keystoned cable. A report will be released shortly.
- The literature was searched for resistance data on RY630. The data indicate this material, 50% by weight glass and 10% by weight mineral, is satisfactory for use.
- Data from the EDM alternative collar tests were consolidated and presented at a meeting. Results indicate that the alternative designs, along with the different methods of loading, provide no significant improvement in prestress retention
- Cryogenic data on stress losses due to thermal contraction were also obtained and analyzed. The results proved difficult to interpret due to erratic strain gage readings. The sole conclusion to be drawn, pending further tests, is that the reported thermal losses to date are somewhat suspect. Note that losses predicted by calculations are < 1500 psi, while reported measured losses are in the 2000-5000 psi range.
- A report, basically a design review, on the magnet collaring was revised for inclusion in the attachments to the Conceptual Design Report.

Extensive effort is continuing on the development of leak checking and assembly procedures:

- A procedure has been established for welding the helium containment shell and leak checking. Detailed instructions for assembling the interconnects are in press.

- The collar packs for the firsts two dipoles have been assembled and are available.

The following is a summary of progress on the electrical interconnections and bus work for the first magnet:

- Superconductor has been soldered to the copper bus previously received from Phelps Dodge and prepared. Some minor problems have been encountered, but these are being worked out.

- Coil assembly is progressing.

The following progress has been made on the trim coil for the first magnet:

- The second trim coil is complete and will be used in LLN-001. Coil No. 3 is having bumpers installed; it will be used in LLN-002.

- Tests performed to date on the short trim coils have indicated a marked improvement in field quality after the fourth 4.5 m dipole. These improvements are incorporated into the long trim coils.

- Substrate for further trim coils has been produced and is being prepared for use.

- Superconductor is being insulated in preparation for winding the next long trim coil at Multiwire.

The following progress with regard to field quality has been made in the coil manufacturing area:

- All wiring of the curing fixture is complete.

- All transducers have been calibrated and, where possible, have been attached to the curing fixture.

- Work has slowed on the operator's manual for the HP computer, but coil curing data taking will resume in March.

- Samples of coil cross section have been vacuum impregnated, to fill all voids, and sent to shops for cutting and polishing

2. Tooling and Facilities

a. Coil Fabrication Tooling

- The new full length curing press and winder are operational and producing coils.

- All drawings for the full length straight-ended coil tooling were released to the shops.

- Drawings for the drive box of the short winder are complete. Design work is continuing on the short winding mandrel and form blocks.

b. Coil and Yoke Assembly Tooling

- The welding assembly fixture is progressing. A station to check magnet twist after assembly has been designed and engineered, and the pertinent drawings have been released to the shops.

- A considerable quantity of side bars and collar compression bars has been received. The ten base plates have also been received. The next step is to assemble the bars to the base plates, with grinding in the heavy shop. These activities are all on schedule.

- The coil assembly station in building 905 is complete, and being used to insulate the coils as they are completed. The next step is the inner-outer coil splice and assembly. This activity is also on schedule.

2. Beam Tube and Trim Coil Tooling

The following progress has been made in the general areas of beam tube plating and beam tube tooling:

- Optimized plating samples have been produced at PCK for electro-desorption measurements at LBL.

- Design work is continuing in connection with photodesorption experiments to be conducted at NSLS.

3. Magnet Test Facility

The following progress may be noted in this area:

- Arrangements have been made for the delivery to building 902 of all materials purchased for use in the Horizontal Test Facility. This will continue for a period, since certain purchase orders are still outstanding.

- A layout was developed showing how the magnet assembly will be transported into the MAGCOOL bay.

- Construction of this facility will be resumed in the shops.

The following progress was made on the Morgan coil system:

- The prototype was fabricated and tested.

- The final test wire pattern, incorporating the changes resulting from evaluation of the prototype, was received.

Considerable progress has been made on the Mole and warm bore tube system. The following is a synopsis of this activity:

- Improvements in coil encoder signal stability were made by replacing the bushings with sapphire ball bearings.

- The first "B" Mole measuring coil has been wound and assembled with sapphire ball bearings.

- Magnetic components in the encoder-gravity sensor activator have been replaced with non-magnetic components.

- Work has begun in the shops on the warm bore tube injection system.

- Prototype warm bore tubes have been wrapped with superinsualtion and pulled through SSC cold bore tubes; the insulation survived this operation.

- A 20-ft sample of tube has been wrapped and also pulled through the cold bore tube. Pull loads were measured.

- The outer skin of the Mole, plus connections between subassemblies, have been made from brass, and the first version of mole B is nearing completion. Work is continuing on the drive.

- Work has begun on the warm bore tube and Mole purging system.

4. Magnet Transport

Design is completed, and the assembly is progressing. All instrumentation, such as accelerometers and temperature sensors, has been ordered.

5. Superconductor

a. Cable Procurement. As reported last month, all SSC cable from LBL was to be insulated during the month of February. As of this moment, the last piece of outer cable is on line being wrapped. Two additional spools of cable are expected from LBL.

b. Tooling. Assembly of the hand held Keystone Measuring Gauge is completed. It is presently being tested; this should be completed during the month of March.

Machining of parts for the hand held Width Measuring Device is progressing in Central Shops. Due to workload and labor restrictions there is no estimate, at this time, for the completion of this measuring tool.

c. Miscellaneous. The last week in January, (too late for last month's report), Al Bertsche traveled to LBL to conduct a series of cabling experiments. Five samples of 30-strand outer cable and eight samples of 23-strand inner cable were made. The purpose of these samples is to determine the effect of packing factor on degradation. The cable samples are presently being tested and will be reported on next month.

During February, representatives of both LBL and BNL traveled to New England Electric Wire Corporation (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. Al Bertsche returned with four SSC outer cable samples (one for each iteration). These samples are being tested 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 the samples submitted for test.

6. Tests and Measurements

The Magnet Test Facility was shut down until February 18 so that the staff could help prepare fixturing for the 16.6 m magnets. Magnet SLN015 warmed up in the vertical dewar during the shutdown, providing the opportunity to check for the effects of a thermal cycle. The 4.5K quench currents were essentially the same as the ones obtained during the initial test. (In fact, they were a small amount--20 amps--higher.)

In testing at reduced temperature, the magnet reached a plateau of 6.6 T at 4.0K with no added training and a plateau of 6.9 T at 3.5K with one training quench. The maximum field reached was 7.1 T at a temperature between 3.5K and 2.6K. Performance at 2.6K is still being investigated.

7. Electrical System

Tests on the control system for the long coil curing fixture were completed and the system made operational. This system is programmed from software and a code for the curing of long SSC coils has been developed and successfully tested.

8. Cryogenic Systems

The 24.8 kW Helium Refrigerator was operated for testing during the period February 13 through February 16. The test was marred by the failure of the shaft of Expander 5. It is believed (by BNL) that the failure was due to an inappropriate choice of material for this shaft. The shaft was replaced by the vendor and another run began on February 27.

B. FNAL.

1. Cryostat Design and Development

a. Cryostat Development

The study of the 5 in. x 7 in. reentrant post failure in flexure at loads less than "design" continues. It appears that failure may be due to flexural buckling of the tube. This failure mode does not conflict with previous analysis since buckling, due to its nature, would not appear as a stress concentration. Possible solutions to the problem involve the increase of the stiffness of the inner tube by increasing its diameter or thickness or by using a stiffer, i.e., higher Young's Modulus, material. Graphite reinforced composites offer a considerable modulus advantage over glass reinforced composites (G10, G11, etc.) and are being evaluated as inner tube material. Due to schedule limitations, the as designed 5 in. x 7 in. G11 CR post will be used for the Long Magnet Models.

The HLM II 5 in. x 7 in. posts have been fabricated and proof tested in flexure and compression. The results of the proof testing are consistent. Three HLM II posts have temperature and strain measurement instrumentation.

The Suspension Heat Leak Dewar heat leak meter recalibration is in process. Measurements of an HLM II instrumented 5 in. x 7 in. post have been delayed by effort allocation to higher priority work. The test post assembly will begin in March.

HLM II preparations continue. The mock cold mass assembly has been completed and is being incorporated into the HLM II cryostat. The HLM I end vessels have been reworked and coupled together for the "zero magnet" background heat leak measurements which are in process. The

"zero magnet" testing is to be completed in early March. The completion of HLM II and the beginning of cooldown is scheduled for April. The open cycle heat leak measurements will be conducted at the ER String Test Facility. Preparations of the ER Facility are proceeding.

The stiffness (EI) of the HLM II mock cold mass assembly has been measured. The increase in stiffness as compared to that predicted for the cold mass skin alone is ≈20%. Corresponding measurements will be made on the BNL magnet cold mass assemblies of the Long Magnet Model Program.

Accelerometers for installation on the HLM II cold mass assembly have been received and will be installed to permit measurements of the dynamic response of the magnet assembly. Some measurements of the dynamic response may be made during the on-site, i.e., Fermilab, movement of the assembled magnet center section as a part of the HLM II program. It should be noted that on-site transportation environment is expected to differ significantly from that to be experienced for SSC magnet over-the-road shipment.

The mid-span anchor struts have been completed and proof tested prior to HLM II installation.

b. Cryostat Design

The design of the external removable axial shipping restraint continues. The remaining element to be specified is the coupling between the end connections of the cold mass assembly and the vacuum vessel.

The procedure for multi-layer insulation installation has been developed and will be employed for HLM II and Long Magnet Models.

The cryostat structural review continues. Items currently under consideration include the overall suspension connection of the cold mass to the vacuum vessel, i.e., ground.

An internal Fermilab safety review of the cryostat is underway. The review is to be completed prior to HLM II cooldown at the ER Facility. The review does not consider the safety of the test facility which is being covered separately.

The design of the magnet interconnections is complete and the details are being incorporated in the Long Magnet Models.

Axial cryostat piping loads due to bellows pressurization, offset, thermal contraction, etc., are being studied analytically and experimentally. Initial results substantiate the piping's ability to withstand the axial loads without over stressing or buckling.

The "sliding" of the cold mass assembly relative to the support posts will be evaluated during HLM II cooldown by monitoring the induced post bending loads that could be applied by an inoperative cold mass cradle slide.

The transportation, handling, and seismic environments for the conceptual design have been defined. Work continues on the in-house structural analysis of the magnet cryostat in response to seismic inputs. The existing modal analysis model has employed input from the NRC regulatory guidelines for earthquakes. The results of the analysis are under review and will be incorporated in the design of next generation suspension systems. Significant changes in suspension performance relative to seismic events can be achieved by varying the stiffness and the damping of the support member materials.

The handling fixture for the cold mass and vacuum vessel assemblies has successfully handled both elements at the Long Magnet Model Production Facility.

c. Spools

A conceptual design and the corresponding costing of the various SSC spools have been reviewed with CDG and LBL.

d. Conceptual Design Report

Narrative contributions were made to the SSC Conceptual Design Report. Included were the sub-sections for cryostat, magnet assembly, and magnet installation in the tunnel. Contributions to the cost estimate were also made.

e. Injector Design and Cost Estimates

The design and costing of the rings for the SSC Injector have been completed.

2. Long Magnet Fabrication

a. HLM II-Heat Leak Model

All of the production facilities have been installed to complete the assembly of the "D" series magnets.

The Mock Cold Mass Assembly has the five support posts, center anchor, and helium piping systems attached and inspected. Measurements before and after welding supports to the single phase skin have been made to determine the effect of weld stresses on dimensional stability.

The vacuum vessel subassembly has been set up on the five support feet and inspected dimensionally; 20K Shield Assemblies have been welded, and instrumentation has started.

All material to complete the Heat Leak Model has been received, and material for the balance of the magnets have all been ordered with 99% of the material on hand.

Because of engineering changes in the design of the anchor system, a new production schedule has been developed.

This new schedule shows a completed assembly date of March 31, 1986. This schedule has been agreed to by Production and Engineering, and we do not see any major changes or problems that would affect this completion date.

Subassembly work for the first BNL Cold Mass Magnet Cryostat will start in March of 1986.

b. HLM II End Vessels

Modification of the end vessels has been completed. Units have been assembled and readied for the zero magnet heat leak test which will begin on March 2.

c. Interconnect Area

The first of the bellows assemblies has been received from the vendor. These include the 20°K shield bellows and the gaseous helium return bellows. Consumable washers for welding have been ordered. These are commercially available items requiring no special tooling. Work continues on the mock-up interconnect which will simulate the ends of two adjacent magnets for physically welding and unwelding bellows in their intended position. This, of course, is to prove out tooling and design considerations. Fixtures for cycle testing of bellows at LN temperatures are being designed.

3. General Magnet R&D

a. Conductor Gauge

On-going modifications of the hydraulic system have been completed enabling a load of up to 25,000 psi to be imposed on the sample while measurements are taken. The footage counter was also modified allowing cable to be measured in 1/10 foot increments as opposed to previous one foot increments. New LVDT's to simplify base line calibration are still

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on order; expected delivery is late March. Although the new LVDT's are considered a nicety they do not inhibit the use of the machine, that is the old LVDT's can be used. The hydraulic system has been fully checked out and is operational. Actual measurement of cable has been delayed due to priorities involving ongoing production of Tevatron coils. Measurement program will resume mid-March.

b. 1 Meter Models

SJ-1012 (wet wound) and SK-1004, SK-1005 (dry wound) were to have been ready for test in mid-February. Failure of outer strain gauges has caused a delay. New gauges should be ready for installation by the end of March.

c. Magnet Tests

The first cold tests of a design "D" dipole were made. The maximum field that this coil reached was 6.35T which is higher than the 10^{-12} Ω-cm perpendicular field value. A full set of measurements were made on this magnet and are being analyzed. The magnet seemed to be more sensitive to ramp rate than other design "B" coils. The training of this magnet seemed about par with 3-5 quenches to reach full field at 4.3K.

A new "S" series 5cm bore dry wound design "B" dipole, SJ1010, was tested. The maximum central field at 4.3K was 6.0T, which was effectively the short sample limit of the cable. The magnet was unusual in that it seemed to operate higher on slower ramp rates of approximately 10 to 20 millitesla/sec.

4. Magnetic Measurements

A 66 inch long Morgan Coil was wound, mounted, and wired with a 1.250 in. o.d. for testing of long magnets.

Short sample cable tests were run on new inner and outer cables for the remaining design "D" dipoles to be wound at FNAL.

The newer "Mulholland" CERN style leads for the MTF and string end cans were tested up to a current of 6800 amps and found to be very stable at a flow of 11 ℓ/hr. at 6800 amps.

Calibration and assembly of MTF and string test thermometry continued this month as well.

Electronics for the signal processing and quench protection for the MTF 17m test were finalized enough to order the components and design boards; Kautzky Valve timing has been measured.

The MTF refrigerator was operated in the mode that is proposed for the 17m dipole tests, i.e., with the 2 second turbine (T2) turned off. The object of this test was to check the liquid depletion rate with T2 off as predicted by calculation. The secondary purpose was to gain operating experience.

<u>Results</u>

T-2 off	sub-cooler full	ended full
	dewar 3/4 full	ended 3/4+ full

Minimum magnet temperature 4.72K, pressure 60 psia, and a flow of 47 g/s leads at 12 ℓ/hr. The system was stable 3 hours.

5. Accelerator R&D

a. <u>Injector Design and Cost Estimates</u>

In mid-October the Fermilab Accelerator Division was requested by the SSC Central Design Group (CDG) to provide the injector design, along with accompanying writen descriptions and cost estimates, for inclusion into the SSC Conceptual Design Report (CDR). The CDR is in the final stages of preparation and the effort on the injector is essentially finished. All text required for preparation of the CDR first draft,

scheduled for release on or about March 3, has been transmitted to the CDG. The injector technical component cost estimate along with all backup material has also been completed and is now integrated into the work breakdown structure set up by the CDG covering the entire SSC complex. Cost estimating of the conventional facilities and EDIA associated with the injector complex is being handled by the CDG.

The only work remaining to be done will involve some editing of text, and further refinement of the cost estimate for inclusion in the final draft of the CDR.

b. Power Supplies & Quench Protection

Chapter 5.5 of the Conceptual Design Report was written. A cost estimate for the Collider main power supplies and quench protection system was also done for the CDR. This work included a one week period at the CDG. As part of this effort, extensive computer studies were done on the proposed multi-sector regulation scheme for the collider. This work will be reported in detail in a later Technical Memo.

We participated in the Magnet Systems Integration meetings and discussed possible configurations for the E4 half-cell test.

The design of the ramp control processor for the half-cell test (dubbed SECAR) is complete and it is well into construction.

c. Theory

A Talaris 2400 laser printer and the TEX typesetting program were recently acquired. This system will be used to transcribe a fourth-order perturbation treatment of sextupole dynamics using MACSYMA to do all the algebra. A program for making the transcription is being written. This non-linear particle dynamics program is a part of the total effort in the study of the beam dynamics in the SSC.

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

6. Half-Cell Test Support

a. <u>String Test</u>

Design on the end boxes and turnaround boxes continues. A cryogenic consultant has been hired to assist in engineering notes, heat leak model run, and string test. The piping for the string test refrigerator is finished. The heat exchanger has been modified and installed.

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

Continued testing and analysis took place to understand efficiency and durability of the cold compressor. The compressor was subjected to upset conditions and first phase sub-atmospheric operation took place.

c. <u>Power Leads</u>

SSC power leads were manufactured and successfully tested at Lab 2. Orders have been placed for leads for MTF and the string test.

C. LBL.

1. Magnet Models. During February the collar comparison test model was completed. Measurements were made of the coil pressures using four types of collars during the collaring and cooldown phases. The room temperature data agrees well with the finite element models of the collars. Some of the cold pressure results were puzzling and further analytical and experimental investigation of cold collar/coil behavior is planned.

Considerable progress was made in an effort to produce end spacers for coils to be used in 1-m models during the rest of the year. Two designs are being pursued, differing in that the turns approximate either a circular or an elliptical shape on a developed (or flattened-out) view of the end; in either case, the turns are spaced to make a minimum distortion in the axially integrated field while also limiting the field at the conductor to a maximum design value. The initial end spacing design was a collaborative effort with BNL (Gary Morgan). Mechanical and magnetic considerations will dictate which geometry to adopt for future models. Both compression molding and CNC machining of end spacers is being tried.

The following tasks were carried out during this period:

- Completed collaring and cooldown of collar test model.
- Completed several model coils to test end geometries.
- Completed 4 coils to be used in model MD-3.
- Fabrication of first laminated yoke assembly 80% completed.
- Placed order for new tooling and stamped 15 mm collars. Due about May 1, 1986.

2. Analysis. Work this month continued on the NC515 cross section described in previous months' reports. Various details for SSC reviews were attended to (graphs, reports, etc.). Isobars of constant $|B|$ were added to POISSON's graphics.

A calculation of superconductor magnetization for the NC515 cross section was done with POISSON. Several questions were raised by this calculation, e.g., the 14-pole harmonic due to magnetization was observed to behave differently in this cross section than in C5.

The locations of corners and strands for one quadrant of the MD-1 autopsy were measured and multipoles calculated. The measurements were done with a high resolution (~2 μm) unit in Bldg. 80.

3. Instrumentation and Measurements.

a. 4.4 K testing of MD-2, tested February 5-11, 1986

MD-2 is the second mechanical design dipole with the new NC515 cross section. Flush ends are incorporated into the new design, but the ends of these first models are not fully mechanically secured. This magnet was not intended for full-current testing; nevertheless, a cold test was made and some modest training behavior was observed: the plateau field of 6.4 tesla required thirteen training quenches. The first quench at 5.5 tesla corresponds to 85% of maximum field, and the 95% value of 6.1 tesla was reached in five quenches.

The magnetic field measurements agree with the warm measurements of MD-1 and MD-2.

b. Room temperature magnetic measurements: the outer layer of MD-3 was tested February 26-27, 1986; the inner layer of collar test magnet CCT-1 was tested February 28 and March 3, 1986.

Magnetic measurements of improved end designs were carried out in the tests listed above. This is a continuing program.

4. Superconductor. Fabrication of cable for the LBL and BNL model magnet programs continued, and an additional 3850 ft of inner layer and 4500 ft of outer layer cable were completed for use in the third long model at BNL. The electrical results for these cables as measured by BNL were quite good. The inner layer cable I_c(5.0 T, 4.2K) is equal to the value calculated from

the sum of the individual wires before cabling, i.e., no degradation was observed due to cabling. The outer layer cable showed a 15% degradation from the sum of the individual strand values in agreement with earlier cable results. In addition to these long cables, several prototype cables were made from fine filament material. An inner layer cable made from strand with 4,000 filaments of approximately 8 μm diameter produced for LBL by Supercon, has a value of I_c(5.0 T, 4.2K) = 15,495 A, measured with the field parallel to the wide side of the cable. This value is equal to the sum of the individual strand critical currents; it is 50% above the original Design D specification value and 30% above the value being used in the Conceptual Design Report. The I_c with the field perpendicular to the cable wide side has not been measured; this value is typically 5-10% below the "parallel field" value, but should still be well above the new specification value.

The conductor problem areas at present are mainly mechanical in nature. The initial piece lengths for fine filament strand produced by U.S. manufacturers is below that experienced for the conventional filament size material. Experiments are being conducted on wire drawing parameters (e.g., die angle, lubrication, and intermediate annealing schedule) in order to improve piece lengths. In addition, some of the high current density strand (both fine and conventional filament sizes) produces a cable with poor flatness. LBL is experimenting with the cabling parameters and with a post-cabling anneal in order to correct this problem.

D. TAC.

1. Correction Magnets. TAC has completed construction of the first prototype superferric dipole correction magnet. It will be tested next month. Field calculations and design are still being done on the cosine theta magnet.

2. Quench Protection Diodes. TAC has put a high priority on preparing diodes for a test in the Texas A&M reactor. This test will be at liquid nitrogen temperature and will test radiation damage and our test set-up. An attached summary on the quench diode project is attached.

3. Theory. S. Heifets and D. Neuffer have recently spent a week at the CDG. Alex Chao of the CDG will visit TAC in March.

4. Superferric Magnets. During the month TAC was able to test one 1-m dipole assembled at IGC in New York and one 7-m dipole assembled at TAC. Both magnets performed as expected. This was the second successful magnet from IGC. The measurements of the skew quadruole through the 7-m magnet averages to 0.9 units. A summary is attached.

The second IGS magnet tested very well. The field shape agreed with the other magnet which had the same conductor placement. There was not training of the superconductor. A field of about 3.5 T was reached with over 13 kA in both the inner and outer coils before the first quench.

The 7-m long magnet, TAC008, also tested very well. There was not training. With equal currents in the two main windings, the magnet quenched at about 3.25 T, I ≃ 11.7 kA. This lower value was due to having a warmer magnet, T = 4.9° instead at 4.5° with the 1-m models. The field shape also agreed with other magnets. The skew quadrupole measured at 4 ft intervals is shown in the following table:

Position	a_1
0	-0.6×10^{-4}/cm
4 ft	-1.0
8 ft	-0.2
12 ft	-1.5
16 ft	-1.4
average	-0.9×10^{-4}/cm

TAC QUENCH PROTECTION DIODE PROGRAM

Work on the Q.P. diode program has concentrated on obtaining relevant information and preparing for tests of diodes at the Texas A&M research reactor. This work is proceeding well, with much effort devoted to circumventing the usual delays in procurement of publications and equipment.

Two computer-assisted searches of literature were conducted at university libraries. These yielded some interesting but highly esoteric references, most of which have now been obtained. Some textbooks found in the TAMU library and in "books in print" catalogues have been obtained or placed on order. Bibliographies have been requested from three different DOD sources. Two of these have been delivered, and copies of cited papers presented at IEEE conferences have been ordered and obtained. Relevant government records have been ordered, and a few have recently arrived. Some information has also been obtained from CERN, which includes excellent summaries of radiation effect studies on various electronic devices. Only a fraction of the material so far obtained has been studied; however, conversations with people at Sandia Laboratories, the University of Missouri research reactor, CERN, and DESY have given us a rough idea of what to expect in the diode tests. Commercially available high-current diodes should show some effects from radiation at around 10^{13} n/cm^2 when irradiated at room temperature. Similar effects should occur with about an order of magnitude less radiation when the diodes are irradiated at cryogenic temperatures.

Preparation for initial irradiation tests at 77K are proceeding rapidly, and a day of testing should be performed at the TAMU reactor within the next few weeks. The first test will teach us a good deal about the test procedures as well as the diodes, so that later tests can be more thorough and efficient. Eight Westinghouse R 90 diodes are on hand, and twenty RA 20 diodes (the type tested at BNL by Sampson, Stevens, et al.) should arrive within a few days. One of ten segments of a 7,500 ampere battery power supply has been constructed and is undergoing tests. This will probaby not be used in the first tests, so that in situ pulses will be limited to about 20 amperes. Six bases for the diodes have been machined, and ten more will be finished within a few days. Construction has begun on frames for the bases and in insulated chamber in which they can be subjected to temperatures ranging from 77 to 600K. The high temperature capability should allow rapid cooling-irradiation-annealing cycles.

Our future activities will depend in part on what we learn in the first reactor test run. This should give us a better idea of the problems of transferring cryogens into the irradiation cell, the irradiation times required, and the best methods of instrumentation and data acquisition. Because of the large cost in time and resources required to perform and analyze each day of tests at the reactor, in the future we wish to test about 20-30 diodes together. Unfortunately, calculations indicate that in situ liquid helium tests on more than a few diodes at a time will be very difficult using a conventional "helium bucket" cryostat. In such an arrangement, each 600 ampere pulse will vaporize about 30 liters of liquid helium, and several such pulses should be given to each diode. Each current lead would have a cross-sectional area of about 1 cm^2, and very rough estimates indicate heat conduction down 2 meters of such a lead will boil off 50-100 liters of LHe over a 10 hour

period if it is not cooled by boil-off gas, or only a few liters if it is gas-cooled. Providing a well-cooled lead for each of 20 diodes appears very problematical. All of this points to using thousands of liters of LHe for each day of tests, at a cost of about $4-$5/liter. We feel the problem should be considered more carefully before deciding on a cryostat design, and this will be done after the initial reactor tests are analyzed. In the meantime, before-after 4K tests can be performed with the facilities available at TAC.

We are still hopeful of obtaining a more radiation-resistant diode. Comments from people at CERN and DESY have tended to discourage but not eliminate this approach. Further contacts with manufacturers will be explored once the next few weeks of experimental activities are behind us.

C. PROJECT COST DATA
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SSC Program Summary	C-6	6

TABLE C-1

CENTRAL DESIGN GROUP - SUPERCOLLIDER

FEBRUARY 1986 COST REPORT (K$)

	PROGRAM ELEMENT	LABOR	MAT'L & SERVICES	G & A	MONTH TOTAL	YEAR TO DATE	ANNUAL BUDGET
1.1	ADMINISTRATION	107	110	49	266	1067	2710
1.2	PROGRAM PLANNING & MANAGEMENT	21	0	10	31	155	650
1.3	ACCELERATOR R & D	150	64	-15	199	849	4060
1.4	CONVENTIONAL SYSTEMS DEVELOP.	27	330	2	359	1269	2560
	PROGRAM COSTS	305	504	46	855	3340	9980
	COMMITTMENTS				319		

TABLE C-2

BROOKHAVEN NATIONAL LABORATORY - SUPERCOLLIDER

FEBRUARY 1986 COST REPORT (K$)

	PROGRAM ELEMENT	LABOR	MAT'L & SERVICES	G & A	MONTH TOTAL	YEAR TO DATE	ANNUAL BUDGET
2.1	MAGNET FABRICATION	117	182	77	376	1248	3020
	PROGRAM COSTS	117	182	77	376	1248	3020
	COMMITMENTS				491		
	EQUIPMENT	31			31	31	250

TABLE C-3

FERMI NATIONAL ACCELERATOR LABORATORY - SUPERCOLLIDER

FEBRUARY 1986 COST REPORT (K$)

	PROGRAM ELEMENT	LABOR	MAT'L & SERVICES	G & A	MONTH TOTAL	YEAR TO DATE	ANNUAL BUDGET
3.1	GENERAL	8.9	11.7	8.1	28.7	85.2	140
3.2	CRYOSTAT DESIGN & DEVELOPMENT	27	9.6	14.5	51.1	326.1	960
3.3	LONG MAGNET FABRICATION	83.3	66.4	59.3	209	781.9	1300
3.4	MAGNETIC MEASUREMENTS	17.1	7.4	9.6	34.1	108.2	600
	PROGRAM COSTS	136.3	95.1	91.5	322.9	1301.4	3000
	COMMITMENTS				179.6		
	EQUIPMENT	8.3	22.5		30.8	100.5	550

TABLE C-4

LAWRENCE BERKELEY LABORATORY - SUPERCOLLIDER

FEBRUARY 1986 COST REPORT (K$)

	PROGRAM ELEMENT	LABOR	MAT'L & SERVICES	G & A	MONTH TOTAL	YEAR TO DATE	ANNUAL BUDGET
4.1	GENERAL	7	0	3	10	39	120
4.2	SUPERCONDUCTOR	12	0	6	18	117	560
4.3	HIGH GRADIENT IR QUADRUPOLES	9	0	5	14	89	270
4.4	MAGNET MODELS	48	0	24	72	219	450
	PROGRAM COSTS	76	0	38	114	464	1400
	COMMITMENTS				306		

TABLE C-5

TEXAS ACCELERATOR CENTER - SUPERCOLLIDER

FEBRUARY 1986 COST REPORT (K$)

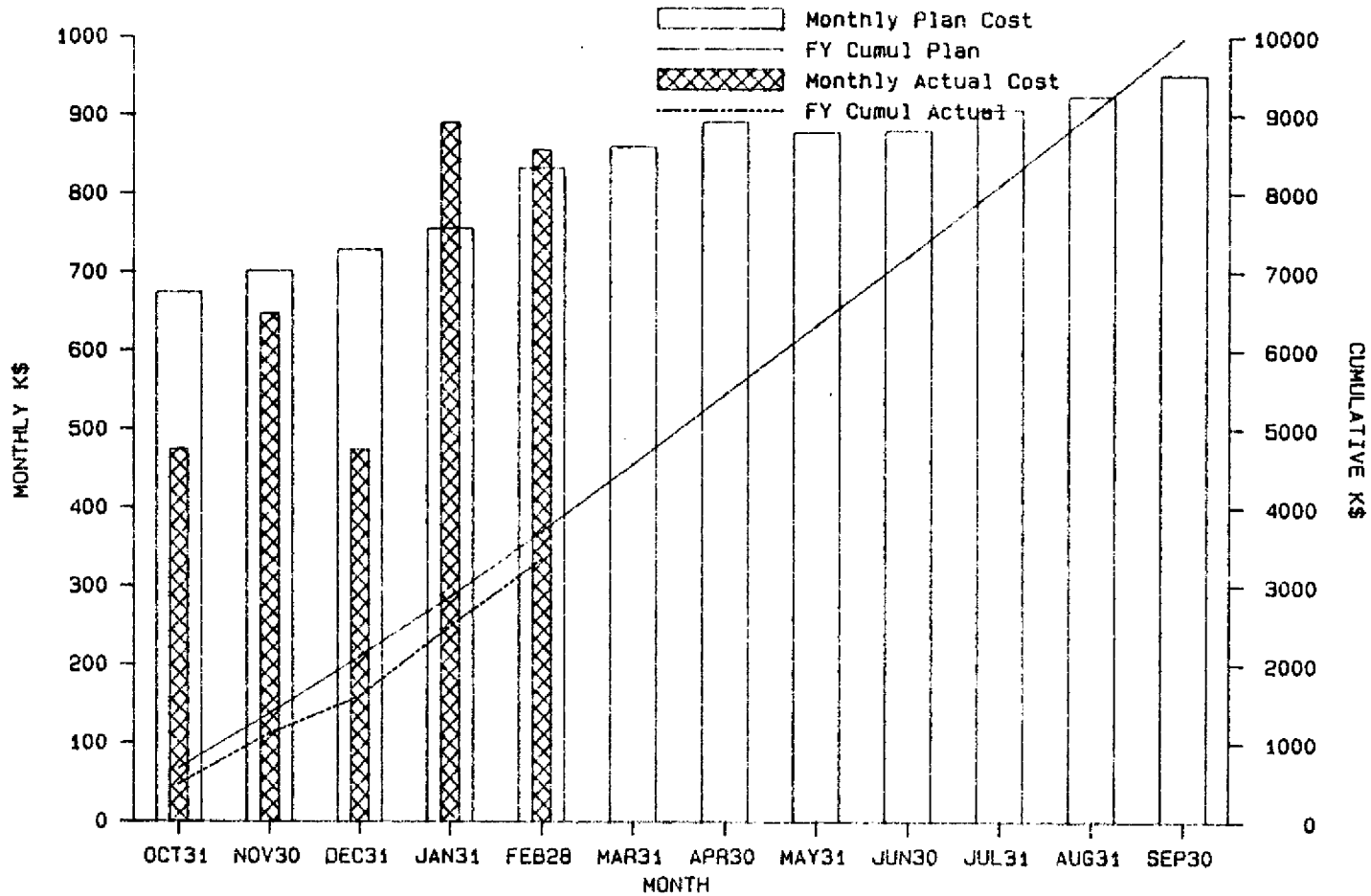
	PROGRAM ELEMENT	LABOR	MAT'L & SERVICES	G & A	MONTH TOTAL	YEAR TO DATE	ANNUAL BUDGET
5.1	DIODE QUENCH PROTECTION	4	0.1	4.9	8.9	49.7	550
5.2	CORRECTION ELEMENTS	7.9	5.1	11.2	24.2	145.5	1025
5.3	ACCELERATOR PHYSICS	3.4	0.1	4.1	7.5	51.4	275
5.4	SUPERFERRIC MAGNET	30.6	27	45.4	103	558.8	750
	PROGRAM COSTS	45.9	32.3	65.6	143.6	805.4	2600
	COMMITMENTS		63.1	51.5	114.6	247.8	

TABLE C-6

PROGRAM SUMMARY - SUPERCOLLIDER

FEBRUARY 1986 COST REPORT (K$)

	PROGRAM ELEMENT	LABOR	MAT'L & SERVICES	G & A	MONTH TOTAL	YEAR TO DATE	ANNUAL BUDGET
1.	CDG PROGRAM	305	504	46	855	3340	9980
2.	BNL SSC PROGRAM	117	182	77	376	1248	3020
3.	FNAL SSC PROGRAM	136	95	92	323	1301	3000
4.	LBL SSC PROGRAM	76	0	38	114	464	1400
5.	TAC SSC PROGRAM	46	32	66	144	805	2600
	TOTAL SSC PROGRAM COSTS	680	813	318	1812	7159	20000
	COMMITMENTS				1410		



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	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							
FY Cumul Actual	474	1121	1594	2484	3339							

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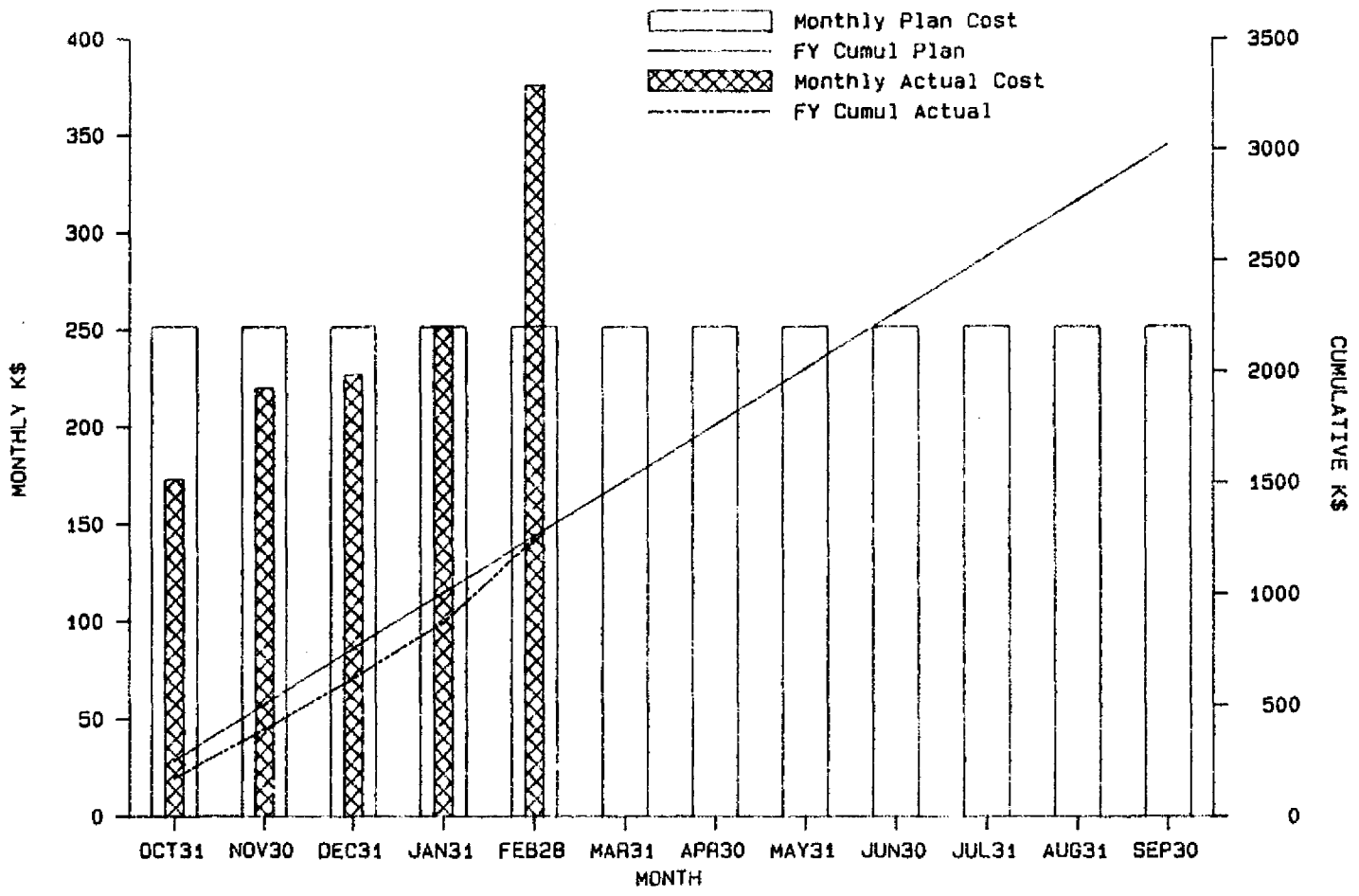
20-MAR-86

Figure 1



	FISCAL YEAR 1986											
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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							
FY Cumul Actual	173	393	620	872	1248							

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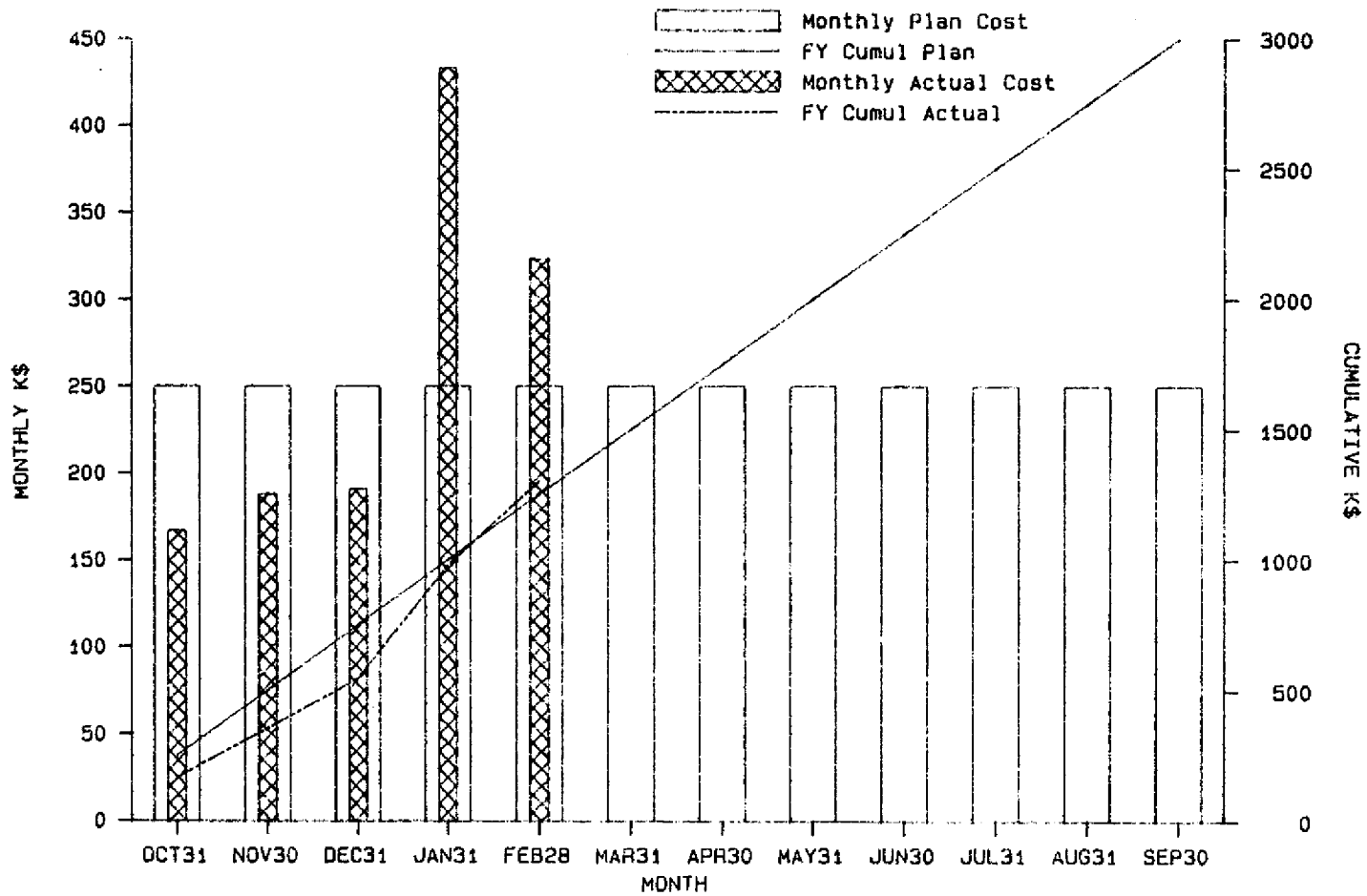
20-MAR-86

Figure 2



	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							
FY Cumul Actual	167	355	546	979	1301							

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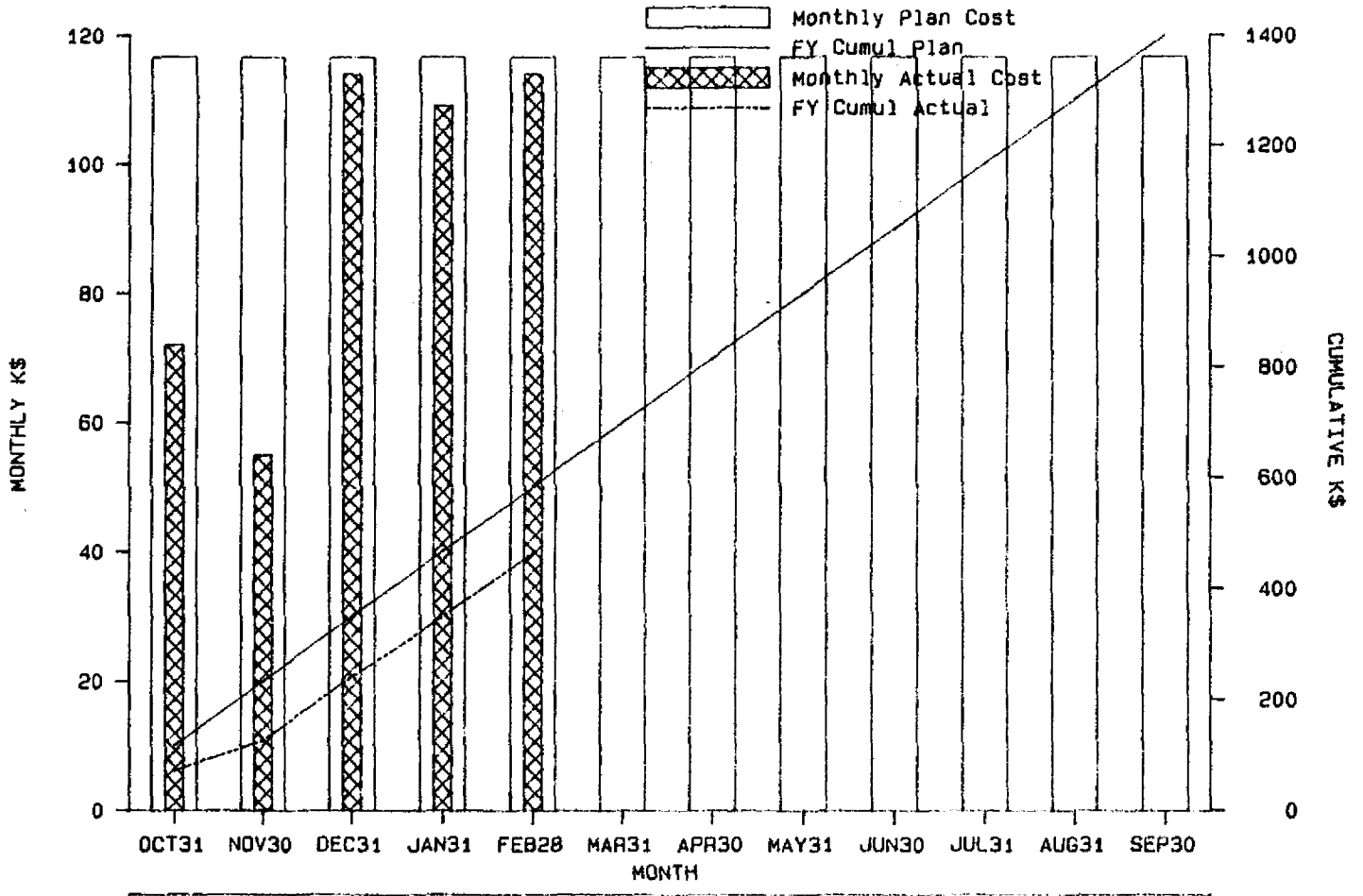
4:27 pm
20-MAR-86

Figure 3



	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							
FY Cumul Actual	72	127	241	350	464							

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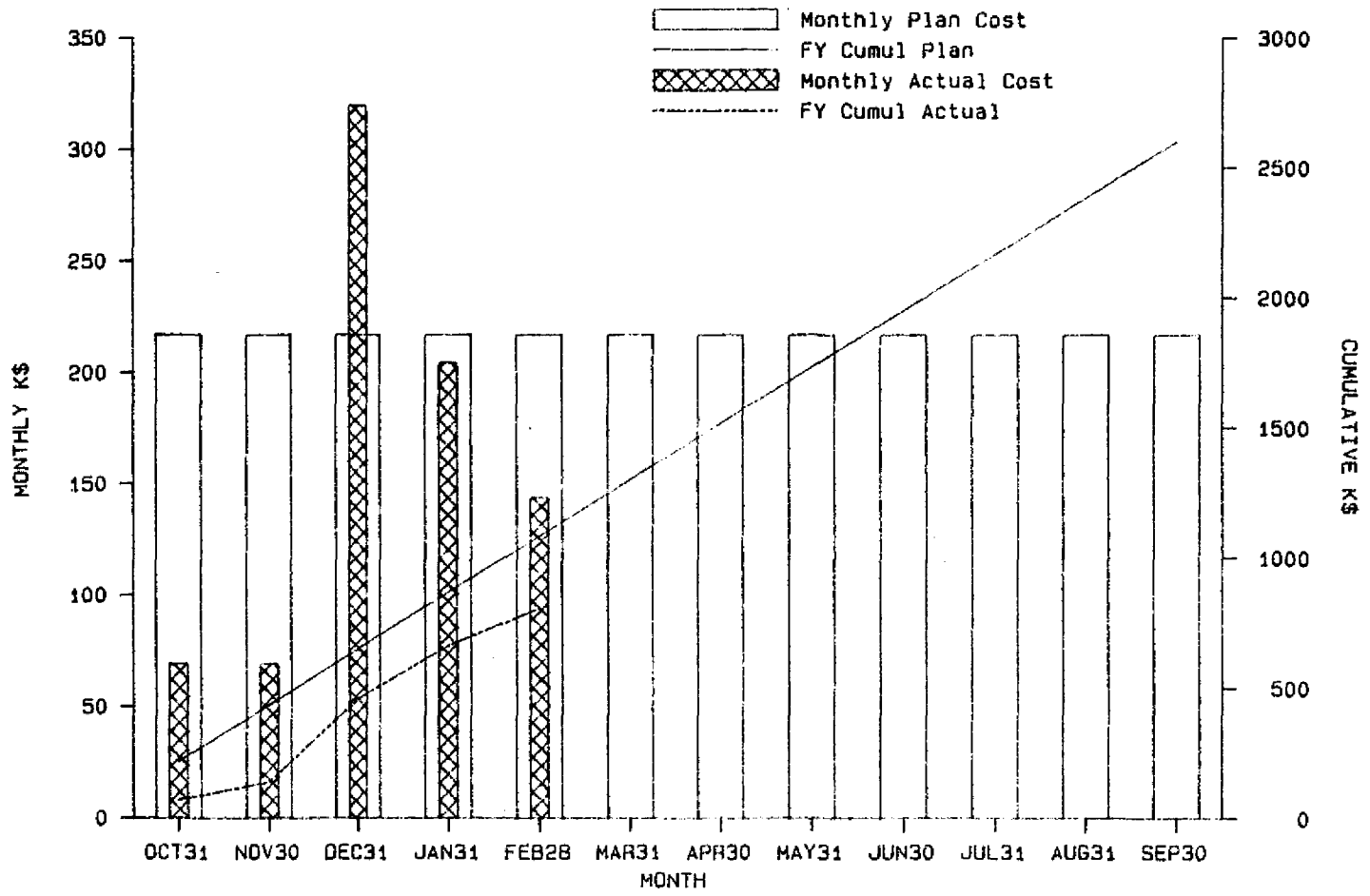
4:29 pm
20-MAR-86

Figure 4



	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							
FY Cumul Actual	69	138	458	662	805							

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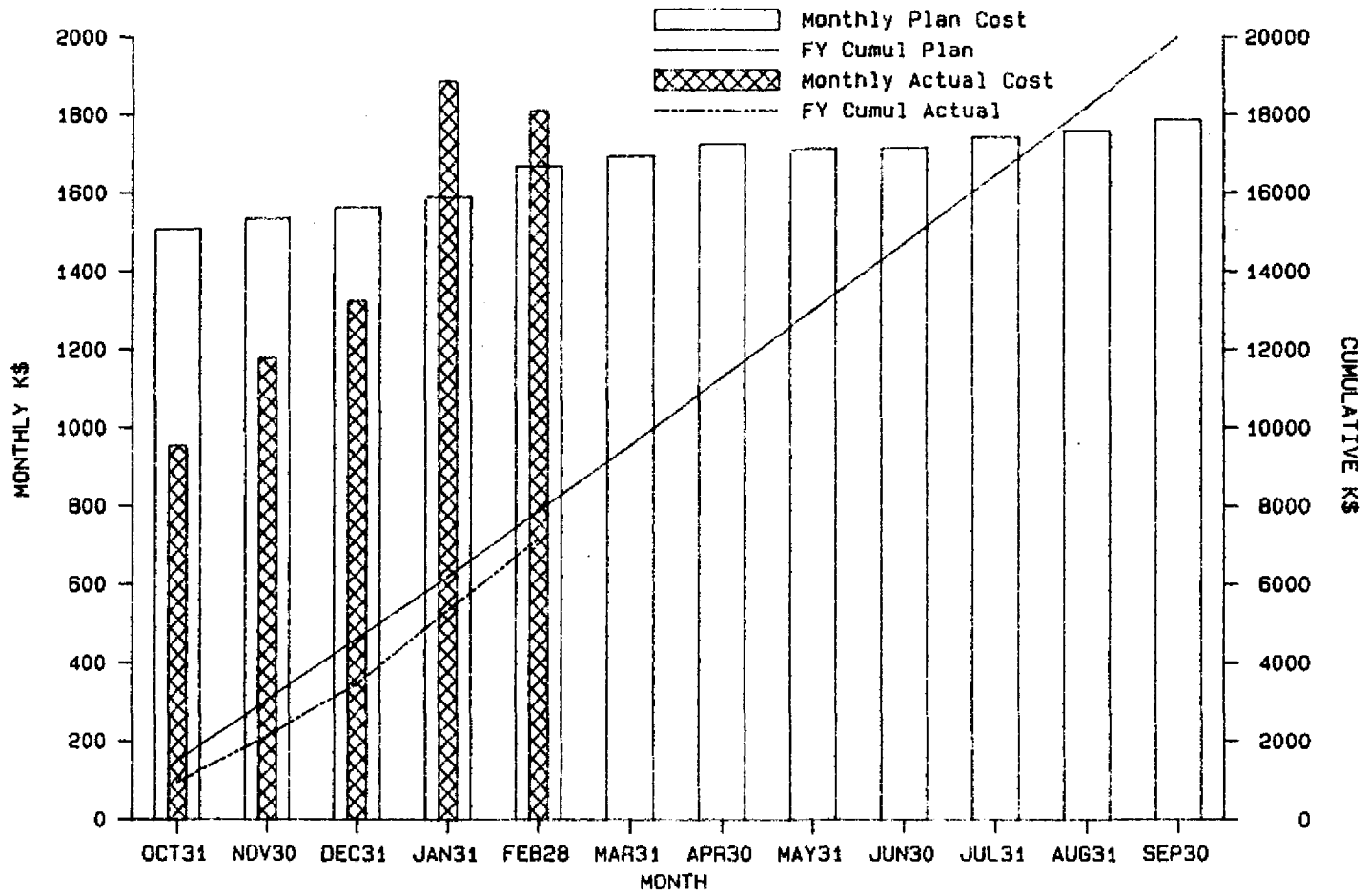
(JSZ)
4:30 pm
20-MAR-86

Figure 5



	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							
FY Cumul Actual	955	2134	3458	5346	7158							

SSC
(JSZ)
4:23 pm
20-MAR-86

Figure 6