STATUS OF THE SUPERCONDUCTING ACCELERATOR PROJECT

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Since the last status report on the superconducting accelerator project in the January issue of **fermilab report**, considerable progress has been made on many fronts.

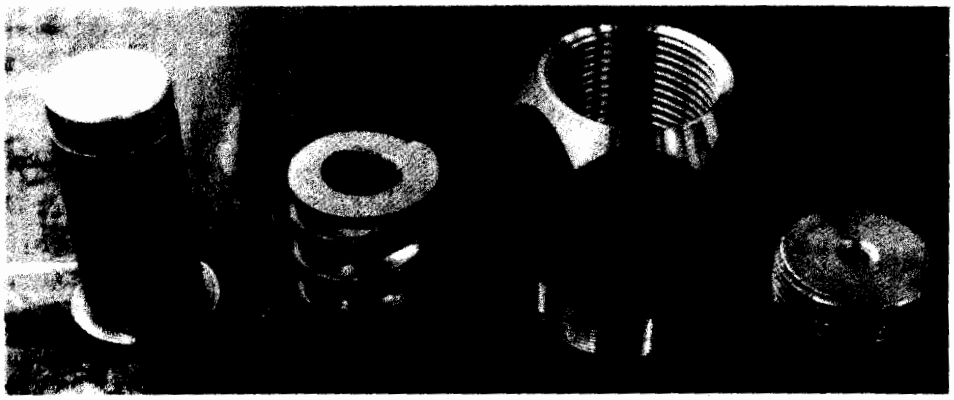
The vertical-plane motion problem of the dipoles has been cured and full-scale magnet production has resumed; production of quadrupoles and trim magnets is also starting. The refrigeration system has made considerable progress and has been used for system tests.

These system tests, both in the tunnel in the A2 cryoloop and above ground in the B12 systems, have settled many questions about installation, leak checking, cooldown, system operation, and heat losses. This report will discuss these and other items making progress on the superconducting accelerator.

1. Magnets

Dipoles

The problem of the instability of the vertical plane of the magnetic field under cooldown proved to be rather intractable. A solution was finally arrived at using four opposed anchors at the center of the cryostat and a series of "smart" bolts to maintain the preload on the cryostat at a constant pressure. A "smart" bolt, a bolt containing a spring-loaded piston, is shown disassembled in the photograph below. The photograph at the top of



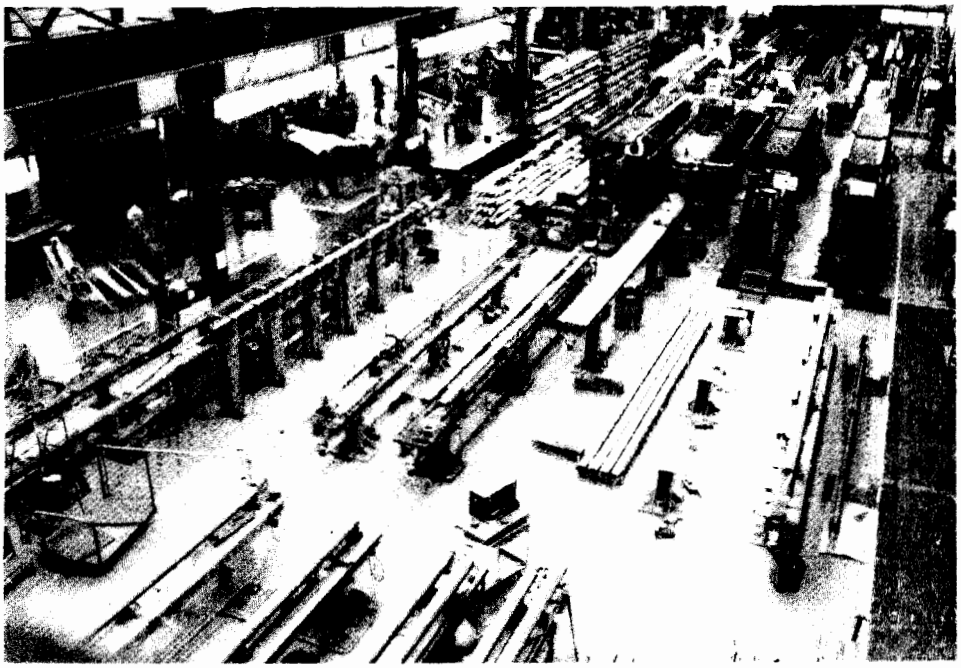
"Smart" bolt components.
(Photograph by Fermilab Photo Unit)

this page shows its mounting in a cryostat. Individual magnets have been thermally cycled more than 60 times with a total measured vertical plane excursion less than 0.5 mrad. We are confident that a full solution of the problem has been achieved and full production of the new design has been initiated.

Cutaway view of the cryostat showing revised anchor. (Photo by Fermilab Photo Unit)

Production of collared coil assemblies has continued during the period of development of the improved cryostat so that over 200 (out of a total of 774) had been produced by the end of August. A recent view of Industrial Building 3 shows many finished stacked coil assemblies.

On the basis of extended systems tests, an alternating bus scheme has been incorporated in the magnets to improve quench-protection characteristics.

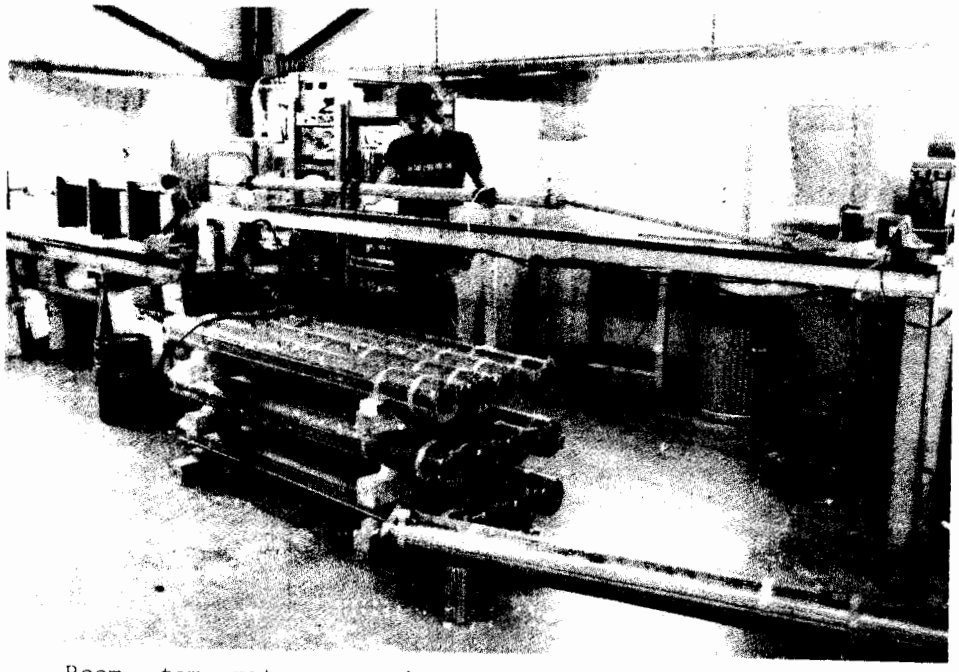


The magnet factory. Many coil assemblies are stacked, awaiting cryostats.

(Photograph by Fermilab Photo Unit)

Quadrupoles

Production has moved along smoothly so that more than a dozen collared coils had been produced by the end of August. The cryostat assembly has now started again, based on the success of the dipole cryostat design change. Some of these can be seen in the photograph below.



Room temperature quadrupole magnetic measurement apparatus. Completed collared coils in foreground; Ned Cummins in background is part of the quadrupole fabrications staff.
(Photograph by Fermilab Photo Unit)

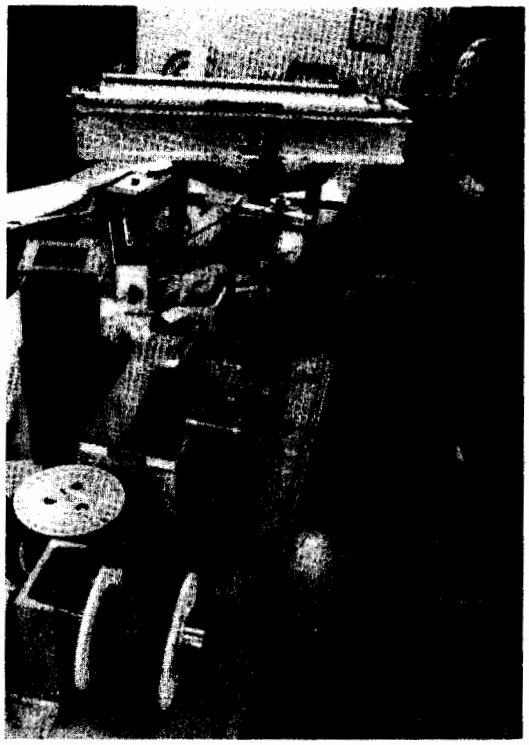
Correction Coils

The correction coil package has been successfully tested to more than 50 A and production of coil assemblies is proceeding on schedule. The photograph at the top of the next page shows the production process. The present package contains dipole, quadrupole, and sextupole elements in coil bundle #1 and skew quadrupole, skew sextupole, and octupole in bundle #2.

2. Refrigerators

Central Helium Liquefier

The Central Helium Liquefier has successfully operated to produce more than 3,000 ℓ/h of liquid in two closed-loop tests,



Walter Wojak winds correction coils.
(Photograph by Fermilab Photo Unit)

In early September, Road D was cut to install a culvert to carry the transfer lines connecting the CHL with the accelerator preparatory to exercising the combined system.

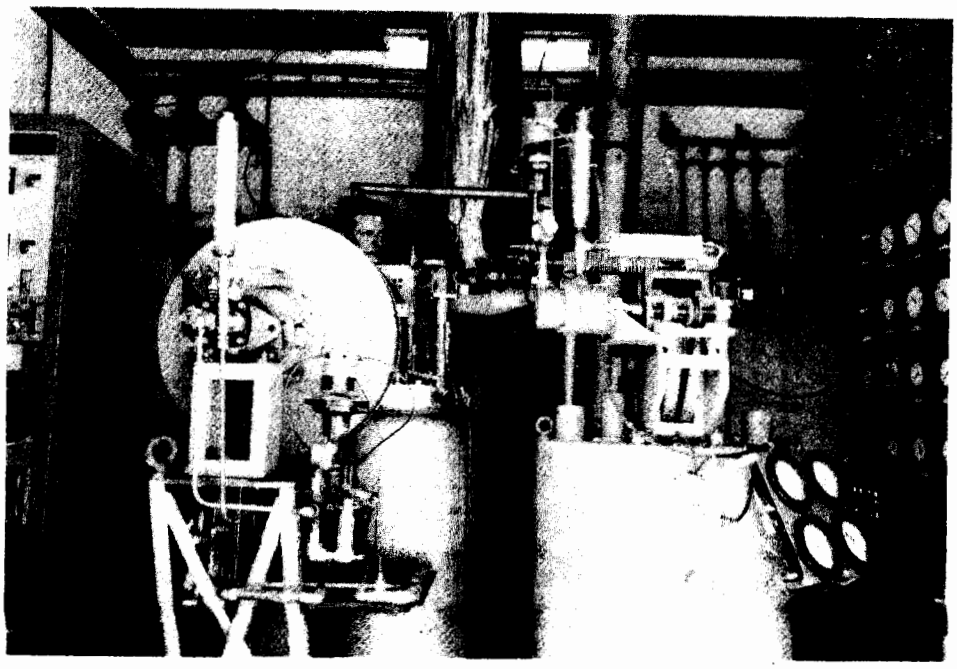
Satellites

The first of the production-model horizontal heat exchangers have been installed at A3 and A4, together with production-model valve boxes and tunnel connections. The rural scene on the next page shows the A4 heat exchanger. A final choice of engines has been made. Installation of the expansion engines and controls is proceeding towards a system shakedown in the late fall.

Meanwhile, the A0 and B0 compressor installations have been commissioned. The high-pressure helium line delivering gas from the compressors to the satellite refrigerators is completed from A0 to B1, one-sixth of the ring. The liquid-helium transfer line is completed from A1 to A2. The A2 refrigerator has operated successfully for over three weeks in satellite mode being fed liquid from the A1 refrigerator. It is shown in the bottom photograph on the next page.

First production model of the heat exchanger installed at the A4 refrigerator building.

(Photograph by Fermilab Photo Unit)



Satellite refrigerator installation at A2. Paul Furio can be seen in the background.

(Photograph by Fermilab Photo Unit)

3. Tests

A2

The A2 cryoloop involving 40 magnets in the tunnel, referred to above, has been successfully completed and operated. Based on the experience of this installation, a crew of technicians can install a half-cell in less than six shifts, including alignment, connection, pumpdown, hipot, and leak check. Leak checking must be done to a level of 10^{-9} atm-mm/s. The techniques for doing this have now been developed.

Further tests are being done in the A2 string before warming it up to measure the heat leak at various cryostat pressures. The measured heat leak for the cryoloop at the canonical 4.6 K is 232 watts, to be compared with the design value of 300 watts.

B12

B12 is an ongoing test of a string of 20 magnets located above ground between the B0 and B1 service buildings. The magnets presently being used are old 22-ft dipoles with old quads and spool pieces. The tests, for the most part, concern power-supply and quench protection and satellite-refrigerator controls. We intend in the near future to convert B12 to the new 21-ft dipoles, with new quads and spool pieces, especially for the purpose of testing the alternating coil-bus configuration mentioned below.

It is an understatement to say that we have learned a considerable amount from the B12 program. Often we have learned by making rather disastrous mistakes. After analysis, of course, all of the mistakes are "obvious," even to the casual observer. The major advantage of B12 is that it is the only large-scale system to which we have continuous and easy access. If there are any disadvantages, it is that it is not big enough, both in concept and operation, and that turn-around time is too long. In other words, we could perhaps invest more money and manpower into this sort of research.

As an example of the tests done at B12, we have paraphrased an internal memo of April 24, 1980, along with comments as to the progress made in each experiment. The purpose of the memo was to outline our research program at B12 for the summer.

Quench Propagation. The purpose of the experiment was to see if quenches started in one half-cell would propagate to an adjacent half-cell, through the "quench stopper."

Up to this time (September 2, 1980), there has been no observation of quench propagation from a half-cell up to a current level of 3500 A.

Measurements of Integral I^2dT (Miits) During Quenches.

(i) For quenches started in a coil or bus inside the coil package, it apears that up to 2000 A, one heater out of the available four per half-cell is sufficient to protect the magnets. Up to 3500 A, two heaters are sufficient. Behavior at higher currents is yet to be investigated.

(ii) It is generally agreed that for currents less than 1000 A, heaters are not necessary for safe energy removal. If we dump 800 J into the heater circuit, all magnets will quench down to 500 A, so we are certainly safe. It remains to be established if all magnets will quench at 1000 A when 400 J are put into the heaters. This is one of the measurements which will be done at the Magnet Test Facility for each magnet. It is clear, nevertheless, from the results of (i) above that if there are a few magnets that do not readily quench with 400-J heaters at 1000 A addition of some heater circuits with 800 J will solve the problem.

(iii) Quenches That Start Outside the Coil Package. It is possible that beam loss can start a quench in the cable outside the coil package, for example, in the magnet interconnections, straight sections, or spool pieces, even though the magnetic field is low at those places. The quench propagation is much slower there, and the number of miits absorbed in the cable is, therefore, much higher before sufficient resistive voltage is present to allow quench detection. The solution to this problem is intimately connected with the level of noise present on the quench-protection monitor, and our ability to lower the detection threshold. With thresholds of a few V (resistive), we are probably not safe. The threshold can be run at approximately 1 V, but some work is still necessary on the quench problem of lowering that threshold. The research on the actual number of miits that a cable can take before damage and on the resistance growth rate will be moved from B12 to the short-sample test apparatus, where the experiments are much easier.

Transient Response on QPM. There is an ongoing problem of improving the transient response and smoothing of the QPM, both in hardware and software. At present, the induced voltages due to coupling in the detection network have been cancelled in software to the level of 1 V. This level cannot be improved until some hardware improvements are made in the uninterruptible power supply for the QPM.

Because B12 is not configured in the alternating coil-bus arrangement incorporated in the final magnet design, there are some special problems of transients. The final scheme using the alternating bus is much easier than that incorporated in B12 at present. Hence, we would like to change to the newer scheme as soon as possible.

Helium Lost During Quench. We have learned that the half loop not involved in the quench is not affected by the quench.

In addition, up to 3500 A, the half-cell adjacent to the quenching half-cell stays cold, and even retains much of its liquid. This is very good news and means fast recovery time after quenches. It also means that we will not suffer a great deal when we go to one-cell quench protection units instead of half-cell units.

Cryogenic Tests. For ramp parameters shown below, ΔT in the single phase was less than 0.1K in one half hour.

Ramp Parameters
0 to 4000 A, 20 s up, 2 s flattops, 20 s down, 18 s dwell

The results would probably have been better if the flattop were longer and the dwell shorter. More tests are planned.

Refrigeration Controls. A PDP-11 is being used to monitor the refrigerator and algorithms for the control microprocessor are being developed. At least one loop has been closed by software. This work is continuing at a satisfactory rate.

Warm-Up Time. We have succeeded in warming up the string in less than 24 hours by carefully spoiling the vacuum.

4. Conclusion

Production and installation of magnets and refrigeration systems is proceeding at a rate consistent with operation of the superconducting accelerator in late FY82. Development work on the control and peripheral systems that are not on the critical path for the accelerator is proceeding in a very satisfactory manner. Development work will continue in order to optimize each system before it is finally installed.