# Problems at Batavia: Delays for High Energy Physics

The huge new protron synchrotron at the National Accelerator Laboratory (NAL) near Batavia, Illinois, is still not in operation some 5 months past the anticipated 1 July start-up date. The delay is the result of electrical problems caused by water-soaked magnets and of a still undiagnosed obstruction to the proton beam. The unexpected problems with the $250-million accelerator, whose 6-kilometer circumference and 200-billion-electron-volt (Gev) design energy make it the largest and most powerful accelerator yet built, have held up experiments whose results are eagerly awaited by high energy physicists and have spoiled an otherwise remarkable record of achievement in building the facility. Although the extent of the accelerator's problems is not yet clear, the setback has sorely disappointed the hopes of NAL administrators—even though their design philosophy admittedly included taking some calculated risks.

Water where it was not wanted has troubled the accelerator before, filling foundations as they were dug and impeding construction. The water that caused magnet failures, however, came from the humid summer air that circulated through the accelerator tunnel in July and August; the magnets and the tunnel walls were still cold, a consequence of the frozen earth with which the tunnel had been covered the previous winter, and as a result, moisture condensed on the magnets before they could be warmed up—a possibility that the accelerator designers had overlooked. Some of the water penetrated into the magnets through microscopic cracks in their epoxy coating, lowering the insulating ability of the epoxy. As the magnets were put into operation, enough current leaked from the coils and flowed along moist, low resistance paths within the magnets to interfere with their functioning. A few magnets, when they were taken apart and examined, were found to have badly burned sections with pits in the metal cores and coils.

The NAL is now reconditioning those magnets that show evidence of failure. When the magnets were originally manufactured, the epoxy insulating material was applied to parts of the magnets separately. No attempt was made to seal off all the interstices between parts—where moisture later collected and was trapped—after their assembly. Apparently the heating and slight bending that occurred during assembly of the 20-foot magnets were responsible for the cracks in the epoxy, cracks that passed unnoticed during tests prior to installation. In the reconditioning process, epoxy is forced under pressure into the assembled magnet, thus sealing all cracks and, according to NAL officials, effectively waterproofing the magnet. So far, about one-third of the 1000 magnets in the main accelerator have been reconditioned.

The accelerator is running at reduced power, equivalent to 120 Gev, while the remaining magnets are tested. How many magnets must eventually be reconditioned will not be known until the machine is run at full power. Although detecting, removing, and treating the magnets is time consuming, the repairs have not proved expensive—the cost is expected to be less than $1 million, an amount within the contingency allowance for the construction budget. The NAL administrators are hopeful that the problem will not reoccur next summer, both because the accelerator is expected to be in operation, so that the magnets will be too warm for moisture to condense on them, and because temperature and humidity within the tunnel can now be controlled when necessary. Mobile air-conditioning units will blow dry air into the tunnel on humid days.

The second problem that has been troubling NAL physicists is an inability to maintain the beam of protons injected into the main accelerator from the booster stage. The beam decays within about a second, as if it were striking some obstruction in the vacuum chamber through which the beam travels. Some small pieces of metal have in fact been found, apparently fragments from cutting open the vacuum chamber to replace weakened magnets. In an attempt to clear out the chamber, the scientists devised a mechanical sweeper that has been circulated through the machine, removing, in the process, a lot of debris. But NAL physicists are still not sure that they have removed all obstructions from the 6 kilometers of vacuum chamber, or if other causes are responsible for the decay of the beam. Trials are now under way to align the magnets, to stabilize the power supplies that drive the magnets, and to test whether a steady beam can be produced. The NAL staff is hoping that more elaborate means of searching and clearing the machine will not be necessary.

The problems at Batavia are in part the difficulties of any large, highly technical construction project, but they also reflect the philosophy of accelerator design adopted by Robert Wilson, NAL director. Rather than build a conservative machine that would have cost much more, he chose to try to stretch a tight budget by designing close to theoretical limits and eliminating whatever could be considered unnecessary, thus accepting a greater probability of making some mistakes. Air conditioning the tunnel and waterproofing the magnets, for example, were at one time considered and rejected. Similar decisions were made in hundreds of other instances during the construction process, in accord with the concept of following a "tight" design.

Now that at least one decision, concerning magnet design, has turned out to be a time-consuming mistake, the NAL administration is beset by some second thoughts on a few other decisions, although they remain confident that their overall approach is correct. They would now like to have on hand, for example, a few extra of the radiofrequency cavities that are used to accelerate the beam in the booster stage. But there is little doubt that in many ways the design strategy has paid-off—the project will be completed within its budget, the accelerator has the potential of operating at more than twice its initial design energy, and the official completion date, 1 July 1972, is still some months ahead. Nonetheless, NAL administrators will be extremely relieved when the present difficulty in maintaining a beam is resolved. And high energy physicists, who have a number of urgent questions about the nature of matter that they hope the new accelerator will help answer, are eager to start experimenting.

—Allen L. Hammond