search & discovery

Batavia accelerator reaches 200 GeV

Now that the Batavia accelerator has reached its design energy of 200 GeV (on 1 March), physicists can breathe a sigh of relief, although considerable effort remains to be expended before the machine operates at full intensity. Director Robert R. Wilson had hoped to bring the accelerator into operation a year early, in mid-1971 (PHYSICS TODAY, June 1970, page 29) and soon after to raise the energy to 500 GeV at reduced intensity.

But the start-up was beset by many difficulties, most notably from failures in the bending magnets of the main ring and excessive losses in the main-ring circulating beam.

With many of the problems corrected, the National Accelerator Laboratory team was able to achieve 200 GeV with the accelerator operating in the so-called "bimodal condition," that is, running successively for 40 pulses at 30 GeV and one pulse at 200 GeV. This method allows the machine to run without water cooling, thus forestalling difficulties associated with moisture in the magnet insulation.

Despite the unexpected delays, the accelerator did reach 200 GeV four months earlier than its original target date and did not exceed its construction budget of $250 million.

The Batavia group chose to operate at 30 GeV so that the machine could be tuned beyond the 17.4-GeV transition energy (the energy at which the accelerating kick must be reversed in phase) of the main ring. Little additional tuning was needed to carry the beam from 30 to 200 GeV. About 10^{11} protons/pulse were injected into the ring. By holding the injection intensity down to this level, unnecessary radioactive buildup was avoided. Significant beam losses occurred in the cycle prior to reaching 30 GeV, but thereafter the beam was retained quite well. The NAL group believes the losses below 30 GeV were caused by a reduced effective aperture of the vacuum chamber. In these tests a beam intensity of 10^9 protons/pulse was reached. The design intensity is 4×10^{13} protons/pulse.

In the early stages of construction things went very smoothly. Ground was broken for the linac in December 1968,

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Robert R. Wilson, NAL director, celebrates achievement of 200 GeV. The chianti was same brand as that used to salute the first sustained chain reaction in Chicago 30 years ago.

New Mexico site for radio telescope

The National Science Foundation has announced the site for the proposed Very Large Array telescope, preliminary funds for which are included in President Nixon's FY 1973 budget proposal. The telescope would be built on the Plains of San Augustin, near Datil, New Mexico, about 50 miles west of Socorro. It would have from 10 to 100 times the resolution of the next largest instrument, which is at Westerbork in the Netherlands.

The array will cost an estimated $76 million and is expected to be finished in the early 1980's. As proposed, it will consist of a Y-shaped railroad track that would fit inside a circle approximately 26 miles in diameter. The legs of the Y will be 120 deg apart, with one leg four to ten degrees away from true north. There will be nine movable dish antennas 82 feet in diameter on each leg.

Resolution. In order to provide the desired resolution—equal to that of the largest ground-based optical telescopes—a radio telescope 23 miles in diameter is needed. Since it is impossible to build a dish of this size, the technique of interferometry will be used. By interconnecting pairs of antennas spread over the area that the large dish would occupy, it is possible to synthesize the information that would be gathered by it. In addition, the rotation of the earth will continually change the projection of the antenna pairs relative to the radio source during the observation period, an effect that can be used as a means of filling in some of the areas of the 26-mile circle where there are no antennas and is called "supersynthesis."

The need for higher resolution has been long-standing in radio-astronomy instrument development. This led, in the 1950's and early 1960's, to the development and use of radio interferometers in Australia, the UK and the US. These instruments were useful, but they produced high sidelobe levels or fan beams that limited resolution. In the mid-1960's supersynthesis was used in the construction of radio telescopes at Cambridge, UK and the National Radio Astronomy Observatory that could chart radio sources with moderate angular resolution. These second-generation instruments were still hampered by a lack of speed and low sensitivity. At this time, the general concept of a very large array of antennas that could provide radio pictures of high resolution, sensitivity and speed began developing.

The design of the VLA is the result of a study completed at the NRAO. A map or image of a radio source made with the VLA will consist of over 10 000 picture elements with a resolution of one second of arc at 2695 MHz and 0.35 seconds of arc at 8085 MHz, two frequencies at which the radio telescope may operate.

The array is of particular interest to researchers because it will maintain a circular beam over most of the observable sky, including the region of the celestial equator, where most other arrays have resolution in only one dimension. Furthermore, the sidelobe levels are low (only about 3%) permitting the study of complex sources, or of sources superimposed on a complex background.

Applications. Radio astronomers hope that the VLA will enable them to unravel some of the puzzling phenomena associated with radio galaxies and quasars. The quality of radio pictures that would be available permits closer study of the physical processes and laws relating to gravity, magnetic fields and plasmas. Extragalactic sources may be used as radio beacons on which cosmological studies could be based.

The VLA should also make it possible to measure the radio emission from novas and stars in the process of formation, providing clues to their structure and evolution.

Use of the array will be open to the scientific community with a minimum of 60% of the observing time allocated to researchers from institutions other than NRAO. A permanent staff of engineers and technicians will remain at the site to operate and maintain the array.

There were many constraints in choosing the site for the array. These include a large flat area, away from the radio interference of populated areas, a site high enough to minimize the effects of atmospheric water vapor and as far south as possible in the US (to achieve maximum sky coverage). The array is expected to go into partial operation in 1976 and to be completed by 1982.

Noise thermometers in millidegree range

John Wheatley is known for his work at very low temperatures. When we recently visited his laboratory deep underground in Urey Hall at the University of California in La Jolla, Wheatley told us that he is excited about a noise thermometer[1] that has its instrumental noise limit in the microdegree region. In work with Richard Webb and Robin Gifford this thermometer has measured 5 millideg K.

The La Jolla noise thermometer resembles a device built by Robert Kamper, James Zimmerman and their collaborators[2] at the National Bureau of Standards in Boulder, Colo. Both groups look at Johnson noise from resistors or resistive circuits and employ a Josephson device as a transducer. The inherent low-temperature limit is similar for both devices.

In the La Jolla device a small piece of Be-Cu (50-microohm resistance) is connected by superconducting wire to a 3-microhenry inductance. That inductance is coupled with a Squid, which is coupled to electronic circuitry. This "black box" enables you to sense minute fractions of a flux quantum. Because of feedback, the output of the device is an exact mirror of what happens at the input; so the output voltage reflects the random current in the input circuit. The source of the random currents is completely analogous to the random motion of an ideal-gas atom; it is Johnson noise.

To measure temperature one uses the relation

$$<\tfrac{1}{2}(Li^2)> = \tfrac{1}{2}(kT)$$

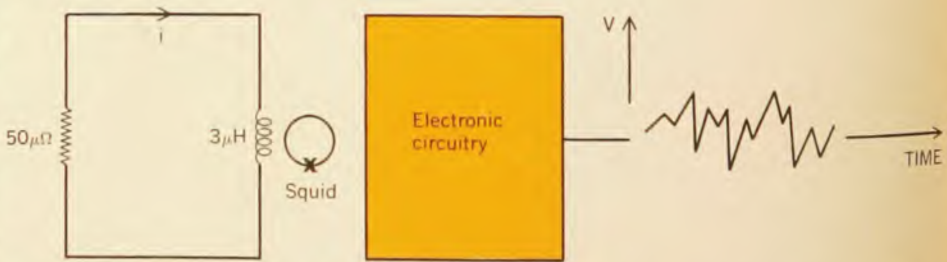
To determine $<i^2>$ you measure the mean square output voltage together with an input-output calibration. The quantity L is more difficult to measure but is not necessary if a one-point calibration is allowed.

Wheatley's group is making different kinds of instruments with the system, and he feels that they will be useful for studying fluctuation phenomena in general, and for applications in chemistry and biology.

The system might turn out to be quite a good thermometer in the intermediate temperature range, say up to 20 K, Wheatley feels, but its greatest importance is at very low temperatures. "It gives us the possibility of measuring temperature where before we didn't really have an easy means to do it." A more fundamental method is to determine temperature using the formula $T \Delta S = \Delta U + W$, an approach used by William Giauque (University of California at Berkeley). Wheatley noted that this kind of thermometry requires tremendously careful, precise measurements. Another technique is nuclear magnetization (nuclear Curie law), but Wheatley believes that it has limited practicality for measuring helium at very low temperatures because of the thermal resistance between the nuclei and whatever you are trying to measure. He says that the noise thermometer may have a more rapid response time and be more reliable than the nuclear Curie law technique.

One point about the device is "kind of cute and interesting," Wheatley noted. The energy in the fluctuations is the same as the energy there would be in one of the degrees of freedom of a single gas atom at millidegree temperature—namely 10^{-25} joule at 10 millideg. Typical time constants are 1 sec, so that energy is exchanged with the lattice at a rate of 10^{-25} watts.

Kamper and his collaborators use as a resistor a small piece of silicon bronze—about 10 microohms. The resistor is connected in parallel with a Josephson junction in a circuit of very low inductance. If you pass a direct current through this shunt it biases the Josephson junction to about 10 picovolts. Then the current through the junction



Noise thermometer used by John Wheatley and his collaborators. The "black box" can sense minute fractions of a flux quantum. The source of the random currents is completely analogous to the random motion of an ideal-gas atom; it is Johnson noise.