haven National Laboratory, Upton, N.Y. 11973, by 31 December 1978. A description of the facility, a statement of policy and outline specifications of the beam lines now being planned are available from the project secretary, C. Albert, NSIS project, Building 911C, Brookhaven National Laboratory.

PLT reaches high temperature

continued from page 17

year—3×10^{13} cm^{-3} sec when the density was 10^{15} cm^{-3} but the ion temperature was only 0.7 keV. These two experiments together suggest that tokamaks can achieve both good confinement and high temperature in more powerful experiments such as the Tokamak Fusion Test Reactor now under construction at Princeton.

This month at the APS Plasma Physics Division meeting in Colorado Springs, Eubank of Princeton is scheduled to report even higher ion temperature—6.5 keV—obtained by raising the neutral-beam power to 2.5 MW. Although previous tokamak experiments at lower temperatures indicate that confinement improves with density, higher neutral-beam-heating powers will be required to extend the high-temperature regime to higher densities and $n\tau_E$-values.

In a summary lecture at the Innsbruck Conference, C. M. Braams, who heads fusion research in the Netherlands, assessed progress in magnetic-confinement experiments. He started his talk with a quote from Lev Artsimovich (who pioneered the tokamak approach) in his summary lecture at the 1961 International Conference on Fusion in Salzburg: "It is now clear to all that our original belief that the doors into the desired region of ultra-high temperatures would open smoothly at the first powerful pressure exerted by the creative energy of physicists, have proved as unfounded as the sinner's hope of entering Paradise without passing through Purgatory. And yet there can be scarcely any doubt that the problem of controlled fusion will eventually be solved. We just do not know how long we shall have to remain in Purgatory. We shall have to leave it with an ideal vacuum technology, with thoroughly elaborated magnetic-field configurations, with accurately prescribed geometry of the lines of force, and with programmed cycles for the electrical circuits, bearing in our hands the high-temperature plasma, stable and quiescent, pure as a concept in theoretical physics when it is still uncontaminated by contact with experimental fact."

Bringing the audience up to date on the passage through Purgatory, Braams noted that "the most striking single result [in magnetic-confinement experiments]" is that "passing the milestone marked 'D–T ignition temperature' was achieved [in a tokamak]. It is true that very energetic ion populations have been produced before; it is also true that we are still some distance away from actual ignition conditions. The reason why, nevertheless, we attach so much weight to the results from the Princeton Large Tokamak is that we now have proof that one confinement method can satisfy both the temperature requirement and the requirements of plasma purity and isolation that are necessary for plasma energy breakeven in a beam-plasma system, or—if one wishes to call it so—for the scientific proof of the feasibility of deuterium–tritium fusion-energy production."

The Princeton Large Torus, when it first started running in November 1975, was briefly called by some the "Princeton Large Turkey," Goldston told us. But the negative connotations of a turkey have surely been overcome in recent operation of the device. The Princeton Large Torus has a 32-kG magnetic field in the toroidal direction. As in a huge air-core transformer, current in the primary induces a toroidal current of about 0.5 MA in the plasma (the secondary). With the ohmic heating power of 600–700 kW, due to this current, PLT has obtained ion and electron temperatures of about 1 keV and 2 keV respectively. A maximum $n\tau_E$-value of about 10^{13}cm^{-3}sec was reached at a density of 1.5×10^{14}cm^{-3}.

Even when no powerful auxiliary heating is introduced, the plasma bombards the wall of the vacuum chamber, and impurities enter the plasma. In early experiments with ohmic heating in PLT, experiments used a tungsten limiter, wrapped around the plasma doughnut like a wedding ring. Goldston explained that tungsten was considered desirable because it has a minimal sputtering coefficient. However, even a very small admixture of partly stripped ions in the plasma turned out to be capable of radiating enough energy to the walls to short circuit the magnetic confinement of the plasma energy.

Neutral beams. Last Fall the experimenters turned on the 40-keV neutral-beam sqources. At first, results were very discouraging, Goldston said. Metallic impurity radiation increased by a factor of three or four, and electron heating was poor: $\Delta T_e = \pm 400$ eV.

Two changes in the apparatus helped alter the picture dramatically. One was to use a water-cooled graphite limiter. Graphite also has a fairly low sputtering coefficient. Furthermore, if one does get carbon atoms in the plasma, they are completely ionized in the core; so the carbon atoms cannot radiate energy from the plasma.

The second change was to use titanium gettering on the vacuum vessel, depositing a fresh layer of titanium on the stainless-steel surface (because it has become contaminated during each 2–5-minute rest period between shots. The rest is needed to cool the coils. The plasma discharge itself lasts for about 1 second.) During the experiment the titanium holds onto the light impurities such as oxygen and also prevents iron from getting into the plasma.

The $13-million Large Coil Test Facility (shown in a scale model) to be built at Oak Ridge will be used to test six 40-ton superconducting magnets, each about 15 feet × 12 feet, roughly half the size of magnets expected to be appropriate for early fusion reactors. The photo shows the 40-foot-high vacuum tank, in which the magnets will be mounted for testing, with its cover removed. In the foreground, a magnet coil is being moved with a lifting device. The facility is to operate in 1981. The design is flexible enough to allow testing later of full-size coils.