CONFERENCE SUMMARY

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In closing this eighth international cyclotron conference, perhaps the most useful contribution would be to comment on the health and vigor of the field from the perspective of the past, present, and future. Seven of us here today--Henry Blosser, David Lind, Dick Lord, Ed Hudson, Reg. Richardson, Ted Welton, and I--were at the first conference at Sea Island, Georgia in 1959. That was 19 years ago, but most of the cyclotrons described at that and the 1962 and 1963 meetings are still in operation. This week we have heard papers on important improvements to many of those cyclotrons. The most notable example was the report on the improved injection system for the Delft cyclotron, which was the very first isochronous cyclotron for protons and the only one operating at the time of the Sea Island meeting. These improvements are a result of both new knowledge and new requirements for research programs. For example, the growing interest in heavy ion acceleration has required new emphasis on center-region design, ion sources, and vacuum systems. The variety of new applied uses for cyclotrons includes such things as trace element analysis, materials studies, and neutron beam production for radiation therapy. All of this activity on older machines proves that the field is very much alive.

The second generation of isochronous cyclotrons, the second wave, so to speak, comprises the machines that came into operation during the past few years, most notably, SIN, TRIUMF, VICKSI, and Indiana. Those cyclotrons are wonderful achievements of our science and technology. Both SIN and TRIUMF are able to run continuously and reliably in the 50-100 μA range; VICKSI and Indiana provide very precise beams for a wide range of particles and energies. All of the new cyclotrons use digital control systems to provide dimensions of operational flexibility and ease of control that were not possible with old-style systems. Transport systems for some of the new facilities are more complex than early cyclotrons, yet are very easy to operate.

Significant extensions and additions are already being planned for the newer facilities. We learned of the new injector for the SIN cyclotron that will bring its output to over one milliampere to exceed that of its most powerful competitor, the LAMPF linac. The TRIUMF group is seriously planning an 8 GeV cyclotron as a "Kaon Factory."

On the heavy-ion front, a number of new large facilities are being built. GANIL, the French project comprising two K = 400 cyclotrons, is expected to begin operation in 1982; the K = 500 superconducting cyclotrons at Michigan State University and Chalk River, Canada are expected to begin operation in 1979 and 1981, respectively.

The electron cyclotron resonance (ECR) ion source for multicharged heavy ions shows promise of producing useful quantities of heavy ions with charge states significantly higher than those available from conventional sources. Dr. Geller reported that his Super-MAFIOS source produces useful output of ions such as Xe^{+26}. A new model, Cryo-MAFIOS, is predicted to produce useful intensities of almost fully stripped ions, and by the use of permanent magnet elements will need only about 50 kw of electrical power--significantly less than the ∿ 1 MW of earlier models. Surely this rapidly developing technology will have an important effect on heavy ion programs at existing machines. ECR sources are being seriously considered for the cyclotrons at Karlsruhe, Louvain, and Berkeley.

All of this continuing development of existing machines and design of new cyclotrons requires scientific and technical competence of the highest order. The superb performance of today's best cyclotrons is no accident, but has come from continued advances in cyclotron theory and design, as well as the development of new beam diagnostic devices and control systems. The most subtle beam dynamics effects, such as the details of coupling of radial and longitudinal motion, are now well understood. There seems to be no doubt that the standards set in the design and operation of the present generation of cyclotrons will be carried forward in the future, leading to machines with very high reliability and operating precision.

Returning to the present, I believe that we are all impressed by the breadth of cyclotron applications reported at this conference. Almost every cyclotron facility has one or more important applications programs. Significant fractions of the operating time of the largest cyclotrons, SIN and TRIUMF, are being devoted to cancer therapy research programs. So this field is also usefully involved in problems of society; but more remains to be done. In connection with the medical therapy programs reported here, there were some challenges give to this community:

- Develop a simple, cheap cyclotron for clinical use in conjunction with computer-based axial tomography scanner systems.
- Develop a cyclotron and beam system optimized for hospital use for neutron production for cancer therapy. A consensus seems to have developed that high energy neutron therapy is very effective.
- Develop a fixed energy simple cyclotron with a proton energy of a few hundred MeV for specialized medical applications in therapy.

The studies reported by the Berkeley group on accelerator concepts for medical applications are illustrative of the type of studies that are needed. I hope that the cyclotron community will continue to respond to these needs as it has in the past.

For me, this has been a very exciting conference. There seems to be no sign of slackening progress. Looking forward to the next meeting, we will hear reports of the first operation of several new cyclotrons and will surely learn of new and ambitious plans for others.

Finally, we should all thank our hosts, the Staff of the Indiana University Cyclotron Facility. The beautifully organized arrangements for the meeting and excellent facilities have made this a very valuable and pleasant week.

(This talk was the last presentation on the Conference program.)

*Oak Ridge National Laboratory, operated by Union Carbide for the U.S. Department of Energy.