Digital Computer Programs at MURA

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I really haven't any business talking at all, since we at MURA are not primarily concerned with cyclotrons but with high energy synchrotrons of the fixed-field type. I was asked to say a few words about some of the IBM-704 computer programs we have developed because, although we have come at it, in a sense, from the backdoor, some of our programs may be applicable to cyclotron problems.

I will perhaps first have to explain that the synchrotrons in which we are interested have a simplifying property which cyclotrons do not have, which we call orbit scaling. By that I mean that we attempt to design accelerators so that orbits at all energies have the same dynamic properties, in the sense that the system of orbits around one particular energy will be simply a photographic enlargement of the system of orbits around some other smaller energy. A necessary and sufficient condition that this be true is that the magnetic field in the median plane be of the form

$$B_z = B_o(r/r_o)^k \, f \, [\theta - \tan \zeta \, \ln (r/r_o)] \quad ,$$

where r and θ are polar coordinates in the median plane k is the mean field index, and f $[\theta]$ is the flutter function which describes the azimuthal variation of the magnetic field. If the field pattern is spiral, we include the second term in the argument of f, where ζ is the spiral angle. Our original computer programs were designed to compute orbits for fields of this type.

Now one can adopt three different philosophies. One can ask to be able to specify first the character of the orbits that one would like and find what magnetic field configuration will give these orbits. Second, one can go to the other extreme, that is, specify the magnets and ask what the nature of the orbits will be. Or one can take an in-between view, specifying the magnetic field that he would like in the median plane and asking, on the one hand, what will the orbits look like and, on the other hand, what sort of magnets will achieve such a field. Our programs follow the latter two procedures. The first, I believe, corresponds to at least one of the programs developed at Oak Ridge.

We have in the first place programs which, given the shape of the magnets and the way in which the poleface windings are arranged, will calculate the resulting magnetic field. We then have programs which will take these calculated fields, or a (scaling) field obtained by other means, and compute orbits.

Secondly, following the third suggestion above, we have a program which allows us to specify the magnetic field that we would like in the median plane. That is, we specify the value of the mean field index k, and we specify the flutter, f, as a Fourier series. The program then computes the orbits in such a field, and it can also be used to compute equipotential surfaces, if one would like to know what the magnets look like. Our programs have various names whose origins are mainly historical and which I won't attempt to justify. This particular program is called the Well-Tempered Five, (WT-V).

Associated with these programs there are a number of auxiliary features that one can use. For example, one can ask the program to find the equilibrium orbit, or to find the small oscillation frequencies around the equilibrium orbit. One can put field imperfections of various kinds into the program to determine the effects of misaligning magnets, and so on. One can ask to have the energy of the particle altered at each revolution so as to correspond to an acceleration process.

More recently we have become interested in magnetic fields which do not have the scaling property. In the first place the actual magnets in a large accelerator would not scale, although we intend to construct them so as to make the magnetic field scale as nearly as possible. In the second place, imperfections and radial straight sections which we would like to put into a spiral sector accelerator introduce non-scaling features. So we have more recently generalized some of our computer programs. We have programs that will compute magnetic fields for non-scaling magnets and orbits in non-scaling accelerators. We also have a program which is called the Ill-Tempered Five (IT-V) which is a generalization of the WT-V, in which the index k as well as the coefficients of the Fourier series for f can be made functions of the radius. This program then is also suitable for making computations of the dynamic properties of orbits in cyclotrons where the orbits necessarily do not scale because this condition is incompatible with the condition of isochronism.

We will be happy to furnish lists and descriptions of our programs, as well as the decks of IBM cards for any of these programs to anyone who requests them. There are reports which describe these programs. Unfortunately, these reports have all been issued as what we call "internal reports," to inform people in MURA about utilizing the programs. They are not mailed out to our regular mailing list, but they are certainly available to anyone who wants them.