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ACCELERATOR DEPARTMENT
Informal Report

PRELIMINARY THOUGHTS ON SURVEYING

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INTERSECTING STORAGE ACCELERATOR NOTES

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The limited allowance for orbit distortions due to quadrupole placement errors dictates a first order survey of the primary monument system. Two methods, if used with proper care and precautions, are capable of approaching the requisite accuracy since they permit measurement of closed triangles:

1. Measurements of distances and angles formed by the intersections of lines between monuments.
2. Conventional triangulation via radial tunnels and appropriate cords.

While the second method noted above may be less time consuming, the large number of radial tunnels required makes it economically less attractive. Method (1) has been used at BNL for the AGS primary survey and it was found possible to close the circle to less than two parts in 10^6 after the third adjustment of the monument positions.^{1,2} Angles were measured with a first order Wild T-3 Theodilite and chord distances were measured by reading offsets from index marks on a constant temperature, constant tensioned, Invar tape. Both tape and theodilite having first been calibrated by the N.B.S. A similar method is proposed now. In order to close the circle on each of the semi-circular ends of the race-track orbit independently, a transverse pipe 20" - 24" in diameter is proposed at each end of the long straight sections. Errors in angular sights due to transverse thermal gradients in air will be minimized by sighting through large cardboard tubes as before. Experiments

at LRL have indicated that chord distances of approximately 150 feet can be resolved to an accuracy of 0.01 inches with a light beam, modulated at microwave frequencies, and reflected from a mirror at the ranging distance back to the instrument. The absolute distance can be measured by phase comparison of the transmitted and reflected beams at two modulation frequencies. This device, developed at the National Physical Laboratory in Great Britain, and now known commercially as a Mekometer would offer several advantages over the cumbersome tape measurements. It will certainly be thoroughly investigated. LRL further reports³ that for accuracies of the order required several precautions must be observed. The speed of light, fundamental to the Mekometer's calibration, changes by 10^{-6} per $^{\circ}\text{C}$, 0.4×10^{-6} per torr change in air pressure at 0.05×10^{-6} per torr change in water vapor pressure. Under field conditions these effects can, at best, be recorded. Sighting through evacuated tubes would obviate these problems at a sacrifice of the instrument's speed of operation. For the moment then it appears prudent to anticipate the chord measurements will be made with constant tension, constant temperature, Invar tapes. Off-sets from two index marks can be read with a total resolution of 0.003 inches independent of the absolute length being measured. The calibration of the index marks will, of course, be dependent upon their separation.

Unless further study should suggest other arrangements it is proposed to use primary monuments spaced approximately 50' apart. This will provide 46 primary monuments for each semi-circular end of the orbit. The longest monument to monument sight during the primary survey will be 100'. This will require a sagitta of only 1.72' and add little, if anything, to the tunnel width for the purposes of satisfying the survey requirements. The possibility of using only one-half the monuments at twice the distance would require a

sagitta of 6.88' for the longest sight and add at least 2' to the requisite tunnel width to satisfy the survey requirements.

As presently visualized each dewar in the regular lattice structure will contain three bending magnets and one gradient magnet. Although the details are not yet in hand it is proposed that the fiducial points for each magnet unit will be brought out external to the dewar flask. A minimum of two fiducial points per magnet unit are required to control translation along three coordinate axis and pitch and yaw angles along the beam path. The azimuthal or "Z" position will probably be preset as the magnet is mounted in its dewar. The vertical position will be initially preset at the same time but final vertical adjustment will be accomplished with an N-3 level equipped with a special two second of arc split level bubble during final ring alignment. The radial position and yaw angle will be fixed by measuring normal offsets to lines of sight established between adjacent monuments. Primarily as an aid in future monitoring, but also as a check on the internal consistency of the initial offset adjustments, a line of sight will be set up between the two outside fiducial marks on each dewar and the short offsets (3.24" maximum) will be measured via a line of sight telescope and a steel rule. The final critical parameter, that of twist or roll about the azimuthal axis will require further study. It appears attractive to control this parameter by letting the magnet hang as a pendulum in the gravity field. It will hang true only if the vertical plane through its support points passes through the center of gravity of the magnet. Since the limit on the angle is only 0.3 to 0.4 milliradians it will require some experimental experience to justify the acceptance of such a solution. One alternate is to bring out a third fiducial point for each magnet so that a level plane can be established

externally. To a large extent the correct placement of magnets will depend on the faithfulness with which the fiducial marks define the significant magnetic parameters of the magnet to which they are attached. This may, in fact, be the largest single source of error.

So far only the normal lattice structure of the machine has been considered. It is assumed, without the benefit of actual numbers, that the placement accuracy required for the quadrupoles in the long straight sections are probably beyond what one can reasonably expect, even from first order survey. Consequently it is assumed that these units will be mounted on remote controlled bases and will be adjusted to their final set positions with the machine running.

References

1. Survey of the 25 BeV Synchrotron at Brookhaven National Laboratory, O.S. Reading (unpublished)
2. Alignment Stability of the 33 BeV Synchrotron at Brookhaven National Laboratory 1959-1963, O.S. Reading, Internal Report OSR-5, July 1964.
3. 200 BeV accelerator Design Study, Vol. 1, Section 3.2.1.

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