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ALIGNMENT TECHNIQUES

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The problem of alignment is primarily one of precision, and I think I can assure you that whatever precision you want in these days of missile guidance, is feasible, if it's worth the cost. The first thing that those responsible for alignment would like to know is the tolerances you want to work to. These might be in two ranges. One would be the widest tolerance that you feel would not handicap the performance of the machine. The other might be the tolerance which you would like to have, if it wasn't unduly expensive, and which would include safety factors, or any parameters you don't know about. So if you give us the tolerances, we could probably figure the cheapest way of meeting the ones you select.

At Brookhaven we have so-called precision optical tooling equipment which will give, without undue work, about one part in 200,000. We also have various length measurement devices which will record to about one part in a million, which are not expensive and which do not take too much time to operate. Tolerances of the order of 0.010 in. in over a hundred feet are not very expensive. The surveying has to be done with care, and also temperatures and temperature gradients of the ambient air must be controlled to get such tolerances. One degree Farenheit is about what we have in the tunnel at BNL, and we've had no trouble meeting the above type of tolerance.

If this type of equipment meets the tolerances, we then must consider whether you want to check the alignment on a machine that is in operation, or during short intervals when the machine shuts down for other repairs. This, in turn, brings in the question of having reference points for the alignment that have a simple relation to the critical part of the machine and are also accessible. Another consideration is whether you need remote control over part of the machine, or remote alignment. This again is a problem in accessibility and mechanics which is much better planned in advance than by emergency measures after you found the radiation too great or something of that sort.

If you have a very long linac, the one part in 200,000 piles up, and you must break it down into shorter sights. Thus, you can carry measurements quite a long distance without getting out of tolerance appreciably. For example, we level the ring, half a mile in circumference, at Brookhaven within about 0.020 in. There we take sights only about 12 ft. long to our bench marks. We read their differences in elevation to the nearest thousandth of an inch with no difficulty. The important thing is to remember to have very good turning points, or stations for your measurements, that are planned in advance to be accessible both in the sense of going from point to point and that are not located in the vacuum tank.

Another consideration is that every sort of material is both a spring and a thermometer. For example, if you have a very long unit, such as a 100 ft. linac tank held together very solidly, any change in temperature is very likely to produce a variation in dimensions, compared with its foundation dimensions. There comes the question of designing flexible supports or flexible connections between the elements so that you're not bothered with warping. An interesting sidelight on this is that we had a hurry-up call to find out what was happening to the foundation of the linac tank at BNL, during some construction. They had assumed that the foundations were being changed quite a bit by the construction. Although some of the foundations did change a bit, not very much movement occurred in the vicinity of the linac. However, at the time, the linac was shut down, with its water cooling turned off. Later, when they got the linac back to the operating temperature, they found that the feet, which had risen off the foundations by 1/16 in. or so, went back down on their pads, back to normal. Hence, there is the question of large temperature ranges. Presumably you're only concerned when you're operating, and it may be that the temperature is then uniform enough so that you wouldn't be bothered. However, the design must take into consideration the fact that you will have certain changes in stresses.

I think that they have a unique problem out at Stanford. They have a long accelerator, and ground that is reported to have moved as much as a half an inch in one year, during a certain period in the past, to say nothing of being located a short distance from the San Andreas fault which moved some 20 or 30 odd feet in 1906, I believe. Therefore, they have quite a problem of alignment, and they have adopted a laser with some special optical targets. At intervals along their line, they propose to sense the variation of these targets with a photomultiplier tube. I understand they have remote control of their adjustments, and they expect to have a trial apparatus in a tunnel about 20 miles away which they will be ready to test in about a month. I think it would be very interesting to investigate whether the Stanford apparatus is any cheaper than the optical instrument type of work.

Discussion (Not recorded - Ed.)