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MINUTES OF MTA PROGRESS MEETING
TUESDAY, OCTOBER 10, 1950

Present:	UCRL:	Alvarez, Baker, Brobeck, Brown, Christy, Cooksey, Dexter, Farly, Hansen, Lofgren, Longacre, Martinelli, Norton, Panofsky, Powell, Reynolds, Serber, Sewell, Street, Twitchell, Van Atta
	CRDC:	Chaffe, Cope, Crandall, Gleason, Hansen, Hildebrand, Kent, Maker
	AEC:	Ball, Fidler

Brobeck said that a definite decision has been made on the requirements for the test cavity to be constructed at Livermore. The drift tube will be designed for a beta of 0.537, which corresponds to 350 Mev and for operation at 20 megacycles. Skin loss will be 6.66 megawatts. The length of the cavity will be 40 feet, which is $1\frac{1}{2}$ times the repeat length.

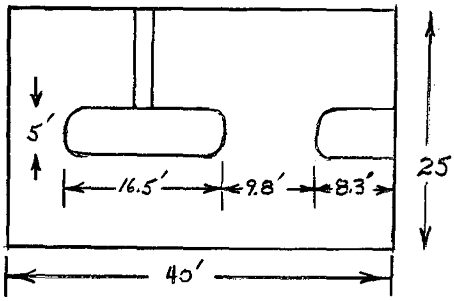

Figure 1

This cavity is being designed to operate at a field gradient corresponding to an energy gain of 1/2 Mev per foot energy gain by deuterons. Panofsky said that model tests will be required to determine the power requirements at 12 megacycles. Panofsky said the reason the cavity specifications have been changed is that the original design of the drydock would permit of a test of the low energy end of Mark II but there was nothing to test the high energy end. The high energy end has different conditions from the low energy end, such as a higher voltage per gap and therefore a longer path for discharges. The change from 12 to 20 megacycles was made for two reasons, first of which was a speeding up of the schedule and secondly, as suggested by Longacre and McMillan, we will by that time have had experience at 12 megacycles and it will be valuable to gain experience also at 20 megacycles. Panofsky said the voltage gain per wavelength, which determines various conditions, will be less. There is a small chance that this 20 mc test cavity will work but that 12 mc Mark II will not. Alvarez suggested that if Mark II is to be operated at 12 mc it would be advisable, in the period between the

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removal of deuteron drift tubes and the installation of proton drift tubes in Mark I, to install within the cavity a single long drift tube in order to have a test load similar to the high energy end of Mark II.

[Ed. Note: There are several reasons, including some not specifically mentioned in the meeting, for building this large test cavity. In approximate order of importance these are:

(1) Test purposes in case Mark I does not work initially. By partitioning the test cavity and installing a properly proportioned drift tube one could closely simulate any desired portion of the Mark I accelerator. This would allow a parallel approach to the solution of operational difficulties on Mark I.

(2) A study of the discharge problems at the high energy end of Mark II.

(3) Study X-ray production.

(4) Gain experience in the use of copper-clad steel in place of a separate copper liner.

(5) Gain experience in operation at 20 mc.

(6) Provide a load for oscillator testing at 12 mc or 20 mc.

(7) Test RF crowbar to spark down a large resonant load.

(8) Determine ultimate field gradients.]

Brobeck said that for convenience the resonant load in Building 52 at Berkeley will henceforth be referred to as B-1 while the resonant load to be built at Livermore will be known as L-1. Following this system of nomenclature subsequent resonant loads built at Berkeley or Livermore will be numbered consecutively at each location and designated as to location by the prefix "B" or "L".

Brobeck suggested the installation of the power equipment for the injector for Mark I be installed on a floor between the end of the tank and the shielding wall. Lofgren, Alvarez, and others stated that they considered it important that this power equipment be located outside of the shielding so as to be accessible during operation of the machine. Lofgren said that it is possible that during initial operation of the machine there would be considerable sparking which would produce X-rays and prevent personnel from working inside the shield. He said if the power equipment were outside of the shield that installation, modification and repair work on the electrical system could go on simultaneously with experiments designed to hold rf inside the tank. Also to be considered is the fact that this equipment must be ordered at such an early date that by the time it is installed it will probably be obsolete. There will thus be reinstallation and modification of parts and this is always harder to do in a cramped area.

Hildebrand said that after an exhaustive study of alternate locations for the power equipment there has been only one location found which appears suitable and this location would be an extension of the basement of the building off of the power line tunnel and would cost an additional $20,000. Considerable discussion ensued during which it developed that Lofgren, Alvarez, Longacre, Panofsky, and others were strongly of the opinion that arrangements need also to be made for convenient and rapid access to the injector itself. The consensus was that several plans should be considered including provision for the injector to be mounted on a truck which could be withdrawn on a track provided with a switch and a siding. This would allow a second injector to be held in readiness on the siding for use as a replacement during the repair of the first injector. CRDC was requested to study the engineering of such an arrangement, together with the provision of the required access to the source through the shielding. Brobeck asked if there were any objection to having CRDC consider the use of chimneys to gain access to the source rather than confining their considerations to designs involving the movement of heavy doors. There was general agreement that such schemes would be satisfactory. Brobeck pointed out that the source being developed here is for ultimate use on Mark II so that additional expense in connection with Mark I to allow flexibility of access to the source and ease of modification would be a legitimate charge against Mark II.

Lofgren pointed out there will ultimately be required a test and development area where work on ion sources may be undertaken and where they may be repaired and tested on a drydock. Reynolds said that such a building cannot be constructed until Mark II funds become available.

Lofgren said there are 3 stages in the development of the ion source. The first stage is one of using a very small duty cycle. This is the stage of development we are in now, where we are using 1 millisecond pulse length once each second. This enables one to determine whether the required intensity can be obtained during the pulse and whether the beam can be focused adequately. He said about the first of December equipment is due which should enable them to enter the second phase in which the actual operating duty cycle of 25 millisecond pulses at the rate of 8 per second can be used. This will undoubtedly result in the overheating and overloading of some of the component parts and will require their redesign. The third phase is in testing the ion source on the accelerator itself. Such operation may uncover difficulties such as back bombardment of the ion source with negative ions and electrons from the accelerator. It is not now possible to predict the extent of this type of difficulty. If it should prove very extensive it could be extremely troublesome.

Baker reported that the B-1 resonant load has been running all morning at 800 KW output from the load itself. This amounts to somewhat greater than 1-megawatt in-put. This has been on pulsed operation with eight 30 ms pulses/sec. It has not been possible to go above 600 KW in the load with CW operation. The limitation on the power is due to sparking in the load and not to any difficulties with the oscillator. The sparking problem seems to have been traced to dust which settles on those parts of the machine having highest field strengths. This has been overcome in part by introducing the nitrogen into the tank through a nozzle located above the high voltage ball so as to allow the dust to be blown off the ball periodically. When first used this scheme allowed the attainment of slightly greater voltages with plain nitrogen in the tank than had previously been obtained using nitrogen plus freon. When loaded to 800 KW the voltage between the ball and the liner is 1.8 megavolts. He said that they have been as high as 18 KV on the plate of the oscillator tube, at which point the efficiency is estimated at better than 80%. Efficiency measurements were made under CW operation with plate voltages as high as 15 KV. Two such measurements gave efficiencies of 75% at 9KV and 78.5% at 15 KV. The efficiencies quoted for pulsed operation at plate voltages above 15 KV are extrapolated from these measurements made under CW operation. On this basis the efficiency of better than 80% at a plate voltage of 18 KV is considered very likely.

Panofsky said several meetings had been held with Professor Lawrence to determine specifications for Mark II to determine the factors affecting the main parameters and to crystallize ideas as to the sort of things they do and do not want. It was decided to consider only two frequencies--namely, 12 megacycles and 20 megacycles. As far as 20 megacycles is concerned, the current density required to get a neutron production of one gram per day is near what appears to be the maximum possible. The current density is also high with regard to present injector performance or from the standpoint of difficulties which may occur with regard to focusing. It has also tentatively been decided that Mark II will be designed for 350-Mev so that in the eventuality that the designed potential gradient of 0.5 megavolts/ft. cannot be maintained it would be possible to lower this gradient, replace the drift tubes, and still have a long enough tank to get particles of at least 250-Mev. One could probably not increase the neutron production of a 20-mc accelerator beyond 1 gm/day. The lower frequency of 12 mc looks more advantageous and it looks desirable to start at 12 megacycles pulsed. In view of the above a design study on Mark II is underway using 12 mc, 350-Mev, and a 700-foot tank. There are still some model tests that need to be performed to get all the data necessary to complete these calculations. They have prepared a preliminary tabulation of the over-all length of each of the drift tubes (which are 29 in number) and the total energy gain that would be obtained if the voltage gradient is 0.5 megavolts per foot as in Mark I. They have also tabulated the magnetic fields and the values of $\int H^2DL$ to continue the focus as at present. $\int H^2DL$, which is needed for focusing, does not increase appreciably with the length of the tank but tapers off due to the E focusing forces; therefore, the power per magnet does not increase very rapidly. The highest individual magnet power requirement is about 180 KW. The power per unit length required decreases appreciably; therefore the power per magnet increases only slightly. The combined power for magnetic focusing will be about 5 megawatts. Longacre has been making calculations to determine the required taper. Here we have insufficient test data. In order to get the exact power estimates it is necessary to evaluate a large number of computations. The principal things which hinder us are the following: If one has a unit cell then to calculate the power the following things are necessary: One needs first to know the purely electrical shunt impedance which Sewell is measuring and for which we now have tables covering this particular range. There is also the transit time factor, which is a measure of the energy actually picked up by the beam for a given applied voltage. For this we also have values. The thing which is needed to be done is to maximize the product of the shunt impedance per unit length and the square of the transit time. This gives the optimum ratio of energy gain to skin power loss. The shunt impedance of successive unit cells drops because as one tries to make the drift tubes longer one effectively adds inductance.

In order to maintain the resonant frequency one would like to reduce the capacity by reducing the diameter, but this one cannot do because of the requirement of the 3-foot inside diameter of the drift tubes and the requirement for gradual curvature of the drift tube end spinnings joining the inside and outside surfaces. Therefore the only way to maintain constant frequency among the successive unit cells is to reduce the inductance by tapering the tank. This reduces the diameter of each succeeding unit cell and consequently there is a smaller flux length and a consequent reduction of the shunt impedance. One might attempt to decrease the capacity by increasing the spacing between drift tubes and thus eliminate the necessity of reducing the diameter of the unit cell. If this is done, however, the transit time factor is worse and the particles do not pick up sufficient energy in crossing the gap. Between these two extremes there is obviously an optimum solution to get the maximum energy per unit cell. Thus, G/L will change from .25 at the injection end to .35 at the target end. The inside and outside diameters of the drift tubes will remain constant. In order to determine the skin losses one maps the magnetic field in the entire region. There is some question as to whether this method gives the right answer or if one must allow for additional power for skin losses beyond those calculated by this method. With the 40-foot linear accelerator, calculations performed by this method were about 30% low in estimating the skin losses. It is believed that the reason for this discrepancy was that insufficient care was taken in lining up the drift tubes so as to obtain an equipotential and the field therefore piled up along the drift tube stems and resulted in a higher skin loss. On a machine the size of Mark I it is of course important to know whether an additional 30% must be allowed for the skin losses. In order to answer this question a series of very careful measurements were made on the 1/10 scale model of Mark I in order to minimize the current flow along the surface of the drift tube stems. It was found that the adjustment is quite critical. The difficulty is that one does not know beforehand where the equipotential lines are located because within the first few unit cells the variation between cells is quite large. They have been determining the Q by measuring the width of the resonance peak and computing the Q based on the theoretical value of the surface conductivity of copper which is the same figure on which the determination of the shunt impedance is based. Thus, if the Q deviates from theoretical the shunt impedance will deviate from theoretical by the same ratio. The integration to determine the field energy is difficult because of the taper in the cavity. The measured Q is 15% below the calculated Q. This is probably due to the fact that the calculations are conservative. The safety factor which now appears proper to apply to correct the measured shunt impedance is about 15% and this may ultimately turn out to be quite close to zero. Sewell said on the question of conductivity of copper they got results on measured Q and calculated Q on an empty cavity which agreed exactly. Panofsky said that this gives us assurance that the only reason for discrepancy between calculated and observed Q on the 40-foot cavity was a matter of geometry. Sewell said it might be well to design the machine so the drift tubes can be moved back and forth slightly by means of their magnetic fields. That is to use the magnetic forces to tilt the drift tubes into positions of minimum skin losses. Brobeck said that using Panofsky's safety factor of 15% gives 113 megawatts peak skin loss in Mark I.

Alvarez said that they now have what appears to be a satisfactory solution to the problem of obtaining satisfactory flat mode in Mark I. He said with the 40-foot Linac the electrical length is 8 wavelengths and that the tuning is extremely critical with respect to motion of the end panels. He said that the resonant frequency will change 5% if the cavity changes dimensions by 3×10^{-5} in all directions. In the 40-foot machine diaphragms were inserted and the resonant frequency of each section of the machine measured independently and adjusted where required by successive approximations. Such a scheme would be formidable for Mark II and it now appears that they have devised a satisfactory and much more simple procedure. This would involve setting up a mode having plurality of nodes and determining the location of the minima. By this means one can calculate the effective diameter of the tank and progress step-wise to a mode involving only one node near the center of the tank. Then by minor adjustments of the tank this node can be positioned in the middle of the tank. This will give a mode sufficiently close to the proper one to allow the application of the perturbation method to determine final trimming required. Alvarez said that in his opinion the simplest way to maintain the tuning of the cavity would be to install mechanisms within each drift tube to allow the flexing of the copper spinning at each end.

Russell H. Ball

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