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MINUTES OF MTA PROGRESS MEETING
TUESDAY, OCTOBER 31, 1950

Present: UCRL: Alvarez, Baker, Brobeck, Brown, Cooksey, Cork, Farly, Gunst, Gordon, Kilpatric, Latimer, Lawrence, Lofgren, Longacre, Martin, McMillan, Norton, Panofsky, Reynolds, Sewell, Street, Thornton, Twitchell, Van Atta

CRDC: Chaffe, Cope, Crandall, Davis, Fossati, Gleason, Hansen, Hildebrand, Maker, Powell, Waithman

AEC: Ball, Fidler

Gordon presented full-scale drawings on drift tubes No. 1 and 4 and discussed some details of their design.

Twitchell said that they have been winding drift tube magnets at the Oscar Krems Company for the past 2 weeks. There are now about a dozen coils in various stages of completion. All of the copper for winding the magnets of drift tubes 5 through 8 is now on hand. Shipment of the copper for the remaining drift tubes is expected in about 2 weeks. The shell for the No. 4 drift tube is also being fabricated by the Oscar Krems Company and is now about 95% complete. The shell is being fabricated from a full-sized sheet of $\frac{1}{4}$-inch copper which is pounded into shape using wooden mallets. The first bore tubes for the large size magnets have been received. The steel for the end plates of the magnet covers are being rolled at Lukens and these are expected to be delivered in about 2 weeks. The drift tube stems are now out for bid. The water lines to be mounted inside of the shells will be fabricated in our own shops. The remainder of the bore tubes are on order and 6 to 8 weeks will be required for their procurement. The copper tubing and calrod heaters for all of the drift tubes are on order.

Panofsky commented on recent considerations regarding the drift tube aperture for Mark II. He said that what one buys with a Mark II machine is an aperture of a certain size through which a certain maximum ion beam may be accelerated. The drift tube apertures in Mark I were set without a very thorough knowledge of all of the variables. Its apertures were chosen so that the particles crossing the gap would pick up a specified fraction (60-70%) of the available voltage across the gap. For the Mark II machine this figure is not too important for the first few gaps since the same final energy can still be obtained by making the machine a few feet longer. If one reduces the fraction of the gap voltage picked up by the particles by increasing the aperture of the first few drift tubes one would require that the length of the 700-foot machine be extended only about 10 feet. This looks as though it might be a worthwhile

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exchange since it would raise the upper limit of beam current which could be injected. Similarly, when the injection energy for Mark II was chosen no one was very sure about the possibility of a high voltage DC injector which would also permit a larger entrance aperture. These two variables of increased aperture of the first drift tubes and increased energy of injection are now being studied theoretically in detail.

Panofsky added that under the conditions of high energy injection with large initial apertures there are new problems introduced. When the aperture is increased greatly a particle traveling down the axis of the accelerator will pick up, say, $\frac{1}{4}$ of the available voltage while a particle which is traveling near the edge of the aperture might pick up as much as 2/3 of the available voltage. The result is that the operating phase angle of the particles will be different for particles near and far from the axis. This, in turn, will lead to very strong cross coupling between radial and longitudinal oscillations. Thus far it is not evident that such coupling would be detrimental but detailed study of this point will be required. Another point which must be considered is that with the present design the gap diameter increases from 4 inches to 36 inches. This means the beam can increase in diameter by a factor of 9 before loss of beam to the drift tube surfaces. If the initial aperture is increased from 4 to 8 inches the allowable factor of blow-up is reduced to about 4. Consequently with the larger injection aperture more focusing power will be required. The incremental magnet power required for the larger aperture will probably not be economically important since at the present time the total magnet power is about 5 megawatts while the total rf power required is about 100 megawatts. In answer to a question from Alvarez, Panofsky said that the magnet focusing power for a 20-megacycle Mark II would be about 9 megawatts.

With regard to the higher injection energy, Panofsky said there appears to be some justification in addition to the theoretical studies for proceeding with an experimental program to investigate the problems of the construction of high energy DC sources. Preliminary specifications for such an ion source have been discussed and the power source required seems to be rather large. Within a few weeks the advantages of increased injection energy and aperture will have been evaluated and it will then be possible to assign a priority to such an experimental program. Panofsky said that it will probably be necessary to engage the services of the UCLA differential analyzer to carry out the computations necessary to evaluate these problems.

Farly said that one of the factors involved in going to higher peak in Mark I is the effect that our type of duty cycle has on the power generating equipment. In the Mark I machine we have a motor generator set which effectively acts as a filter and presents a rather smooth load to the power system. The question naturally arises as to the possibility of eliminating the motor generator sets and going directly to the turbine-alternator. Some inquiries have been made to this end with manufacturing concerns to determine the effects of our duty cycle upon such equipment. The worst feature which our type of load involves is the induction of high currents on the surface of the rotor with consequent overheating of the rotor. In steady operation of the alternator the magnetic field and rotor revolve at the same speed and there is consequently

no current induced in the rotor. Under pulsed operation, however, there is repeated variation in the magnetic flux through the rotor. Conventional turbo-alternators are built with solid steel rotors and the windings are held in place with wedges in such a way that it is difficult to provide low loss paths for the induced currents. The rotors are long and the end windings are capped with special end sections that take the centrifugal forces. These sections must also be connected across to the rotor body to carry the current pulses. The combination of extra losses and the difficulty of removing heat from the long rotor adds to the design problem. Kilgore of Westinghouse feels that an alternator with a rating of 60 megawatts peak, 15 megawatts average could be made using a single phase design which they have developed. Another serious problem is to determine the effect upon a steam plant of frequent and abrupt dropping of a major part of the load. A steam plant for Mark II would be producing about 3/4 of a million pounds of steam per hour and the sudden dropping of the load will present the problem of handling what may become enormous quantities of excess steam. It seems clear that one could not reduce the heat load nor activate large valves in a time comparable to that required for large fluctuations of the load due to arcing or fluctuations in the behavior of the injector. Lawrence said that these problems are beyond the scope of either UCRL or CRDC and are of such importance as to require the consulting services of a competent electrical engineering firm. Norton said that this emphasizes the necessity of getting some of the large equipment suppliers in on this problem in its earliest phases so they can participate in the initial planning. Brobeck said that it was originally hoped that the design of a steam generating plant could be avoided in the construction of Mark II since it was hoped that the necessary electrical power could be obtained from an existing source. If this is to be done it will be necessary to begin discussions very shortly with the power company. Reynolds said that this is one of the major reasons for requiring the choice of the Mark II site to be made at an early date.

Van Atta discussed the radioactive hazards of the Mark II target. Questions have been raised regarding the total amount of activity that will be stored in the target at the time of shutdown and the total amount of heating that will occur after shutdown. Experience from pile operation indicates that at 0.1 sec. after shutdown the fission product activity is down to about 15% of the operating power level. Thus, for the specific example studied in which the operating fission power level was 10 megawatts the fission product activity will be 1.5 megawatts at 0.1 sec. after shutdown and will decrease rapidly thereafter with time. The corresponds to about 250 megacuries at 0.1 sec. assuming the average energy per disintegration is one Mev. The maximum power dissipation within the uranium in the target under operation has been taken at 15 kilowatts per cubic inch. This means that if the cooling were abruptly removed the uranium would melt in about 2.5 seconds if operation of the accelerator were to continue. In the event of pump failure it is estimated that about 6 seconds would be required to heat the one ton of water within the target to the boiling point provided the thermal load of 45 megawatts (beam plus thermal neutron fission) continues uninterrupted. Alvarez said calculations indicate that if as much as one cubic centimeter of water were to escape into the accelerator chamber the pressure would rise to such a degree that the beam would be automatically

disrupted. Crandall pointed out that even if these accidents were to occur they would not result in serious hazard to the community in view of the enclosure of the accelerator and target in such a heavy reinforced concrete shield. Brown said it would be necessary to provide for shutoff of the ventilating system in case of an emergency in order to prevent the discharge of radioactive materials outside of the building. In answer to a question by McMillan, Van Atta said the uranium would require more than an hour to be melted by the fission product activity alone. Van Atta said consideration should be given to a scheme which would flood the target with water in the event of an emergency.

Brobeck said that all of the specifications for the L-1 test cavity have been determined. Hildebrand said that CRDC now has all of the information it requires to obtain bids on the power supply and to obtain steel for the vessel.

Alvarez said that recent estimates of the electron loading of Mark I had varied from a few kilowatts to as much as 9 megawatts. He said recent experiments have reduced this figure to about one megawatt. This recent data also agrees well with X-ray yields from Baker's B-1 test cavity, which has quite different geometry and operates at 10 megacycles. There is now rather good agreement between several independent measurements. He said if the field gradient is reduced by 30% the X-ray production will be decreased by at least a factor of 20. We are thus on a rather steep portion of the curve but apparently we are rather safe. Panofsky said that the X-ray production of Mark I at the design field gradient is not all important since it would be possible to get most of the required data by accelerating protons using $\frac{1}{2}$ of the designed field gradient.

Lofgren said that recent experiments have improved the accuracy of alternate methods of measuring the ion current from the injector. He said that improvements in thermal measurement of the beam have improved its accuracy considerably; for example, one typical measurement of the beam using the biased cup gave 650 ma while the thermal method gave a reading of 670 ma.

He said they have also improved the measurement of the ion current by the induction method and have obtained such typical readings as 750 ma measured by the induction method as against 500 ma measured electrically. This discrepancy is believed to be due primarily to drifting low voltage ions and electrons.

Lofgren said it has been determined that an ion beam can be obtained from the injector when the first two accelerating electrodes are grounded. They are now preparing to study this type of operation. When the first two electrodes are grounded they are at the same potential as the anode of the arc. Under these conditions the arc plasma extends into the region of the first 2 electrodes but stops before it gets to the gap facing the third electrode. Positive ions are then pulled out of the plasma by the third electrode. Using this method, ion currents as high as 1.7 amperes have been obtained using 60 KV on the last electrode. The variation in beam with electrode voltage in this region is about 200 ma per 10 KV. The present power supply is limited to 60 KV under this type of operation but an extrapolation of present results to 80 KV indicates that the total ion current would be about 2.1 amperes.

Lofgren said they have installed a new biased cup which is provided with vanes near the entrance end so as to allow the determination of the variation of beam current with the aperture of the cup.

Lofgren said that measurements of the focus of the beam using the vanes on the shielded cup have shown that under normal operation where the 3 electrodes are used as an accel-decel system 90% of the ions pass through a hole 3 inches in diameter while with the first 2 electrodes grounded as described above about 90% of the beam passes through a hole 3½ inches in diameter. Sewell inquired about the effect of bombardment of the source under operation with the first two electrodes grounded. Lofgren said that the problem of bombardment of the source exists with both types of operation and that he does not yet have sufficient data on hand to evaluate the relative seriousness of this phenomenon between these two types of operation.

Baker said that the electronic crowbar has been perfected so as to operate satisfactorily in a vacuum. It appears to be very reliable. While no exact measurements have been made it appears from tests on the XC equipment that only a few rf cycles are required to short the load. This crowbar worked so well that they decided to measure the X-ray level from XC as a function of the power level and as a result burned out the connection between the liner and electrode in a manner similar to that experienced with the B-1 cavity in Building 52. That is, the soft solder joint failed at current densities of about 100 amperes per inch. About one week will be required to get this equipment back into operation. The new hat structure for the oscillator tests with the B-1 cavity has been installed but a parasitic of 72 megacycles has appeared and some additional work will be required in order to eliminate this.

Russell H. Ball

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