HARTH: The second question concerns both chambers, the 20″ and the 80″. Have you thought of the possibility of filling them with helium, and what would be the economy question of helium consumption? Do you think it is feasible, or advisable, to fill a chamber of this type, a hydrogen chamber, with helium?

RAHM: With the 20″ chamber, and with our present loss rates of 6 l per hour, I think it would be rather difficult to use helium unless you had a helium refrigerator, simply because the latent heat of helium is so much lower than that of hydrogen. But, in principle, helium could be used. We have not considered it as yet.

DERRICK: In your 80″ chamber, does the expansion piston connect to the chamber through a circular pipe or is it an oval pipe which is flared out?

RAHM: The pipe will be 80″ long by about 6″ wide. The pipe will run essentially the full length of the chamber up to a transition region connecting to the 40″ diameter piston.

HIGH FIELD BUBBLE CHAMBER

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The presentation of this contribution is in response to a friendly request to put forward, in a discussion, our ideas on how to approach the technically difficult task of constructing a high field bubble chamber. Therefore the following is meant as a footnote rather than a fully-fledged paper. It comprises the joint efforts of J. Gruber, K. Moustafa, G. Lütjens and myself, and led us, after a careful study of the available data, towards the conclusion that it is today technically feasible to construct a bubble chamber operating in a pulsed field of 100 000 to 300 000 Oe, the latter figure giving approximately the upper limit of the attainable field strength. Since the desirability of such an experimental tool needs no elaboration here, we want merely to outline the design concept at which we arrived and which we intend to test experimentally in the future in order to arrive at a final design. It needs no further stressing, that even after having carefully evaluated the available information on the production and effects of such high fields, some points still remain to be experimentally tested. But the conclusion that such an undertaking appears today feasible, and also achievable within a reasonable time, is justified.

The first problem one encounters immediately is the energy requirement for high fields in large volumes. It implies for a coil of about 20 cm diameter and an appropriate length of 35 to 40 cm—in order to insure satisfactory field homogeneity in the chamber—10^6 to 10^7 joule. This makes an efficient energy storage and transfer mandatory, which can be obtained by discharging condensers through a solenoid in the fashion of a damped oscillation, being short circuited at the first current maximum through a resistance which is large compared with that of the coil. Transfer efficiency is obtained by minimizing the resistance in the initial circuit and the discharge time, which also minimizes the heat dissipation in the coil. This necessitates the use of a single turn solenoid constructed of a beryllium-copper alloy and a voltage of 10 to 25 kV, which in turn yields pulse rise times of the order of 10μs and heat dissipations in the coil of 10 to 100 cal. per pulse. A further necessary condition for achieving efficient energy transfer is to make the inductance in the condenser aggregate small compared with that of the solenoid. This is also possible since one has to switch a large number of condensers parallel, which decreases sufficiently the stray inductance. The single turn coil has the further advantage of being mechanically the most rigid coil structure in view of the electrodynamical forces creating pressures of up to 5000 kp.cm^{-2}. The effect of these will be lessened to a certain degree by the short rise times permitting the utilization of inertial effects. In view of the fact that these forces also prohibit the cutting of radial openings into the coil, and in view of the eddy current problem and that one desires to utilize as much as possible of the cross-sections of the coil for the chamber, the following design may be suggested, if one wants to fill the chamber for instance with propane. Two glass plates are mounted at about 1/3 and 2/3 of the solenoids height, perpendicular to its axis, thus forming the chamber between the latter ones and the inside surface of the solenoid, which is covered by a layer of insulating material. The upper glass plate is fixed and photographs are taken through it. The lower one is designed to operate as a diaphragm in a similar fashion as in W. Powell's 30 inch propane chamber, with the difference that we illuminate only through it. Principally this chamber can be designed as a hydrogen, propane or any other heavy liquid chamber, with the consequence that the magnet coil itself operates at the chamber temperature, entailing the proper thermostatic system. A repetition rate between 10 and 100 sec appears feasible. The compression and decompression being synchronized with the accelerator, while the magnetic field is controlled together with the necessary rapid beam ejection system, the exact field strength at the time of beam arrival will be determined with the aid of a scintillation device placed in front of the chamber and an oscillogram of the field current.

In conclusion it may be remarked that Kapitza was able to construct, already in 1924, a small cloud chamber operating reliably in a pulsed field of 80 000 Oe and in 1926 he achieved 320 000 Oe in a small pulsed coil, with which he carried out his famous experiments.

Thus it appears at least reasonable to test how far these ideas may be realized or how far they belong in the realm of science fiction.

DISCUSSION

LAMBERTSON: How short would the beam pulse have to be, to have reasonable definition of the momentum?

BERGMANN: If the pulse is long compared to a microsecond, then one would use a scintillation chamber with a coarse matrix of two perpendicular crossed layers in front of the chamber in order to obtain some knowledge about the time and the location of the transversal of each individual particle passing the chamber.

LEONTIC: I would like to ask whether you have examined the possibility of using the cross ignitron system so that you recover some of the energy from the coil after pulsing, thus obtaining possibly higher repetition rates?

BERGMANN: We have at the moment not yet gone into the detailed study of whether it is possible to reclaim some of the energy which we initially put into the condensers. One difficulty is, as was pointed out to us by manufacturers, that one can only charge the condensers to about half to two-thirds of the design voltage if one wants to use such large condensers with backswing.

VILAIN: I believe it is doubtful whether you can make this chamber with hydrogen.

BERGMANN: Why?

VILAIN: Because you will never get it tight.

BERGMANN: Tight, in which sense?

VILAIN: Hydrogen!

LITTAUER: I would like to ask whether my impression is correct that the peak total current is of the order of 10^7 A.

BERGMANN: That is correct.

WHITE: At 300 000 G are you getting close to the plastic flow point for the copper coil?

BERGMANN: No, I am still a factor of 2 below, at least.

AMATO: If I understand correctly, your peak current is around millions of amperes, and the rise time is a few microseconds. Where do you pass these millions of amperes?

BERGMANN: At the moment we believe that we will copy, more or less, the design which Colgate has incorporated in his so-called " Green River Bank " because it looks to us as a rather reliable switching circuit. The essence of it is that each condenser which has about 1 000 J has its own ignitron connecting it into the circuit and a second ignitron short-circuiting it. This certainly means a lot more expenditure. The price of the condenser unit will be raised by about a factor of two, but this is already included in the estimated SF 1 per joule installed.

HARTH: I did not quite understand the point about making a rise time of the current as short as possible to use the inertial forces of the ring to prevent the thing from going apart.

BERGMANN: The electro-dynamic forces create a shock wave which—I use a rather qualitative picture—travels through the coil body with the speed of sound. If the pulse is over before this wave travels through the body, then one is utilizing the inertia of the material of the coil.

ADAMS: I would like to ask Shutt a question. Rosenfeld has explained that he is very satisfied with a vertical magnetic field and a horizontal glass in the Berkeley chamber. The Brookhaven one has a vertical glass and the field is round the other way. Now I gather that you are also happy with the latter orientation, and it has been on of the controversies of CERN, started off by Luis Alvarez, that we are building our chamber round the wrong way. I wonder whether Shutt would like to say why he too has chosen the other way round from the Berkeley design?

SHUTT: Our only reason is that we want to prevent dirt from settling on any part of the optical system. At one time we had other reasons, but they have evaporated. In our particular case we are working with a piston, which has piston rings and there may be some abrasion, and you might procude little particles, for instance. We might also expand with hydrogen at the top of the piston, perhaps without a seal, in which case our purification system would have to be very good.

ADAMS: Perhaps I could ask a supplementary question. Do you expect to have any trouble in putting the beams from the AGS into this chamber because of your particular orientation of the magnetic field? For example, will the beam be fanned out in the horizontal plane, which might give you difficulties in viewing the particles in your chamber?

SHUTT: Rau has performed a number of calculations on this problem, and perhaps he would rather like to answer this question.

RAU: Yes. We have looked into the problem somewhat and been in consultation with some of the beam people on AGS, and in view of the fact that our chamber will have an enormous beam window in it, the fanning out in the horizontal plane will not be of any consequence as far as we can see at this moment. There will, however, always be a problem, if you want K particles to stop inside of your chamber—and in this we will require an auxiliary magnet in order to have K particles of the order of magnitude of 500 MeV/c stop in the chamber. However, one can keep rationalizing very long on this problem, one way or another, and I would just like to say one more thing about it. In the AGS machine, the good K beams, I believe, according to Cool and Courant, will come from the internal targets in the machine and, with the general geometrical shape of the big machine and the fact that big bubble chambers will be a very long way away from the machines, low energy K beams, for example, will be much better studied by smaller chambers which can get close to the machine.

ADAMS: There is just one other thing which is an obvious connection of two things that have been brought up at this conference. Has nobody any plans for making cryogenic coils in a hydrogen bubble chamber in order to reduce the power input to the coils—I do not mean the pulsed ones that we have just heard of here but d.c. coils cooled by hydrogen or helium?

BERGMANN: From conversations with Colgate I learned that Harold Furth has some rather undefined plans about trying a so-called force-free coil in a bubble chamber.