NOTES ON VISIT TO U.S.A.

(19-30th June, 1961)

CAMBRIDGE ELECTRON ACCELERATOR PROJECT (CEA)

The machine is in an advanced state of construction. In previous tests the linac has been shown to give a current of about 500 mA, and is now being installed in the injection area. All magnet units are tested and installed and most of the RF cavities are in place. Many units of the vacuum system have been tested, but not installed as the poleface windings are not yet delivered.

The major difficulty is with the central choke, whose coils have broken down at low voltage. A new set will not be ready until October, but one third of the magnet units will be powered with a temporary circuit for injection studies.

Experimental apparatus is already under construction and a good selection delivered. There are 9 quadrupoles with 12" aperture, sundry large bending magnets, and an excellent stock of electronic components for counter experiments. Especially interesting were transistorized plug-in units for the assembly of more complex counting circuits.

An electromagnetic "slow" ejection system will be ready at about the time the machine first comes into operation. It consists of a current strip with about 5 kA, 60 cm long x 15 mm high to be placed on the inner side of the vacuum chamber. This sheet will shift $Q$ from about 6.4 to 6.5 thus causing a build up of betatron oscillations and subsequent traversal of the beam through a suitably placed bending magnet of 1 cm vertical aperture on the outside of the orbit. From computation an efficiency of about 70% is believed possible.

The ejection time will be about 1 ms and the deviation about 22 mrad.

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There is an excellent stock of shielding blocks and some with collimating holes already cast in. Sets of steel or lead plugs can be used to adjust the aperture.

**Experimental Programme.**

About six different groups are preparing for experiments.

1) Large angle $\mu$ pair production without magnetic separation: There will be a large absorption hodoscope array with about 200 counters, but small angles will be inaccessible.

2) Small angle $\mu$ pair production with magnetic separation: A gas Čerenkov counter will be used. The experiment may be changed to stop the $\mu$'s and look at the polarisation.

3) Search for $X^*$ with scintillation chamber.

4) Electron scattering experiment: Planning large spectrometer.

The experimental programme will be refereed by a steering committee of three from Harvard and three from MIT.

5) Bubble Chamber: A circular hydrogen bubble chamber of about 40" diameter and volume 500 litres is under construction. It will have retrospective illumination (coat-hangers), 4 cameras, 70 mm film. The 2 MW magnet will weigh 300 tons and give 16 kG. The window will be supported with helium gas.

The philosophy of the bubble chamber experimental programme seems to be one of look and see with respect to photo production with the $\gamma$-beam. Practically all strange particles are possible.

**Cryogenic Facility.**

The CEA will have the largest liquid helium plant in the USA, with more than 100 litres per hour. It has a 300 HP compressor and will have 3 expansion engines to increase the efficiency. All liquid hydrogen will be
made by direct condensation using the liquid helium, and a recovery system will be used for the helium.

It is claimed that the original handicap of not being allowed to store large quantities of liquid hydrogen in the vicinity of the CEA buildings has been turned to advantage. In the event of superconducting devices becoming important this is obviously true — and the inconvenience of liquid hydrogen transport is absent.

The maximum liquid hydrogen capacity will be about 60 litres/hr.

**Vacuum Pumps.**

All high vacuum pumps on the accelerator system are getter ion (Varian). They have a central positive electrode (+ 4500 V) and two adjacent - 4500 V titanium grids. The whole is immersed in a magnetic field and there are no moving parts.

The expected life is about 20,000 hrs at 10⁻⁶ mmHg which gives an ion current of 1 ma. A current limited power supply gives a maximum of 500 ma. Pumping speed is a few hundred litres/second for the throat diameter of 20 cm.

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**MIT MAGNETIC LABORATORY**

This laboratory provides facilities of high magnetic fields for research in a wide range of sciences.

There are a number of high field magnets using:

a) A 2 MW DC generator set.
b) Submarine batteries.
c) Various pulsed power supplies up to about 100kJoules.

Typical fields are several hundreds of kilogauss over a few cm³.

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Next year a new laboratory with four 2 MW generators will be available (continuous rating) giving up to 32 MW on pulse.

Some 30 samples per week are tested for superconducting properties.

A superconducting solenoid of diameter about 20 cm and about 1 metre long is being planned for 25 kG. This will probably use Nb-Zr which is more satisfactory to handle than Nb3Sn. It can be insulated with e.g. electrodeposited ceramic. The Nb3Sn can be insulated with quartz fibres to permit heat treatment after winding.

For simple low temperature insulation nylon film has been used satisfactorily.

There is no work on cryogenic magnets as they were considered to offer no particular advantages for the type of magnet required.

A design service is available for magnet construction, and a computer programme exists into which the saturation curve of the ion can be fed to predict the operating characteristics.

Pulsed power supplies are obtainable commercially. E.g. a 105 Joule set from Magnion Corp., Albany street, Cambridge, for about 3 x 104 £.

A magnet for more than 100 kG at present under construction has three concentric coils. The inner has a 1½" hole and is 3" long with 400 kW. The second about 1 MW and the outer of maximum diameter 30" about 12 MW.

The Bitter magnets for 2 MW are about 50 cm diameter by about 30 cm long with 5 cm hole.

ARGONNE NATIONAL LABORATORY

Stimulants magnets are under construction and assembly of the machine is just commencing. The linac is well advanced and will be similar to Brookhaven, except for the use of Varian pumps. A 400 l/sec unit costs £ 3375 and £ 955 for the control panel. (A 5-litre unit costs ~ £ 200 and ~ £ 900 for the controls).

PS/2643
There are minor difficulties with the components of the magnet, most of the field measuring equipment is ready. A 7 MW ignitron power supply will be used to give about 700 V.

A beam handling conference of about 1 month is in progress to consider problems applicable to the use of the machine.

A separator model will be ready in October and quadrupoles are being designed. Floating wire techniques for precision measurements somewhat similar to CERN will be used.

A Piccioni ejection system will be used and it is hoped to have 50% efficiency.

It seems technically feasible to inject 100 turns into the machine and a beam current of $10^{13}$ protons per pulse may be obtained. The space charge limit would be about $7 \times 10^{15}$ protons per pulse.

A magnet for 10 MW and some 6 metres in diameter is being planned for use with circular bubble chambers about 1 m diameter and will give 40 kG with pole and 25 kG without. The bubble chambers will be built in associated Universities.

A preliminary report on some work described by Dr. E. Lyman of University of Illinois, Urbana, to study breakdown between electrodes in vacuum to $10^{-9}$ mmHg showed no advantage until now from the improved vacuum.

A bell jar about 10 cm diameter, with Kovar seals was used with various cylindrical electrodes, baked at 450° C and pumped with Vacion. It was thought that $10^{-8}$ was obtained while hot and soon after removing the bake-out furnace the pressure was $10^{-9}$.

Forming of the electrodes was necessary and finally a situation was found where the breakdown was independent of field up to a gap of about 1 mm, and then $V \propto d$ after. The phenomena seemed independent of materials and vacuum.

This work will be written up in late summer and further tests are in progress.

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PS/2643
The work of superconductivity has been considered of such importance that some 30 to 50 professional staff have become connected with it, despite the fact that there will be no budget appropriation until 1963. Most of the work is confined to the Nb$_3$Sn and Nb-Zr alloys. Superconducting magnets up to 50 kG have been made with Nb$_3$Sn, although due to inability to achieve a sample of Nb$_3$Sn as good as at the first trial no claim is made above 25 kG.

A coil for 100 kG for a liquid hydrogen bubble chamber is under design, which would have a stored energy of some 50 MJ.

**Alloys.**

There is great commercial interest in the production of alloys, both Nb$_3$Sn and Nb-Zr are available and many large organizations are active. Both alloys have been worked at Oak Ridge, but Nb$_3$Sn was most in evidence, probably because of the higher field possibilities it offers.

Fabrication is from chemically pure vacuum melted metals with \(< 0.1\%\) gaseous impurities, mixed in a blender, put into a niobium tube, copper jacketed and then processed to wire between 0.3 to 0.5 mm diameter. The copper can be removed by etching, and a heat treatment of 2 hrs at 1000\(^\circ\) C in vacuum is used, otherwise 970\(^\circ\) C for 16 hrs.

The proportions of Nb:Sn are not critical to 5\% neither is the diameter of the original niobium jacket (\(\sim 6\) mm with 1.5 mm wall at Oak Ridge). The tube is first swaged at room temperature to 0.070 inches and then drawn to the final size. About 3 to 5\% reduction per pass through the dies is used and no heat treatment between passes is used nor is desirable. The copper acts as a lubricant.

Commercially available wire is about 0.30 \$/per foot dropping to 0.24 \$/per foot in lots of 150,000 ft (diameter 0.015 inches).
With all the superconducting alloys cold work seems advantageous. In a small coil the wire can be insulated with quartz fibre sleeving, then mechanically formed and then heat treated. After this it may be soldered with indium, but is extremely brittle and the inner core is harder than glass.

There is an established niobium industry in the USA, chiefly in connection with reactors. It is a refractory metal, similar to tantalum and titanium and vacuum melted costs about $50 per lb in ingots.

The alloy of Nb and Zr which is superconducting also to very high fields is much more satisfactory mechanically than Nb₃Sn.

Phase diagrams exist (Hansen - A compilation of Phase Diagrams).

The alloy with 30 % Zr is suitable for high fields and low current, and 50 % Zr for high currents and lower fields.

With \(10^3 A/cm^2\) get 80-90 kG with 30 % alloy at 4.2° K for small wires \(\approx 0.5 \text{ mm}^2\), according to tests on samples.

There is no problem from mechanical forces on the wire in the magnet as it improves for example on stretching.

Niobium wire is readily obtainable and is a useful superconductor.

If no heat treatment is necessary it seems that nylon and some other plastic coating are quite satisfactory at liquid helium temperatures. Until now all tests at Oak Ridge have been at 4.2° K for convenience.

It seems essential to avoid internal joints in wires in coils. A technique of bringing the superconducting wire into cold places outside the main field where a joint in a heat sink can be made, will be used (e.g. in a copper block, or in large amount of indium). The best joints so far have been obtained by welding and then covering with indium solder.

Coils are designed for excitation in sections, both to avoid joints, but more especially for safety should a section become normal. Each section is excited through a series resistance, and a current distribution is therefore
possible. Some 3000 km of wire might be used in a bubble chamber coil, wound on nesting stainless steel cylinders. A rough estimate shows \[ L \sim 10^6 \text{ H} \] hence it might take hours to establish a current in view of \[ \frac{dI}{dt} \].

In a small magnet at present on test the coil was Nb$_3$Sn, insulated with quartz fibre sleeving, having about 100 turns on a core some 3 cm x 4 cm and pole gap about 1 cm, with a yoke of Hypersol (65 % Fe, 35 % Co). With the first winding it gave immediately 50 kG. However within a few hours faults developed and the maximum attainable field dropped to 45 kG, probably due to faults in the core. Finally the field dropped to 27 kG.

Until now it has not been possible to achieve again the properties of the first winding.

A stainless steel former is used and the wire was heat treated after winding. Copper leads about 3 mm diameter were used, along a stainless supporting tube about 80 cm long.

Tests were made in a dewar about 10 cm internal diameter by about 80 cm long in liquid helium with nitrogen precooling. About 7 litres of liquid helium are used for the cooldown and this lasts for about 3 or 4 hours. Some three litres are used at the next fill. If pressed the precooling takes about 2 hrs, otherwise overnight. Total liquid helium consumption is about 50 litres per week.

Power is from car batteries. A distinct click can be heard when the coil goes normal.

Tests will be made with Nb-Zr coil cast in epoxy resin. There is interest in making coils of some alloy silver soldered together.

**Liquid Helium and other Information.**

Members of Linde who were also visiting ORNL stated that there seemed to be no problem in shipping by air freight to Geneva. Cost of liquid helium about \$ 10 per litre. Shipping container is 100 litres and loses 2 %
Can be dropped off a lorry in handling. Uses "SI" insulation, costs 10¢ per cubic ft. (Normal conductivity $\sim 0.35 \times 10^{-6} \text{ W/cm/°K}$. Could achieve $\sim 1 \text{ mW per ft length of a cylinder}$).

They are studying small refrigerator units of 1 watt to go in $\sim \frac{1}{2} \text{ m}^3$ which may cost $\sim 2 \times 10^4$¢.

A.D. Little is working on superconducting transformers of 15 kVA with lead windings.

Other firms have project studies for 1000 kW installations with 0.1% loss. Would thus need $\sim 1 \text{ kW}$ refrigeration at liquid helium temperature.

It is imagined that thermal loss due to leads can be kept down to equivalent of 0.01% loss in transformer.

The cores would be at room or liquid nitrogen temperature.

There are also studies of superconducting transmission lines.

**High Field Test Magnet.**

For testing conductors a 3 MW magnet, to give a field of $\sim 10^5 \text{ G}$ over about 4 cm. diameter cylinder some 6 cm long, has been made.

It has 5000 A in each conductor, about 6 mm x 6 mm with 3 mm x 3 mm hole. Each pancake is wound double with eight in hand and there are about 12 sections making about 100 turns. There are two motor generator sets of 1.75 MW each. Input leads are 2 cm x 2 cm water cooled. An iron pot about 50 cm diameter and 70 cm long forms the yoke. The whole circuit is ready for trial.

**Electron Analogue.**

An electron analogue of a spiral ridge machine about 1 metre external diameter is almost ready for testing.

The coil is of $r = 16$ inches and central field 42 G.
For the final 850 MeV proton machine a central field of 5.5 to 6 kG will be required and \( B = 22 \) kG at the ridges. Average will be 11 kG. Beam current \( \sim 100 \mu A \) continuous and hope to extract half.

It was stated that the main advantage of superconductors for this was that one could so avoid the design study necessary with iron, and be able to use the results of the electron analogue directly.

The transverse field at the conductors was so high that with \( Nb-Zr \) an edge field of some 50 kG was probably all that could be anticipated.

*Homopolar Generators.*

An opportunity arose for a telephone conversation with an engineer from GE.

They have built 4 machines which can each give 45 V at 1.2 MA for 10-15 secs, with flywheels and 1 MW motors at 1800 rpm these could give 6 to 7 MW continuous. They are now building two 3600 rpm machines to give 60 MW pulsed.

The first four machines were used to feed into an inductance which could store some 120 MJ in about 8 seconds. (The air cooled coil was about 10 ft diameter by 6 ft high with hole in centre of a few feet diameter and in which the field rose to 35 or 40 kG. Repetition rate once per 30 minutes).

This energy could then be dissipated in a 20 kV arc in 20 ms in a wind tunnel device.

For this duty the machines are safer than commutator types. GE who have the contract for the MIT magnetic laboratory power supply suggested them for that project also, but MIT wanted more than the 90 V obtainable from two. The whole contract is worth about 1.25 M $ and the unicyclic machines would have saved 10 to 15%.

Allis Chalmers have built a machine for AEC at Livermore which is 1.5 to 2 MW. It also uses NaK but GE thinks their own better with respect to NaK seals and current leads.

\( \text{PS/2643} \)
If there was a demand, smaller ones might be built. For those already designed there could be a 12-month delivery. If a design study was necessary, then 18 to 24 months.

The 1800 rpm machines have run in the factory for one year and are at present being installed at the Talahoma Air Force Research Centre. They have an Allis Chalmers machine already.

GE hopes there may be an application for these machines in the electrochemical industry and would be willing to receive any visitors to discuss the machines.

BELL LABORATORIES

There is fundamental research to investigate the properties of the alloys Mo-Re, Nb₃Sn and Nb-2r.

It appears that dislocations play a very important role in the superconductivity. Especially as increased cold work improves the properties.

For a "soft" superconductor Imax \( \propto d \) whereas with the "hard" Imax \( \propto d^2 \), which is consistent with a volume distribution of the dislocations.

The cold work does not change appreciably \( H_c \) at a particular temperature, but it does change greatly the current carrying capacity.

\[ \log I \]

\[ \text{much cold work} \]

\[ \text{annealed} \]
Three alloys were discussed:

Mo-Re may be of interest for very low $H_c$, but will always be expensive because of the rhenium. The wire costs 700-800 $ per lb. A sample bobbin with 30,000 turns about 5 cm long x 2½ cm diameter exterior was made from gold plated wire for insulation. $L \sim 1$ H.

$\text{Nb}_2\text{Sn}$ is glass hard and brittle. The first work was on small crucible melted alloys. Subsequently the cored niobium tubing has been used (¼" external x 1/8 internal). The composition is not critical to a few percent. The finished wire is 0.015 inches external with a 0.006 inch core. This will carry 24 amperes, i.e. $6 \times 10^3 \text{A/cm}^2$ for the core. At 14·15° C, $H_c = 65 \text{kG}$.

The core is not pure $\text{Nb}_2\text{Sn}$ but contains crystals of $\text{Nb}_2\text{Sn}$ in matrix of Nb and Sn, and the estimated $H_c$ at 0° K would be about 250 to 300 kG for the best samples to-date. According to a preliminary NES report a stretch of $10^5$ lb in ² for the overall wire does no harm, but it is not clear if enough sensitivity was available in the test to be sure of the superconducting state.

In manufacture tin and niobium powders have been mixed by hand and packed into the tube with a rod, as well as being inserted after the mixed powder has been made into pellets in a machine. Electron melted metals have been used. Purity of the tin has been 99.999 and the niobium 99.8, and the effect of impurities is unknown. The melting point of $\text{Nb}_2\text{Sn}$ is about 2400° C. It was stated that the best annealing temperature is 1000° C for at least 1 hour and preferably 16 hours, but these variables are still being studied. Boxes containing sample alloys with serial numbers above 300 were noted.

No experience with quartz sleeving exists, and the insulation has been obtained by nickel plating.

$\text{Nb-Zr}$ seems very interesting, no samples were seen, but data was available. The 33 % Zr alloy can withstand a current density of $10^4 \text{A/cm}^2$ at 80 kG at 4.2° K. The knee may be about 100 kG and the knee for the 50 % Zr alloy may be a few percent higher, but the current is down. Thus the alloys in the range of 25 to 35 % of Zr appear most interesting unless the highest field is needed.

PS/2643
The alloy can be joined by spot welding, it was claimed that the joint would be superconducting, but in the course of discussion it did not appear as if a joint had been used in a coil.

**Cryogenic Arrangement.**

A very simple cryostat was used for testing the samples. It consisted of a dewar flask from Hoffman Laboratories, Newark N.Y., of about 8 cm bore.

At liquid helium temperatures 26 B & S copper wire will carry 30 A, at liquid nitrogen about 20 B & S the same. The helium gas passed out through a spiral of the leads to make a simple heat exchanger. Stainless steel tubes of about 0.010" wall thickness were used for supports. Quadrupole coated Formvar wire was used for leads. GE adhesive 7031 works at liquid helium temperatures.

For the particular cryostat 4 litres of helium would cool down and provide cooling for 8 to 10 hrs (2 litres wasted initially).

A simple pump system was used for leaving the temperature below the equilibrium value for atmospheric pressure, both for helium and hydrogen. A small room in the main building was used, with the only precaution that during transfer of hydrogen the lights were turned off.

**Test Magnet.**

A Bitter type magnet from A.D. Little was used with 1.5 MW and gave about 68 kG over a volume of about 1 inch $^3$. No trouble had been experienced in 18 months of operation.

**Miscellaneous.**

For indium soldering a small ultrasonic soldering apparatus was considered essential for Nb-Sn and Nb-Zr. For the latter also spot welding was adequate.

A review article by J.E. Kunzler will be available in 1 month.

Some 10 people are engaged in the work, including the metallurgy.
The AGS is operating well, mostly with a repetition rate of 2.4 secs at 30 GeV and with a beam about $1.1 \times 10^{11}$ protons per pulse. Improvements to the ion source, and a prebuncher are expected to bring a significant increase shortly.

There is a full experimental programme, mostly involving total cross section measurements, and deuterons and tritons. A run on 3 GeV/c $\bar{p}$ is scheduled for September, as well as a neutrino experiment with a spark chamber.

**Separators.**

The two circular tanks are being operated with glass electrodes at about 115°C.

The maximum potential difference achieved has been 540 kV without field, 500 kV for several days and 460 kV with magnetic field, all on a 5 cm electrode spacing. The separator runs steadily at 460 kV with a field and $6 - 8 \times 10^{-4}$ mmHg of $N_2$.

Individual glass plates are 3 feet long x 12" wide of 1" plate, with 5 sections. The potential difference to ground is not symmetrical, -270 and +190. At 80°C spurious sparks set in on the edges.

Sorensen supplies of + and -300 kV are used. These tanks will be used in a double image antiproton beam. The image lines are expected to be about 0.1" wide and the unwanted pions will be stopped in heavy metal. The flux should be 12 $\bar{p}$ per $10^{10}$ protons with the machine. Momentum acceptance will be to $\pm 1\frac{1}{2}$%, emission angle 9° and solid angle acceptance $50 \times 10^{-6}$ ster. The maximum useful momentum for $\bar{p}$ should be 3.5 GeV/c and for K, 2.5 GeV/c.

A positive SANS set has just arrived and has not yet been tested. The only safety resistor available at present is 3.5 MΩ, but a 15 MΩ should arrive soon.

Two High Voltage Engineering 600 kV, 3 ma insulating core transformer supplies have been ordered at $\frac{1}{2}$ 40,000 each, regulated to 0.1%. They are in tanks about 7' high and 44" diameter.
Also two Radiation Dynamics sets of 600 kV, 8 ma costing about £68,000 each.

A 25 ms recovery time has been specified.

The first larger separator tank body has been delivered and is being assembled, with a stainless steel electrode first. The stand off insulators have been tested to 480 kV.

The feed through bushings have once given 480 kV at $5 \times 10^{-5}$ mmHg but it is felt that they were too short. A new one, 55 cm long in the vacuum side has just been installed in the test tank and will be tried shortly. A perspex prototype would only reach 200 kV, but there have been vacuum troubles.

For the total order of tanks there are 7 with 10 service sections.

1000 GeV Machine.

J. Blowett has a design study for 400, 700 and 1000 GeV machines. For optimum conditions of tolerances $B/\bar{B}$ is 6.8 $\%$/cm independent of $R$.

Length of straight section is $L = 0.47 \sqrt{R}$, semi aperture 0.45 cm. Assumed an alignment to 0.1 mm and 0.05 $\%$ in $B$. A model study on a magnet has been started. Approximate figures:

<table>
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<th>400</th>
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<th>1000 GeV</th>
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<td>Total steel weight</td>
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<td>9000</td>
<td>13000 tons</td>
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<tr>
<td>Total copper weight</td>
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<tr>
<td>Radius of curvature</td>
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</table>

Aperture $3 \times 5$ cm.

It should be possible to reach $10^{13}$ protons per pulse using linac injector (of 7 GeV for the 1000 GeV machine).

As soon as the report is released a copy will be sent, but first impressions are that the overall cost of the machines would be less than from a simple scaling of the PS.

PS/2643
Superconductivity.

A study to assess the value of starting work on superconductivity is in progress. C. Lasky has just returned from a visit to Livermore and Oregon and Boulder.

At the Wah Chang metallurgical company there has been commercial scale production of Nb-Zr alloy with 250 lb ingots.

The alloy is swaged to a 1" diameter bar at $800^\circ$ C, then machined to $\frac{3}{4}$ diameter to provide a smooth surface and then drawn to 0.100" diameter. It is hard and abrasive, but can be rolled easily. This company does not draw it finer - but is convinced of the feasibility provided some lubricating technique is used.

Atomics International have used metal of origin from Wah Chang.

The 33 $\%$ alloy costs about 196 $\$/ per lb for a guaranteed cold reduction of 65 $\%$.

The Nb is vacuum processed. Zr can be obtained either as electron beam melted (300 parts of gaseous impurities for $10^6$) or as crystal bar quality (50 parts of gaseous impurities for $10^6$).

The same firm has also made Nb$_2$Sn and supplied 200 ft of 0.060" wire to Berkeley, who continued the drawing and obtained results similar to Bell. However there has been great difficulty in winding a solenoid due to the wire breaking.

Berkeley and NBS have not as sensitive testing equipment as Bell for measurements ($10^{-4}$ v instead of $10^{-3}$ v).

They have found that the current limit may be improved over that of Bell by changing the method of making joints. The Nb is etched in a mixture of 1 part HF, 2 parts HNO$_3$ and 2 parts of H$_2$SO$_4$ by volume, washed in cold water and immediately dipped in molten zinc. From then on soft solder may be used, and contact lengths of up to 3/8" are used. The Bell joints could carry only 40 A whereas by this method >100 A may be achieved.
Pulsed fields are used for testing, and the test current applied for about 1 ms. The results duplicate these in DC conditions if the rise time of the magnetic field is greater than 10 ms. However, according to results from Van der Bilt University, pulsed fields cause a steady deterioration of the superconducting properties.

Livermore is still very active with cryogenic coils. A unit to give 100 kG over a working volume 8" diameter x 16" long is ready for cold tests, and should be lowered within 3 months. It is wound from sodium filled rectangular stainless steel tubing.

At the NBS a cryogenic magnet for 100 kG is being wound from high purity aluminium tape (99.9985 %) insulated with kraft paper.

There is sufficient refrigeration for 4 kW available. At Livermore the coil will work 6 secs per hour.

C.A. RAMM.

Distribution: (open)

NPA Staff.

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