

MASS SPECTROMETER STUDIES OF ION SOURCES FOR ONE
SHOT ACCELERATOR TUBE

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MASS SPECTROMETER STUDIES OF ION SOURCES
FOR ONE SHOT ACCELERATOR TUBE

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XR-1 Project
Radiation Laboratory, University of California
Berkeley, California

December 12, 1951

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Mass Spectrometer Studies of Ion Sources
for One Shot Accelerator Tube

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XR-1
December 12, 1951
Berkeley, California

I. DESCRIPTION OF SPECTROGRAPH

A simple mass spectrometer using 60° focusing was set up to study the e/m of the ions produced by various types of sources. A schematic diagram of the apparatus is shown in Fig. 1, which is to a large extent self-explanatory. The isolation transformer was simply a piece of RG 8/U cable about 3 feet long and was used in order to operate the source at high accelerating voltage allowing the collector to be at essentially ground potential. The collimating slits were 0.05 cm wide and were spaced 4 cm apart. The coarse slit immediately preceding the collector cup was 0.5 cm wide. The electrometer was the integrating type which indicated the potential due to the charge collected on a known capacitance. The vacuum tube voltmeter indicated the potential of the 9.5 MFD capacitor due to the total charge reaching the slit system. It thus served as a monitor of the source output for each firing. The neon lamp was a protection for the condenser against breakdown discharges of the tube.

The capacitance of the condenser C_f is not critical. Values from 0.05 to 0.15 mfd can be used. The voltage to which this capacitor was charged depends upon the type of source used and varied from 5 to 12 kv.

The magnetic field between the pole pieces was established by passing rectified alternating current through suitable coils around the magnet yoke adjacent to the pole pieces. The value of the magnetic field was determined by measurements with General Electric gauss meters. A plot of the field vs. exciting current is given in Fig. 2. In order to be quite certain of the trajectories expected to be followed by accelerated protons we made use of the stretched wire technique. To do this, we removed the brass drift tube and placed the wire in such a position that it entered and left the magnetic field in the places formerly occupied by the slit system. With the magnetic field on and suitable tension on the wire, the current in the wire was adjusted to make the wire stay in a smooth curve in the magnetic field. H_p in gauss-cm is then given by $10T/I$, where T is the tension in dynes and I the current in amperes. Values for a typical adjustment of the spectrograph were $T = 10 \text{ g} \times 980 = 9800$ dynes, $I = 5.5$ amps, giving for H_p 1.8×10^6 gauss-cm. The magnet current was 6 amps, making a field of about 1140 gauss. The accuracy of the measurement was probably about ± 10 percent.

II. EXPERIMENTS WITH Tl FILAMENTS

The first sources upon which measurements were made were deuterized Tl filaments .005" thick, .020" wide and about 1/8 inch long, swaged between copper supporting rods 1/8 inch in diameter. These filaments unexpectedly gave copious amounts of ions whose e/m corresponded to protons (mass 1).

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The ions were collected with an accelerating potential of 15 kv and a magnetic field of 1040 gauss. H_p of singularly charged particles is given by:

$$H_p = 1.11 \times 10^{14} \sqrt{m} \sqrt{V}$$

where m is the mass of the particle in grams and V the accelerating potential in volts. For 15 Kev protons H_p is 1.74×10^4 gauss-cm. This value of H_p is sufficiently close to that of the stretched wire measurement to establish that the accelerated particles were protons.

Having established the field and accelerating voltage at which mass 1 was received, we could quite confidently set the conditions under which higher masses should be collected. Leaving all settings constant, the ratios of charge collected by the Faraday cup Q_f to the charge collected on the slit system Q_s were not constant from one firing to another. However, by taking the data of many firings we could get an idea of the relative amounts of masses 1 and 2.

With a typical deuterized Ti filament we obtained the curve of Fig. 3, which shows Q_f/Q_s versus magnet current. Mass 2 ions were barely detectable. They numbered perhaps 1 percent of the mass 1 particles. Masses 6 and 12 were detected in amounts of about 30 percent of the mass 1. These were attributed to doubly and singly charged carbon. Many attempts were made to detect larger relative amounts of mass 2 from various deuterized Ti filaments. The results were always practically the same: The abundance of mass 2 was 1 percent or less than that of mass 1. We suspected that oil from the diffusion pump, rubber gaskets and general contamination were supplying the masses 1, 6 and 12.

Next we replaced the deuterized Ti filament by a plain Ti strip, not deuterized. This filament was heated in vacuum by passing a steady current through it until it was quite well out-gassed. We then attempted to fire this filament in the regular manner. When a typical deuterized filament is fired, there is a visible bluish glow around the filament which seems to be somewhat characteristic of such discharges. These discharges liberate bursts of gas which show on the ionization pressure gauges connected to the tube system. At first the undeuterized filament refused to give the blue discharge and gas bursts, but after many firings and settings of the voltage on the charge storing capacitor C_f the filament began acting as if it were deuterized. The spectrograph showed about the same amount of charge reaching the slits as with a normal filament. Mass 1 was present in about the same abundance as with a deuterized filament and masses 6 and 12 were in evidence. We could detect no mass 2. These experiments indicate that we are troubled by hydrocarbons probably from the oil diffusion pump, even though a liquid N_2 trap is used.

The next experiment was to coat the deuterized filament with a small quantity of deuterio paraffin $(CD_2)_n$. This was done by gently warming the deuterized filament over a Bunsen flame and touching it with a piece of paraffin.

*Several attempts were made to detect masses 3 and 4 from deuterized titanium filaments. There was no indication of a mass 3 peak and the abundance of mass 4 was equal to or less than that of mass 2.

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The filament was then installed in the mass spectrograph where it behaved in a normal manner. We again obtained the usual abundance of mass 1, but the mass 2 abundance was greatly increased as is shown by Fig. 4 which gives Q_2/Q_1 versus magnet current. The abundance of mass 2 was increased perhaps 50 fold over that of a plain deuterized filament. Immediately we wondered if the neutron yield of the accelerator would be increased proportionately. We tried it in an accelerator which was in operation and found that the yield increased only by a factor of 2 or 3 over that of a plain deuterized filament. No satisfactory explanation has yet been advanced for this behavior.

III. EXPERIMENTS WITH GAP TYPE SOURCES

Several types of sources were studied which used a point electrode spaced a few thousandths of an inch from a deuterium containing material on the opposite electrode. We became interested in spark gap sources when we noticed that Ti filaments would continue to fire and emit gas and ions even though they were burned out and were not electrically continuous. This was true of both deuterized Ti filaments and deuterio-wax covered Ti filaments.

The first deliberately made gap source consisted of a 0.010 inch diameter tungsten wire placed opposite a small cavity in a 1/8 inch diameter copper rod into which had been melted a small quantity of deuterio-wax. The abundance curves were similar to those of deuterio-wax covered Ti filaments.

Next, the cavity containing deuterio-wax was replaced by a crystal of lithium deuteride mounted on the end of a copper or tantalum rod as illustrated in Fig. 5A. Again the abundance curves were similar to those of the deuterio-wax covered Ti filaments. In addition to the usual masses 1, 2, 6 and 12, there appeared a peak of mass 7 from the Li which was in abundance about equal to that of mass 2. All these sources were tested in an accelerator tube and gave neutron yields comparable to the yield from deuterio-wax covered Ti filaments.

Although the above described gap sources might emit a satisfactory amount of mass 2 ions they are not desirable for use in the final accelerator tube from the standpoint of stability and the possibility of contaminating the tube. At the present writing, it is thought that one of the hydrogen occluding metals would more nearly fulfill the requirements for the deuterium containing material of the source. Also it is comparatively easy to saturate a small mass of the occluding metal with hydrogen isotopes.

Obviously the next gap type source to try was a tungsten point near a piece of deuterized metal such as zirconium or titanium. A piece of deuterized Zr was mounted on the end of a copper rod and a W point spaced about 0.010 inch from it. Such a source was tried directly in an accelerator tube and gave the usual gas burst. The neutron yield was approximately the same as with a deuterio-waxed Ti filament.

An improved version of the deuterized metal gap source was made by melting a globule of Ti onto a hairpin curve of Ta wire as illustrated in Fig. 5B.

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The assembly was then heated in an atmosphere of deuterium. This source has given the best results of any tried to date, and looks quite good. Its ratio of mass 2 to mass 1 was considerably greater than with previously tested sources as shown by Fig. 6. Also the neutron yield of an accelerator tube was increased by about a factor of 2 over the same apparatus using a deuterio-waxed T1 filament.

Clyde Wiegand

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FIGURE CAPTIONS

Fig. 1: Schematic diagram of mass spectrometer.

Fig. 2: Magnetic field versus magnet current. H was measured by General Electric gauss meters.

Fig. 3: Deuterized Ti filament abundance of mass 1 versus magnet current. The ordinate scale shows the number of micro-micro coulombs collected by the Faraday cup per micro-coulomb collected by the slit system. The accelerating potential was 15 KV.

Fig. 4: Ti filament covered with $(CD_2)_n$ abundance of masses 1 and 2 versus magnet current. The ordinate scale is the same as Fig. 3. Accelerating voltage was 20.3 KV.

Fig. 5: Lithium deuteride crystal and deuterized Ti gap type sources.

Fig. 6: Deuterized Ti gap type source abundance of masses 1 and 2 versus magnet current. The ordinate scale shows the number of micro-micro-coulombs collected by the Faraday cup per micro-coulomb collected by the slit system. The accelerating potential was 10 KV.

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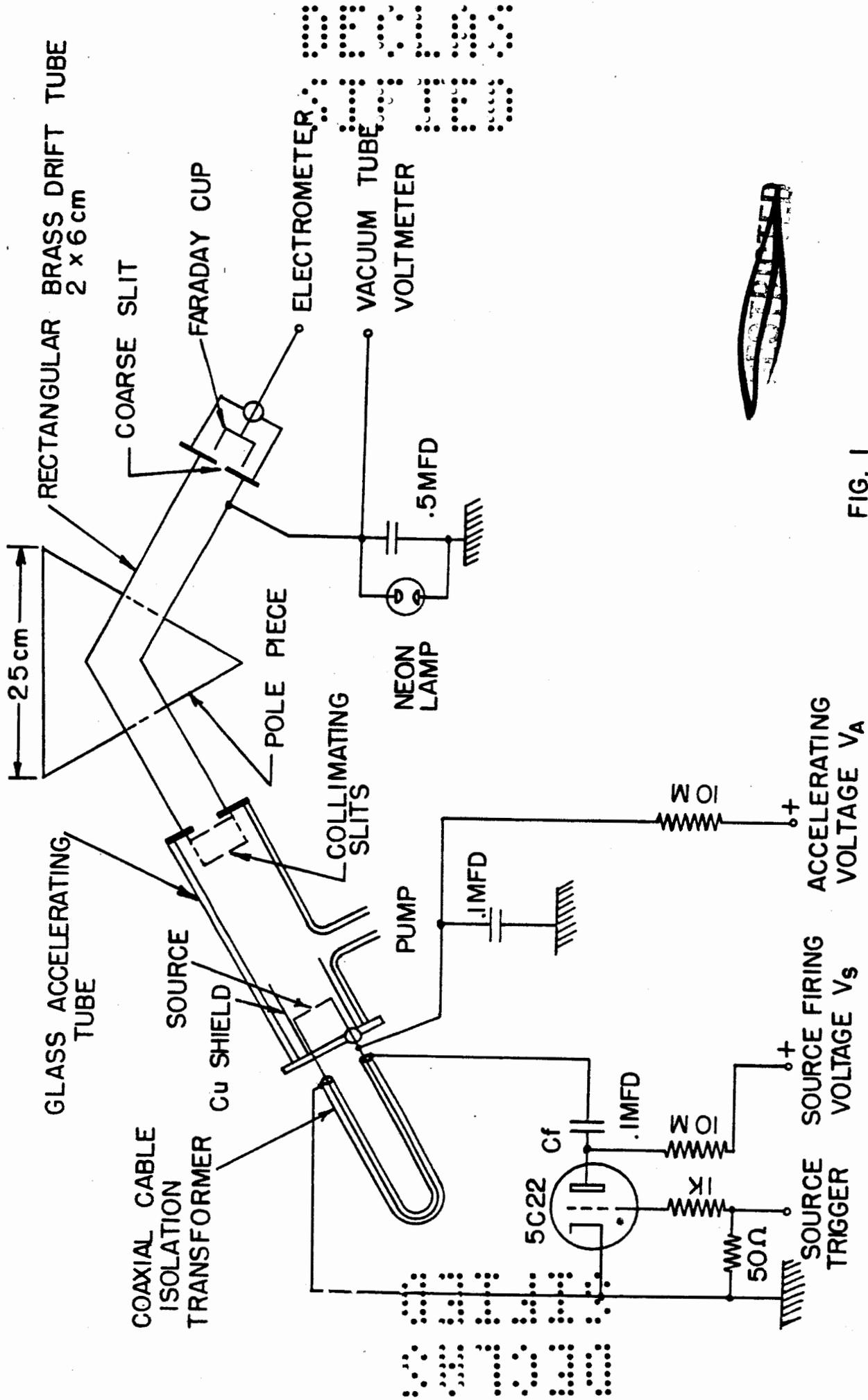


FIG. 1

359T-14G KEUFFEL & ESSER CO.
Millimeters, 5 mm. lines accented, cm. lines heavy.
MADE IN U. S. A.

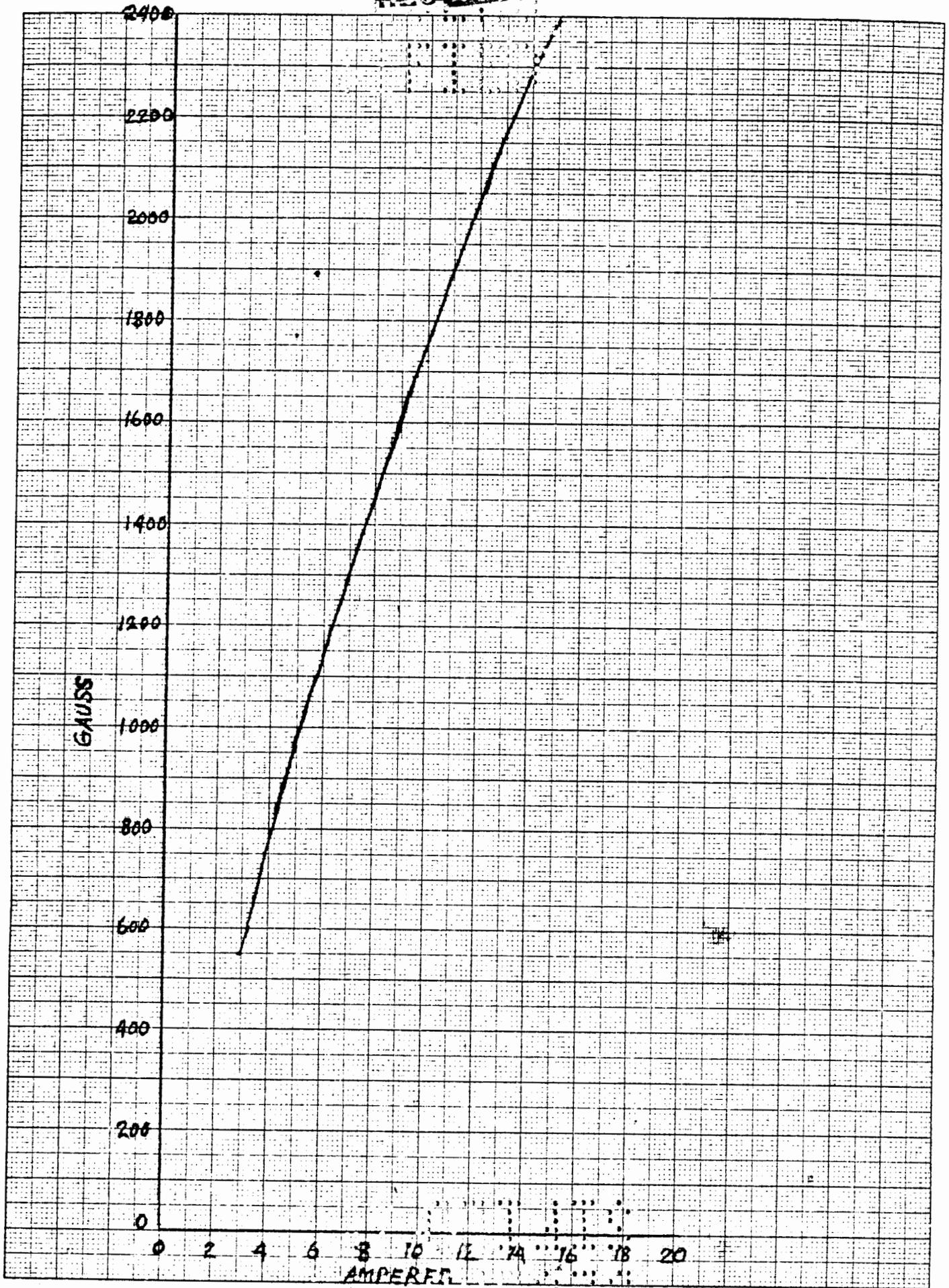
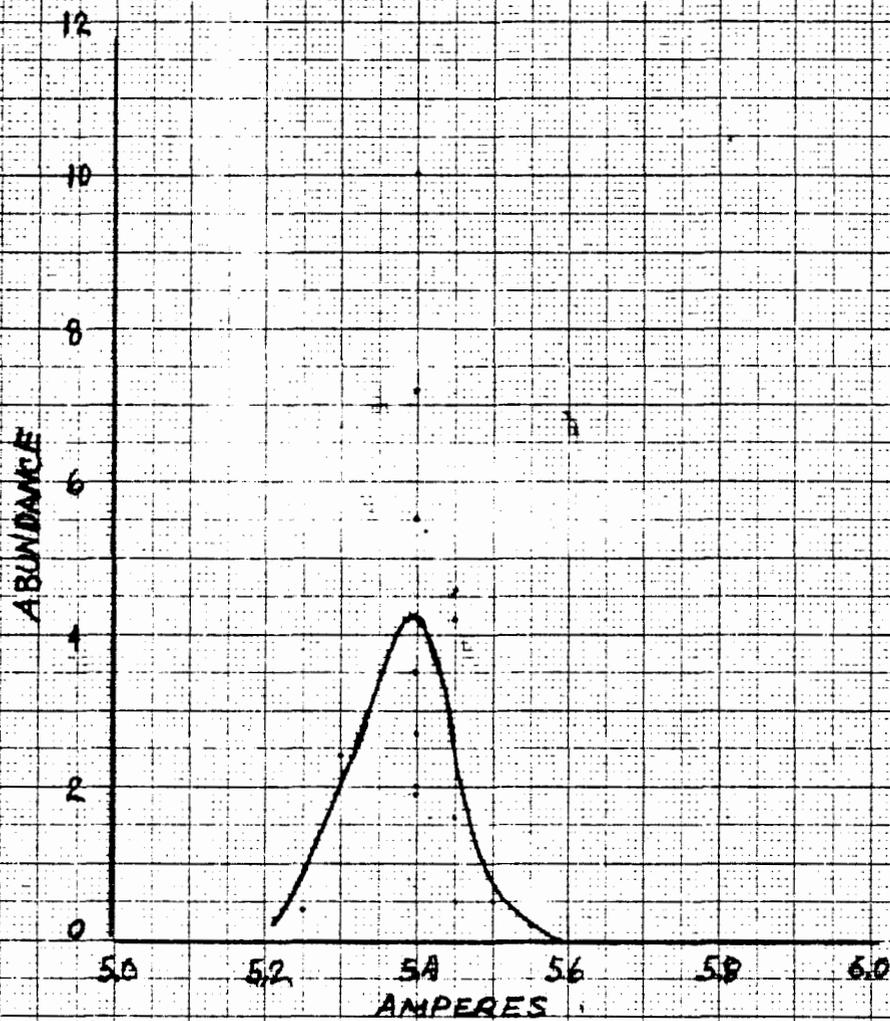


FIG 2

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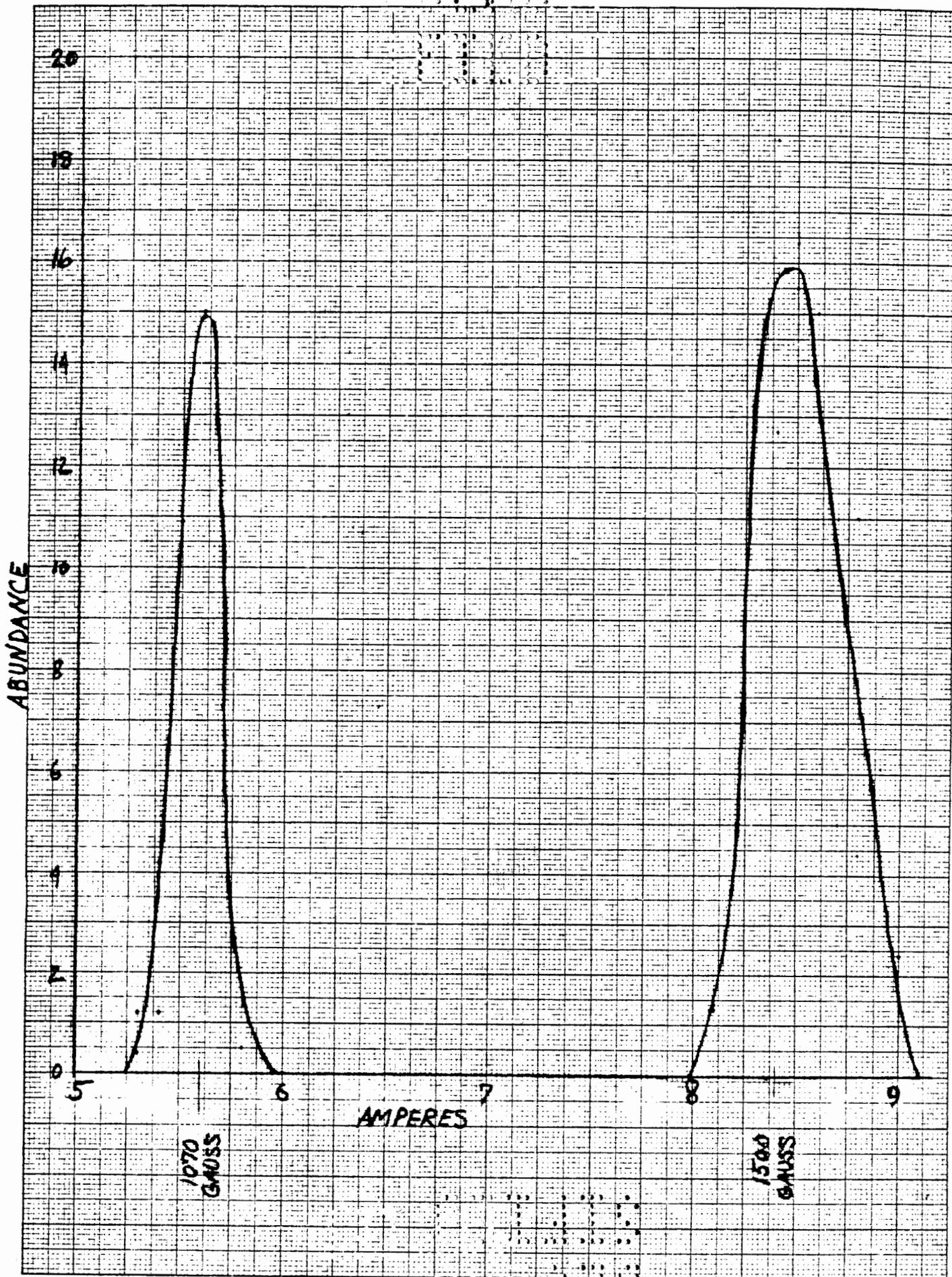
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Millimeters, 5 mm. Lines accented. cm. lines heavy.
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FIG. 3

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359T-14G KEUFFEL & ESSER CO.
Millimeters, 5 mm. lines accented, cm. lines heavy.
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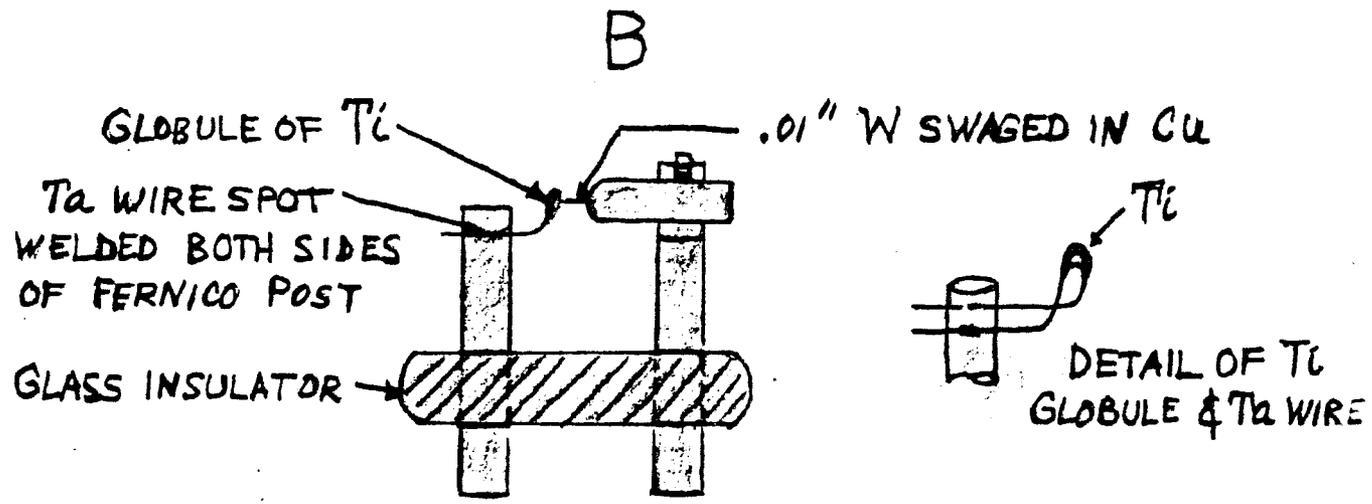
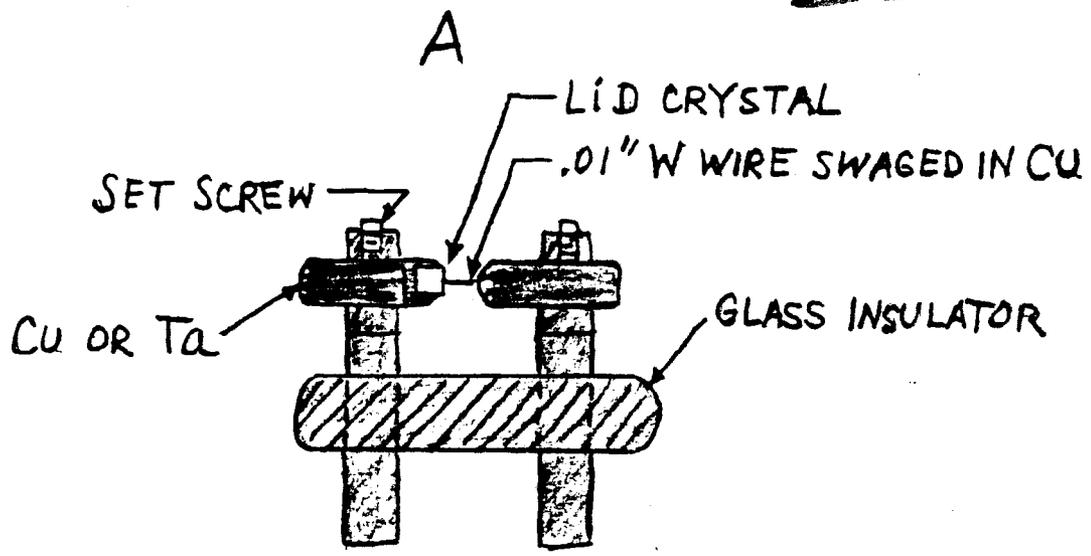


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FIG. 4

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DRAWING APPROXIMATELY 2 X ACTUAL SIZE

Fig. 5

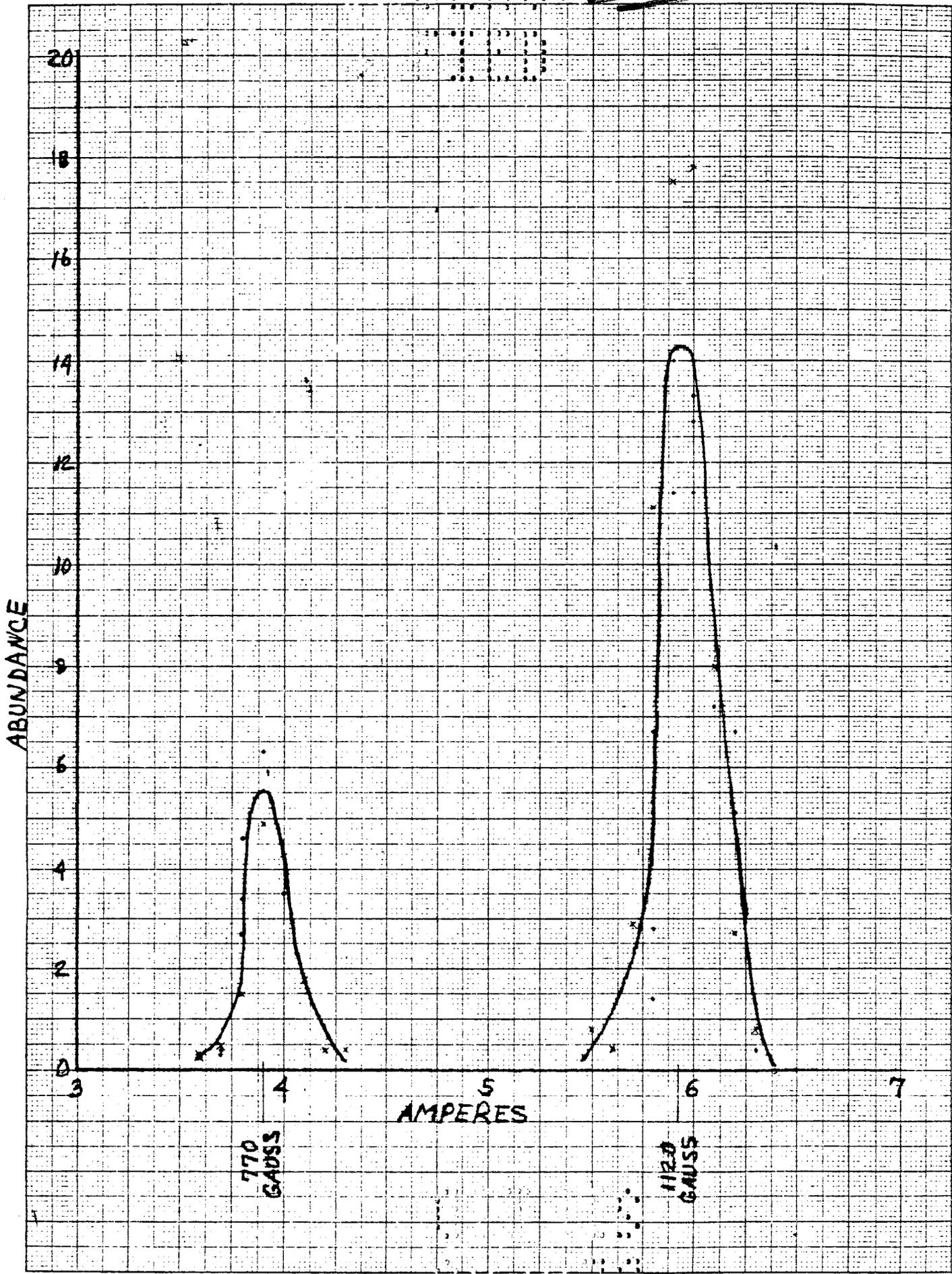
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359T-14G KEUFFEL & ESSER CO.
Millimeter is 5 mm. lines recessed, cm. lines heavy.
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FIG. 6