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NEWARK, NEW JERSEY

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NEWARK PLANT
PIGMENT COLOR RESEARCH REPORT

ELECTRON DIFFRACTION STUDIES

PART I
CONSTRUCTION AND OPERATION OF CAMERA

Period Covered: June 1943 - June 1946.

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NEWARK, PLANT
PIGMENT COLOR RESEARCH REPORT

Final Report

Title: ELECTRON DIFFRACTION STUDIES
PART I
CONSTRUCTION AND COPERATION OF CAMERA

Period Covered: June 1943 - June 1946.

SUBMITTED BY: F. Karush DATE SUBMITTED: Sept. 20, 1946

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ELECTRON DIFFRACTION STUDIES

PART I

CONSTRUCTION AND OPERATION OF CAMERA

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A. INTRODUCTION

In 1942, a report on electron diffraction, entitled "Electron Diffraction in Pigment Research", KN-42-147, was issued. This was a survey report designed to indicate the possible applications of electron diffraction to pigment research. Some time after the preparation of this report, the construction of an electron diffraction camera was undertaken at Newark and was successfully completed. Following this, a considerable amount of experimental work was carried out in the attempt to ascertain the applicability of the diffraction technique to various pigment problems.

In presenting a formal report on the electron diffraction studies, it has seemed preferable to issue it in two parts. The first part, which is contained in this report, is devoted to the construction and operation of the camera. It is intended to serve as a description of both the various parts of the camera, and, to some extent, the problems involved in their construction. In addition, it will, function as a fairly detailed manual for the operation and maintenance of the instrument. The second part, which will be presented in a future report, will describe the detailed applications which have been made to date of the diffraction technique. This will include a discussion of results obtained and, wherever possible, their interpretation in terms of pigment properties.

Literature references relevant to this report can be found in KN-42-147.

B. GENERAL CONSIDERATIONS IN ELECTRON DIFFRACTION

The diffraction of electrons is in many respects similar to the diffraction of X-rays. The scattering of electrons can be described as the interaction between matter and a periodic wave with a definite wavelength. If the scattering material is periodically distributed on an atomic scale then diffraction effects will be observed. Compared to X-rays, the scattering of fast electrons of the same range of wavelength is a much more efficient process, being of the order of a million times greater. This arises from the fact that the scattering of electrons is largely due to the interaction between the intense localized electrostatic fields surrounding the atomic nuclei and the charged beam electrons which are strongly deflected. Because of the efficiency of scattering of electrons by matter, electron diffraction is especially suitable for the study of the structure of thin films and surfaces. This is indicated by the fact that crystalline films of only a few atoms thickness yield strong diffracted rays.

In addition to the elastic scattering of electrons which gives rise to diffraction, there are inelastic collisions, i.e., collisions in which the electron loses part of its energy thru excitation or ionization of the struck atom. These inelastically scattered electrons are responsible for the considerable background which appears in electron diffraction patterns. The fraction of electrons undergoing inelastic collisions is increased by a decrease in the accelerating voltage and by an increase in specimen thickness. For 30,000 volt electrons the effective free path in a solid is a few hundred Angstroms.

Unlike the X-ray diffraction technique, the low penetrating power of electrons requires that electron diffraction experiments be carried out in an evacuated chamber. For the usual size camera, and with accelerating voltages above 10,000 volts, a vacuum of the order of 10^{-4} mm. of Hg. is satisfactory.

As indicated above, associated with the wave character of electrons is a wavelength for the electron. This wavelength λ is related to the velocity of the electron v thru the de Broglie relation $\lambda = h/mv$, where m is the mass and h is Planck's constant. In terms of the accelerating voltage P, which is used to impart velocity to the electron beam, the wavelength is given by

$$\lambda = \sqrt{\frac{150}{P}} \times 10^{-8} cm$$

For the commonly used value of P of 40,000 volts, λ has the value of $.0612 \times 10^{-8}$ cm. or .0612 Angstroms. This should be compared to the wavelength of 1.54 Angstroms frequently employed in X-ray work. It is of particular advantage that in electron diffraction work it is possible to alter the wavelength simply by changing the accelerating voltage. A variation of voltage also means a change in the penetrating power of the electron beam, a fact which can be put to good use in studying thin surface layers.

Since in pigment work, polycrystalline specimens of more or less randomly ordered particles are ordinarily employed, the usual form of the diffraction pattern obtained is a series of concentric circles with an intense central spot and with a background diminishing in intensity away from the center. The width of the diffraction ring or circle depends, among other things, on the width of the electron beam or spot size and is often limited by it. In order to obtain best resolution therefore it is of great importance to reduce the spot size to a minimum.

C. CAMERA CONSTRUCTION

The camera at Newark was built on the basis of blueprints supplied by M. L. Fuller of the Research Division, New Jersey Zinc Co. A schematic diagram of the camera is shown in Fig. 21. It is essentially an evacuated chamber containing a source of electrons, a means for manipulating the specimen and a device for photographically recording the diffraction pattern. The main features of the camera can be seen in the photographs of Figs. 1 and 2. The main section of the camera consists of a brass tube six inches in diameter and two feet in length. Attached to the front end of the tube is the electron gun, most of which is within the metal cage. To the rear end is connected the plate holder housing. The camera is constructed entirely of brass except for platinum jaws on the aperture and parts of the electron gun. "Sylphon" bellows have been employed to permit the transmission of motion into the evacuated chamber.

Two types of electron guns which will be described later have been used. With the original gun it was necessary to employ apertures to limit the spot size. These apertures consist of two pairs of platinum jaws, each pair mounted separately. The jaws form a slit with a width of approximately 0.1 mm. The slits are placed at right angles to each other in such a way that the beam after passing through them has a square cross section with a length of 0.1 mm. on the side. The positions of the slits can be altered from the outside by manipulation of the bellows to which they are attached. The slits are placed close to each other and about three inches from the electron source. Fig. 3 shows a photograph of the apertures, and their position in the camera is indicated by A on Fig. 1.

Since the electron beam as it emerges from the apertures is divergent, it is necessary to focus it in order to obtain a minimum spot size. For this purpose a focusing coil is used, a photograph of which is shown in Fig. 4. It consists simply of a brass core, with a one inch diameter hole, on which has been wound several hundred turns of #18 B & S insulated copper wire. One end of the coil is grounded, while the other is connected to a six volt storage battery through a one ohm rheostat. A current of between 3 and 4 amperes is used to focus the beam. The focusing coil is placed immediately before the specimen carrier and gives a diamond shaped spot on the fluorescent screen which represents a slightly enlarged and distorted image of the crossed slits. The insulated lead-in post for the coil is indicated by B in Fig. 1.

In the original construction of the camera two pairs of deflection plates were placed between the slits and the focusing coil. By the use of a variable potential between the plates of each pair it is possible to deflect the beam both horizontally and vertically, and thus to center it on the screen. With the installation of the new gun these plates have been removed, together with the slits and focusing coil. It appears likely that these parts will not be necessary with the new gun.

The specimen carrier (C) is shown attached to the bottom side of the camera in Fig. 1. Fig. 5 is a photograph of the carrier with three transmission type mounts. By the motion of the two bellows it is possible to effect a vertical movement of the specimens and, independently, a rotation about an horizontal axis perpendicular to the beam direction. The latter motion is required only with reflection type specimens. To süccessively place the three specimens in the path of the beam, a pushing device, indicated by D in Fig. 1, is employed to move the specimen screens in a horizontal plane perpendicular to the electron beam. On the opposite side of the pushing device and in line with it, there is located a window which permits viewing of the specimens under vacuum.

At the rear end of the camera is mounted the plate holder housing indicated by E in Fig. 2. Within this unit is contained the plate and plate holder (Fig. 13) and the mechanism for the motion of the plate holder. The latter is introduced into the camera at F, Fig. 1, and is moved horizontally thru a gear and rack arrangement by means of the bellows at G, Fig. 2. The plate holder carries a 4 x 5 in. plate and is light-tight, so that loading of the diffraction camera does not require darkness. Immediately in front of the plate is a metal disk with a rectangular opening of 1 in. x 5 in. This serves to limit the area of the photographic plate exposed to the diffraction beam at any particular time and thereby makes possible the recording of three patterns on a single plate. The plate to specimen distance is 36.9 cm.

When the plate holder is in its extreme position (left side of housing, Fig. 2) the beam falls upon a fluorescent screen (H, Fig. 2) which renders visible the undeviated beam, and, in many cases, also some of the diffraction rings. Viewing of the screen has to be done in a darkened room. The fluorescent screen is prepared by spraying a dispersion of a fluorescent pigment on to a circular piece of leaded glass. The pigment used, together with directions for its application, is obtainable from RCA, and is the same material as that used in fluorescent screens for the RCA electron mircroscopes.

The instrument panel, which is shown in Fig. 6, carries all the electrical controls except the four additional ones necessitated by the new electron gun. The latter are located just above the top of the plate holder housing. The panel is arranged so that any of the controls can be manipulated while viewing the fluorescent screen.

D. VACUUM SYSTEM

As indicated above, it is necessary to operate the diffraction camera under high vacuum, in the neighborhood of 10^{-4} mm. of Hg. Furthermore, since frequent exposure of the camera to atmospheric pressure is essential, it is desirable to reduce to a minimum the time required to pump down to operating pressure. A satisfactory arrangement which is employed with the diffraction camera is indicated schematically in Fig. 7. The forepump is a "Cenco Megavac" operated at 600 RPM and powered by a 1/2 h.p. motor. It serves both for the initial evacuation of the camera to a pressure at which the diffusion pump can operate, and also as a backing pump. The diffusion pump is a high speed all-metal oil pump sold by Distillation Products Co., (type MC 275). The pump is water-cooled and has a speed of 275 liters/sec. at 10^{-4} mm. It requires a forepressure of 100 microns and uses about 200 grams of "Amoil-S" as the distilling liquid. The pump heater requires about 3 amperes and is operated directly from the 110V line through several ohms of external resistance.

The valve arrangement illustrated in Fig. 7 is designed to permit the diffusion pump to remain in operation while the camera is at atmospheric pressure, and during the pre-pumping period. Valve A is a wide-bore two-way glass stop-cock which connects the fore pump either to the low vacuum side of the diffusion pump or directly to the camera through valve B. Valve C on the high vacuum side of the diffusion pump is used to seal off this pump from the camera. Both valves B and C, 1/2 inch and 1 1/2 inch respectively, are packless radiator valves of the bellows type which have been adapted for vacuum work.

The cycle for evacuation of the camera is as follows: With the camera at atmospheric pressure and the diffusion pump at operating temperature, valve C (already closed) remains closed, while valve A, which has connected the forepump to the diffusion pump, is opened. This isolates the diffusion pump and opens the camera to the forepump after valve B has been opened. When the pressure in the camera has reached a value between .2 and .1 mm. (Hg), valve B is closed, valve A turned to connect the diffusion pump to the forepump and valve C opened. The camera is then evacuated to operating pressure and maintained there while the diffraction experiment is being carried out. Valve B serves to prevent the rubber hose connection between valve A and the camera from being exposed to the high vacuum. However, it does not seem to be essential. Finally, to open the camera to the atmosphere, valve C is closed and air permitted to leak through a small opening until the inside and outside pressures are equal.

Fig. 8 gives a photographic view of the vacuum system showing valves A, B and C and the oil diffusion pump D. The forepump is located at F where it is enclosed in a sound-proof box. The evacuating system is connected to the body of the camera by a pair of two inch brass pipes fitted with "Sylphon" bellows. These permit slight motion of the camera relative to the vacuum system. The time required to pump the camera from atmospheric pressure down to operating pressure ranges from 10 to 15 minutes.

Two types of vacuum gauges are employed for the measurement of the low pressures used in the camera. The thermocouple vacuum gauge measures pressures in the range from 200 microns to about one micron (Hg). It is identified as J in Fig. 1; the associated meters on the instrument panel can be seen in Fig. 6, in which the heater current meter, labeled "T.G. HEATER", is in the lower right hand corner. It is a 0-200 microammeter shunted by a 1/2 ohm resistor so that a reading of 100, which corresponds to a heater current of about 70 milliamperes thru the thermocouple gauge, gives a reading of the thermo-current of 195 microamperes when the pressure is less than 10^{-3} mm. of mercury. This is read in the low resistance (55 ohms) 0-200 microammeter, labeled "VACUUM", shown in the upper left hand corner of Fig. 6.

For the measurement of pressures in the range of 10^{-3} mm. to 10^{-5}mm. (Hg) an ionization gauge is employed. A portion of this gauge can be seen in Fig. 1 at I. The filament current for this gauge is supplied by a six volt storage battery. Fig. 6 shows the associated meters and rheostat. The meter labeled "I.G. FILAMENT" indicates the filament current, usually about 1.6 amperes, which is controlled by the rheostat with the same identification. When the reading on the meter marked "I.G. GRID" is 9 milliamperes, corresponding to an actual grid current of 21 milliamperes because of a 2 ohm shunt resistor across the meter, the pressure in the camera in mm. of mercury is approximately five times the positive ion current in amperes. This is read on the microammeter labeled "I.G. PLATE." Thus a reading of 20 microamperes on this meter corresponds to a pressure of about 1 x 10^{-4} mm. of mercury.

The satisfactory operation of the ionization gauge requires the removal of adsorbed gas after exposure to air. This is carried out by placing the voltage available from the battery charger in series with that from the storage battery and passing a current of 2.5 amperes thru the filament. The DPDT toggle switch at the left of the "I.G. GRID" meter in Fig. 6 serves to make this connection when it is in the upper position. The lower position is used for normal operation of the gauge and for charging of the storage battery. Both the grid current and plate current meters must be shunted during the degassing period. The former meter is shunted when the above toggle switch is in the degassing position and the latter is shunted by the toggle switch at the upper right of the "I.G. PLATE" meter. The circuit diagrams for the thermocouple gauge and the ionization gauge are given in Figs. 9 and 10 respectively.

E. <u>HIGH VOLTAGE SUPPLY</u>

To furnish the constant high D.C. voltage required for the operation of the camera, a used medical X-ray high voltage supply was purchased, together with a constant voltage transformer and a high voltage condenser. A circuit diagram of the high voltage supply is given in Fig. 11 and a photographic view of the high voltage equipment in Fig. 12. The high voltage transformer, the rectifier tube and its filament transformer, and the filament transformer for the electron source are enclosed in a cylindrical metal container (A, Fig. 12) and submerged in oil. The 500 watt "Sola" constant voltage transformer can just be seen at B in Fig. 12. It serves to maintain constant the voltage supplied to the primary of the high voltage transformer and thus stabilizes the accelerating voltage of the camera. The high voltage condenser (C, Fig. 12) has a capacity of .012 microfarads and can withstand 50,000 volts. It is mounted on an insulated base and is grounded thru a 10,000 ohm, 100 watt resistor (D, Fig. 12) to prevent surges.

The primary voltage for the high voltage transformer is supplied from an auto-transformer which is mounted on the panel and is labeled "HIGH VOLTAGE" in Fig. 6. This permits the selection of any accelerating voltage in the range from 0 to 50 kilovolts, although 40 KV is usually employed. For reasons of safety all the high voltage equipment is contained within a metal cage. When the door to this cage is opened an interlock switch shuts off the power, and at the same time a grounding cap grounds the high voltage side of the condenser.

The value of the high voltage can be read directly in kilovolts on the 0-50 microammeter labeled "HIGH VOLTAGE" in Fig. 6. One side of this meter is connected to ground while the other is tied to the high voltage thru a 10^9 ohm, 100 KV resistor. This measurement of the high voltage is not very accurate.

F. THE ELECTRON GUN

In the original construction of the camera, a relatively simple design was employed for the electron source. This consists of a tungsten filament of 6 mil diameter connected to two long insulated nickel rods. Details can be seen in Fig. 14 which shows the old electron gun disassembled. Surrounding these rods, and extending just beyond the filament, is a copper tube on which is mounted a nickel disk containing a rectangular slit. Both the tube and disk are at a potential of 45 votes positive with respect to the filament, thus serving to enhance the electron emission from the filament. The emission current is measured by a microammeter which is contained, together with fuses and a 45 volt battery, in the copper sphere placed at the top of the high voltage condenser. This is visible in Fig. 12, in which the slot to permit reading the microammeter may also be seen.

The gun described above was not wholly satisfactory because it required frequent replacement of the tungsten filament, and also, because of inadequate intensity, particularly at lower voltages. In order to overcome these disadvantages, and especially to diminish the spot size and thus improve the resolution of the camera, a new and more elaborate electron gun was installed. This gun was taken from a "DuMont" type 5JP cathode-ray tube and adapted for use in the camera. This change involved the substitution of a tungsten filament for the oxide-coated cathode originally present, because the latter loses its emitting power after a few exposures to the atmosphere. A photographic view of the gun and associated parts is shown in Fig. 15; some details are partially obscured however by the wide silver band coated on the inside of the glass tube in which the gun is enclosed. The electron beam is focused by the adjustment of the potential on the focusing electrode and the intensity regulated by the voltage on the control electrode. This voltage must always be negative relative to the cathode potential. The direction of the beam, and consequently the position of the spot on the fluorescent screen, can be altered by varying the potentials on the two pairs of deflection plates. These plates permit adjustment in both the horizontal and vertical directions and thus make possible accurate centering of the beam.

The controls for the gun are enclosed in a brass box shown at the right in Fig. 15. This box is maintained at high potential, usually 40KV, and contains the required potentiometers, resistors, condensers and batteries. The manipulation of the potentiometers while viewing the screen is possible by the insulated extensions from the box, as is evident in Fig. 1. The circuit diagram for the gun is shown in Fig. 16 where the portion enclosed by the broken lines corresponds to the equipment contained withint the brass box. The gun is maintained ment contained within the brass box. The gun is maintained at high potential with a maximum drop across it of 2KV. The voltage for the deflection plates is supplied by two 45V batteries thru a pair of dual 1 megohm controls. A toggle switch which can be reached at the back of the high voltage box is provided to avoid continuous drain of current from the batteries. The dual potentiometers are arranged so as to make the voltage drop between the deflection plates of each pair symmetrical with respect to the electron beam and thus to minimize distortion.

To avoid distortion and defocusing of the electron beam and spot, the pyrex tube within which the gun is contained is coated on its inside surface with a wide silver band and three silver rings shown in Fig. 15. Electrical connections to the latter can be made with the rounded brass posts which make contact with the rings thru wire-glass seals. The wide band is at the potential of the accelerating electrode of the gun and makes contact with it inside the tube. It serves to shield the gun, particularly the deflection plates, from the accelerating voltage. The silver rings permit the 40KV accelerating voltage to be applied in steps of 10KV by the use of 200 megohm resistors between them, as shown in the circuit diagram of Fig. 16.

The silver rings and band were coated on the tube by applying with a camel's hair brush to the tube mounted on a lathe, a paste of colloidal silver in turpentine. For this purpose silver paste no. 38 from Hanovia Chemical & Mfg. Co. is used after it has been thinned to brushing consistency with turpentine. After the paste has been applied, the tube is placed in an oven and heated to between 600 and 650°C. This heating removes all organic material and leaves a strongly bonded silver film.

G. LOW VOLTAGE ELECTRON GUN

In the examination of massive specimens where the reflection technique must be employed, difficulty in obtaining diffraction patterns is often encountered due to the development of an electrostatic charge on the sample. This problem can be avoided by bombarding the specimen with low voltage electrons (a few hundred volts) simultaneously with its exposure to the high voltage electron beam. For this purpose a low voltage electron gun has been incorporated in the diffraction camera. It can be seen at the top of Fig. 1 connected to the main body by means of bellows, which is used for aiming the gun. For the construction of the gun, an all-metal RCA cathode ray tube (No. 913) was used. The case was removed together with the cathode, heater and control electrode. As with the main gun, a tungsten filament was installed as the source of electrons. Only one pair of deflection plates is used since it is sufficient to direct the beam to the specimen. The circuit diagram for the low voltage gun is shown in Fig. 17.

H. OPERATION OF THE CAMERA

1. Preparation of specimens

The preparation of mounts for the diffraction camera is a critical and sometimes a difficult matter. Pigment samples, as well as other powdered materials, are almost invariably examined by the transmission technique. In this case the ideal mount consists of a densely packed monoparticular (one particle thick) layer thru which the electron beam is transmitted. The first step in the usual preparation of mounts of pigment samples is to deposit a thin film of nitrocellulose (about 400 angstroms) on a 200 mesh stainless steel screen disk, 1/4 inch in diameter. This is done by placing one drop of a 2% solution of nitrocellulose in amyl acetate on the surface of distilled water contained in a six inch evaporating dish. After the solvent has evaporated, leaving a thin nitrocellulose film on the surface, a screen carried by a screen support is brought up from below the water surface to just above the surface causing the film to rest on the screen. The film is then severed with a sharp point and the screen support is lifted out of the water. In Fig. 18, row A shows a photograph of three screens, and row B, three screen supports.

The most successful technique found for preparing the pigment film has been to first disperse the powder in ethyl acetate, with a small amount of nitrocellulose as a dispersing agent if necessary (as in chrome yellows). Then a drop or two of the dispersion is placed on the surface of hot water in a beaker. There is almost instantaneous evaporation of the solvent such that, if the operation is done properly, the pigment remains on the surface in the form of a coherent film usually without much flocculation having occurred. In the case of chrome yellows, electron microscope examination has shown that a densely packed film of about one particle thickness can actually be prepared by this procedure. The next step is to place the pigment on the preformed nitrocellulose film simply by raising the latter, resting on a screen and screen support, from below the surface of the water thru the pigment film. This action causes the film to break around the edge of the support with a circular section of the film remaining on the nitrocellulose. When the mount thus prepared has dried it is ready for use. After examination in the camera, the screen with the pigment specimen on it is removed from its support and is filed in a numbered gelatin capsule for possible future reference.

Two kinds of screen supports are employed, as shown in rows B and C of Fig. 18. Those in row B are used when it is desired that the electron beam strike the mount at perpendicular incidence. When evidence of the orientation of pigment particles is being sought, the supports in row C are used. In this case the beam makes an angle of 45% with the normal to the pigment film and if the particles are not randomly oriented, arcs appear in the diffraction pattern instead of rings. Such results are useful in connection with the study of the shape of pigment particles. In Fig. 18, D is the screen support holder which is attached to the specimen carrier for examination in the camera. It has provisions for three samples.

The examination of pigment samples by the reflection technique can be executed by placing the samples on solid, polished stainless steel supports which have been made for the purpose. These fit into the screen support holder.

2. Examination and Recording of Diffraction Pattern

After the specimens and a photographic plate have been placed in the camera the latter must be evacuated to a pressure of about 10^{-4} mm. of Hg. before the electron beam and high voltage are turned on. Usually the ionization gauge is not used, but the system is regarded as having reached a working vacuum when the thermocouple gauge gives its maximum reading (195) on the meter labeled

"VACUUM" IN Fig. 6. To obtain the high voltage, the switches in Fig. 6 marked "RECTIFIER" and "HIGH VOLTAGE" are turned on and, after a moment, the voltage from the autotransformer is slowly increased by turning the knob marked "HIGH VOLTAGE" until the high voltage meter indicates the desired voltage.

Although the direct beam can always be seen on the fluorescent screen, with the old gun diffraction rings could be seen with relatively few samples. With the new gun it is expected that the diffraction rings will be visible with practically all samples which show diffraction.

For photographic recording of the pattern a plate is shifted into position in front of the screen. A marker on the bellows controlling the motion of the plate holder indicates the correct position for each of the three exposures to be recorded on a single plate. The type of plate most frequently used is the Eastman Kodak 4 x 5 Process plate. The plates are dehydrated before use and kept in a desiccator so that the moisture contained in them will not unduly lengthen the evacuation time.

The exposure conditions for photographic recording vary for different patterns, but range from 10 seconds to 2 minutes with an emission current between 100 and 200 microamperes. With the new gun it is anticipated that exposure times of a few seconds will be sufficient. The plates are developed at 68°F. for 1 1/2 minutes in Eastman D-8 developer and hardened in a bath of chrome alum for about 1 minute. Several typical patterns are reproduced in Fig. 19.

3. Diffraction Data

In general the information which it is desired to secure from a diffraction pattern is the interplanar spacings corresponding to the diffraction rings and their relative intensities. The accurate measurement of the ring diameters, which range from a fraction of a centimeter to 3 or 4 centimeters, is required for this; calibration of the apparatus with a standard at the particular voltage employed is also necessary. A device for measuring ring diameters was constructed and is shown in Fig. 20. It is essentially a low power travelling microscope and measurements to an accuracy of 0.1 millimeter can be made with it.

For the calibration of the diffraction apparatus, iron blue is very suitable since it gives a strong and sharp pattern of about 28 rings and in addition, its lattice constant is accurately known (cf ICI Report R1.4030 "A General Account of an X-ray Examination of Prussian Blue". 12-5-35). This has a value of 10.2 Angstroms which, for example, gives a conversion factor of 4.42 Angstrom-centimeters for 40KV electrons. Thus, by dividing the ring diameter into this factor, the corresponding value of the interplanar spacing in Angstroms can be computed.

To facilitate the estimation of relative intensities, a photographic scale was prepared by photographing several times the electron beam, in the form of a narrow line, at constant intensity at various known exposure times. Fourteen exposure steps covering a 11-fold range of intensity were obtained. By matching the lines of the scale against the diffraction rings it is possible to make rough quantitative estimates of the relative intensities of the rings in any given pattern. This can be done in spite of the fact that in most patterns the background intensity varies considerably from ring to ring.

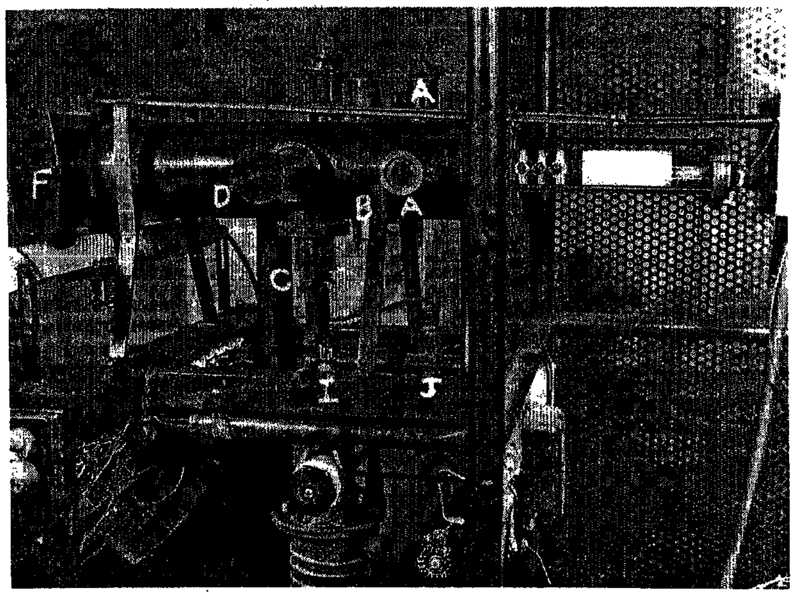


FIG. 1 - GENERAL VIEW OF RIGHT SIDE OF CAMERA

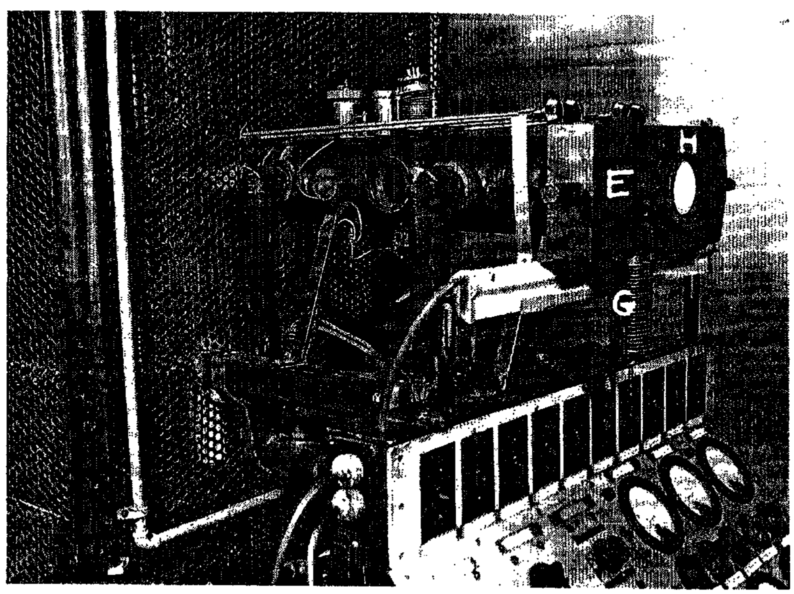


FIG. 2 - GENERAL VIEW OF LEFT SIDE OF CAMERA

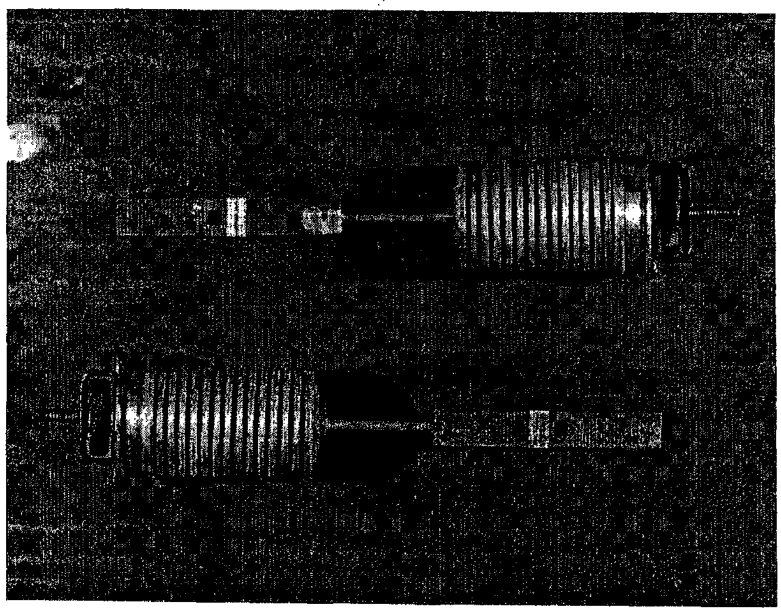


FIG. 3 - ADJUSTABLE APERTURES

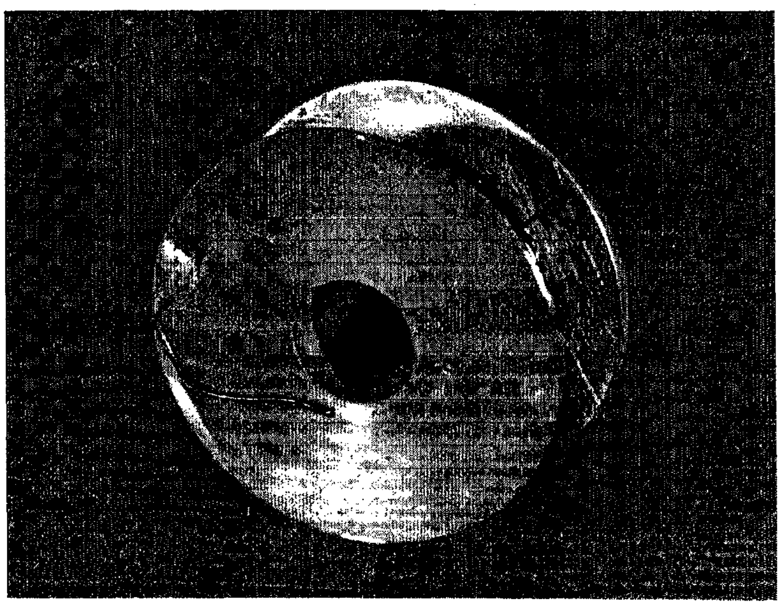


FIG. 4 - FOCUSING COIL

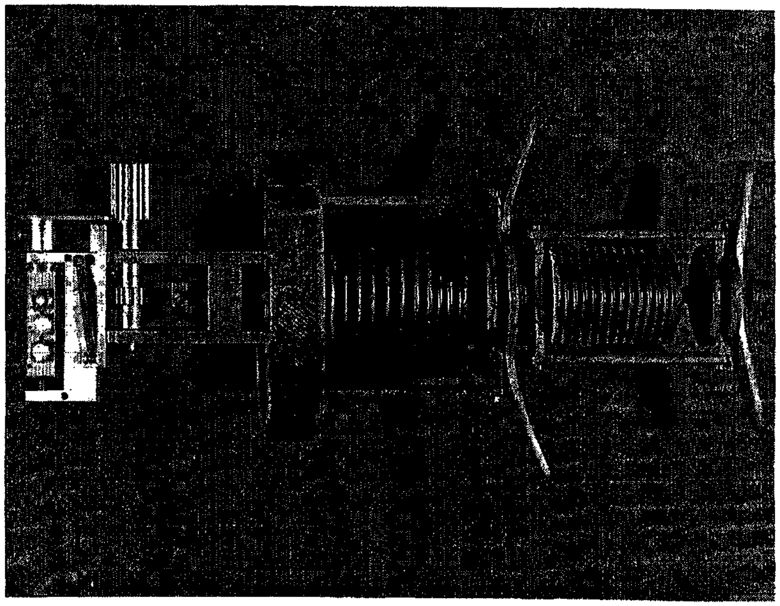


FIG. 5 - SPECIMEN CARRIER

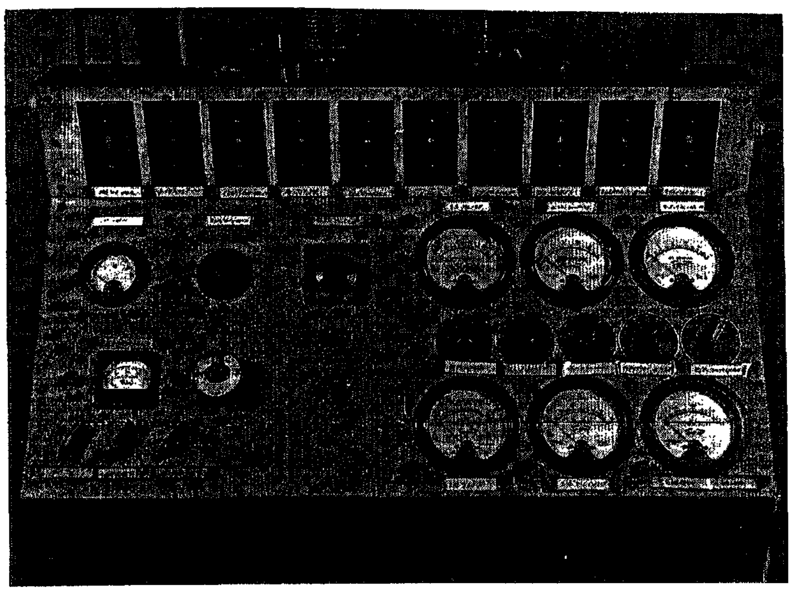


FIG. 6 - INSTRUMENT PANEL

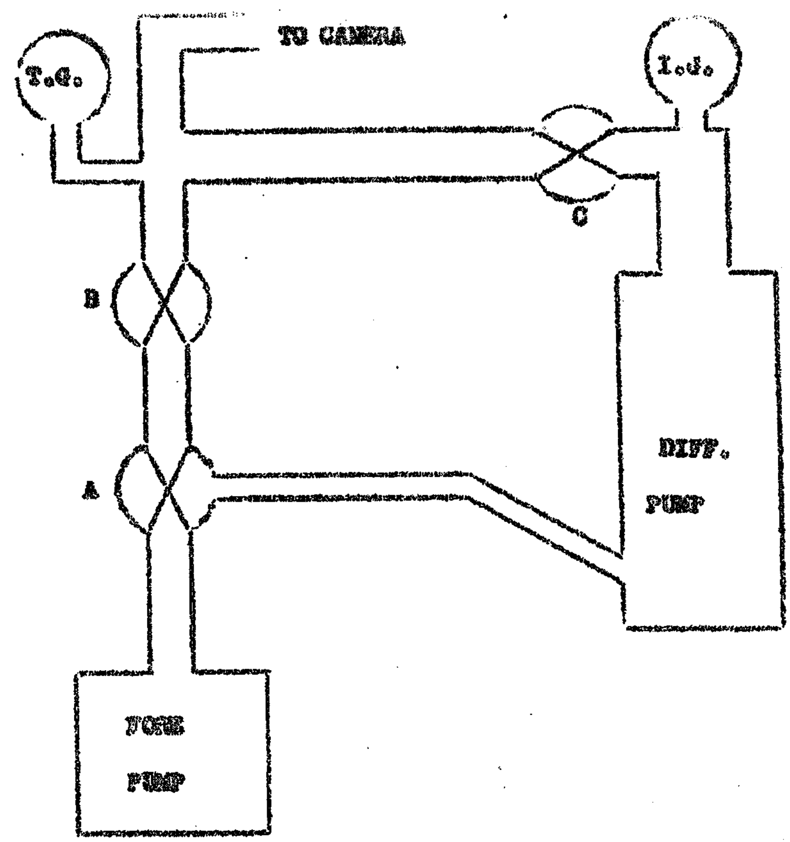


FIG.7 - VACUUM SYSTEM

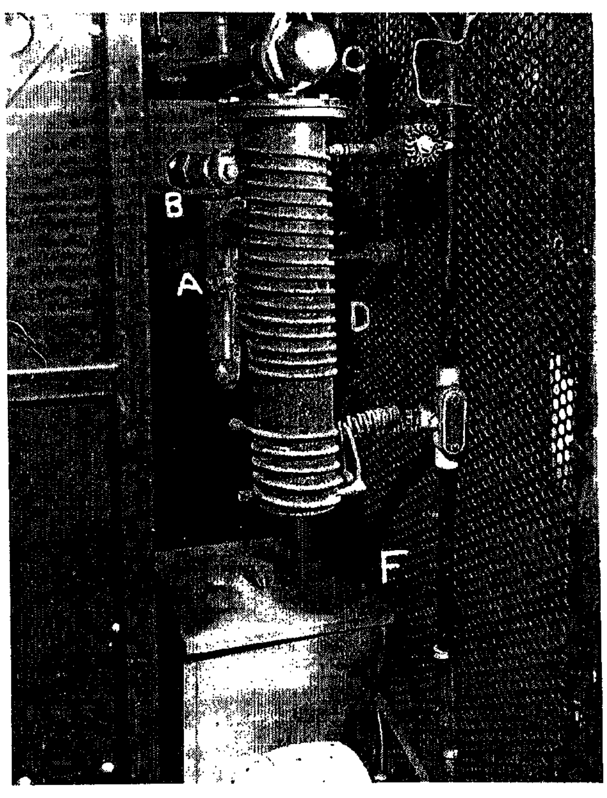


FIG.8 - VACUUM PUMPS AND VALVES

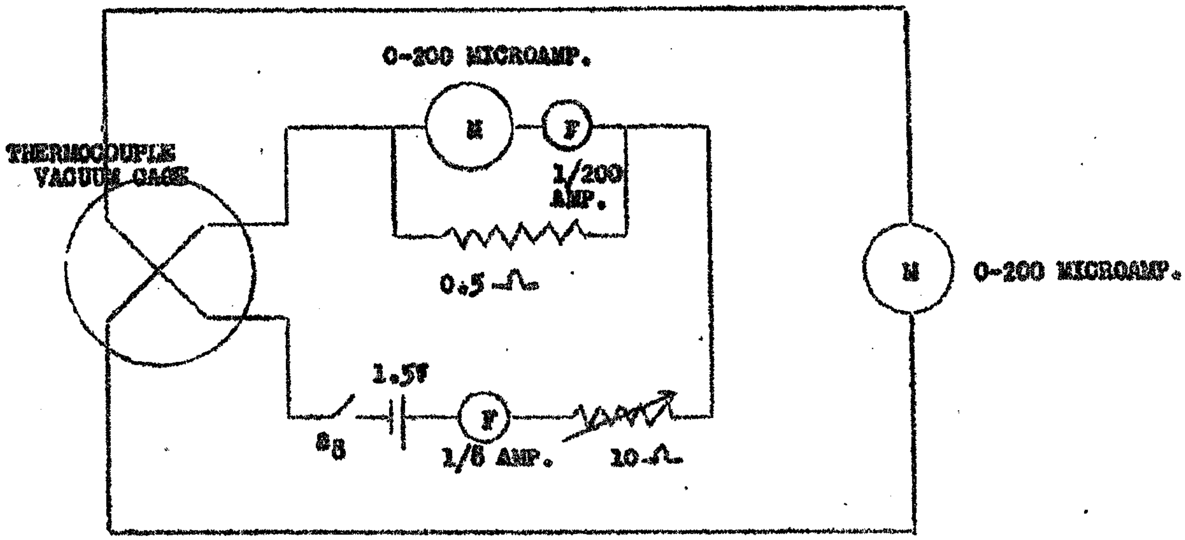


FIG. 9 - THERMOCOUPLE VACUUM GAUGE CIRCUIT

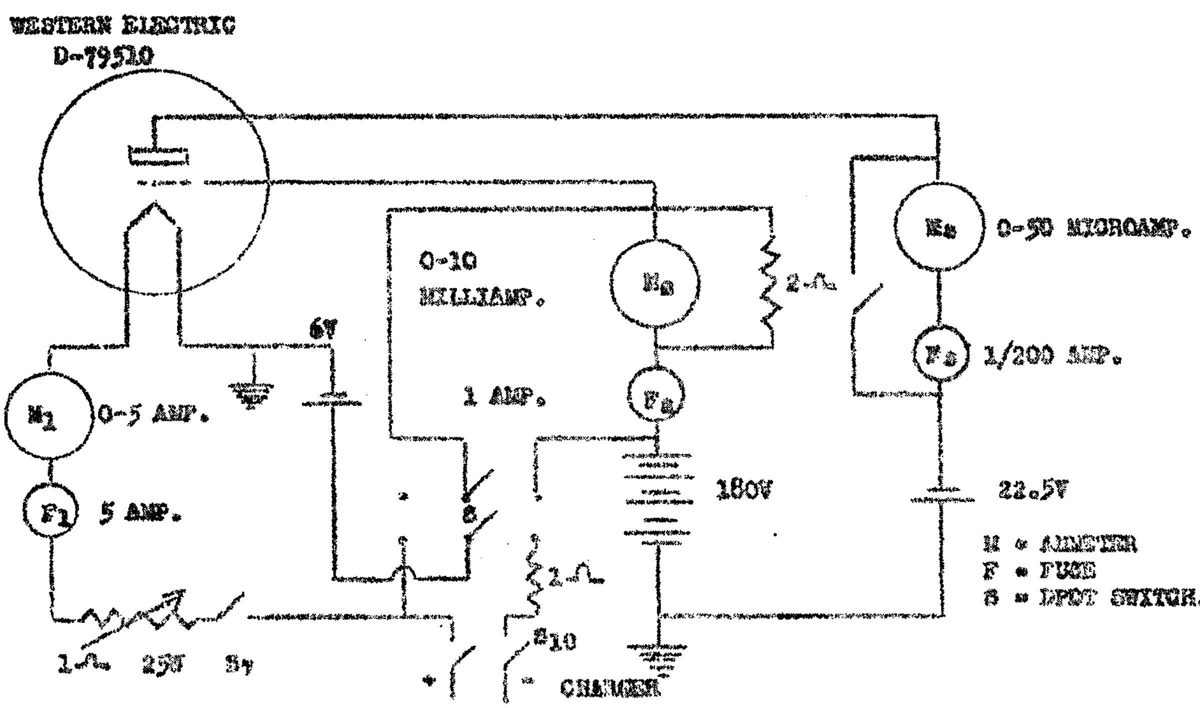


FIG. 10 - IONIZATION GAUGE CIRCUIT

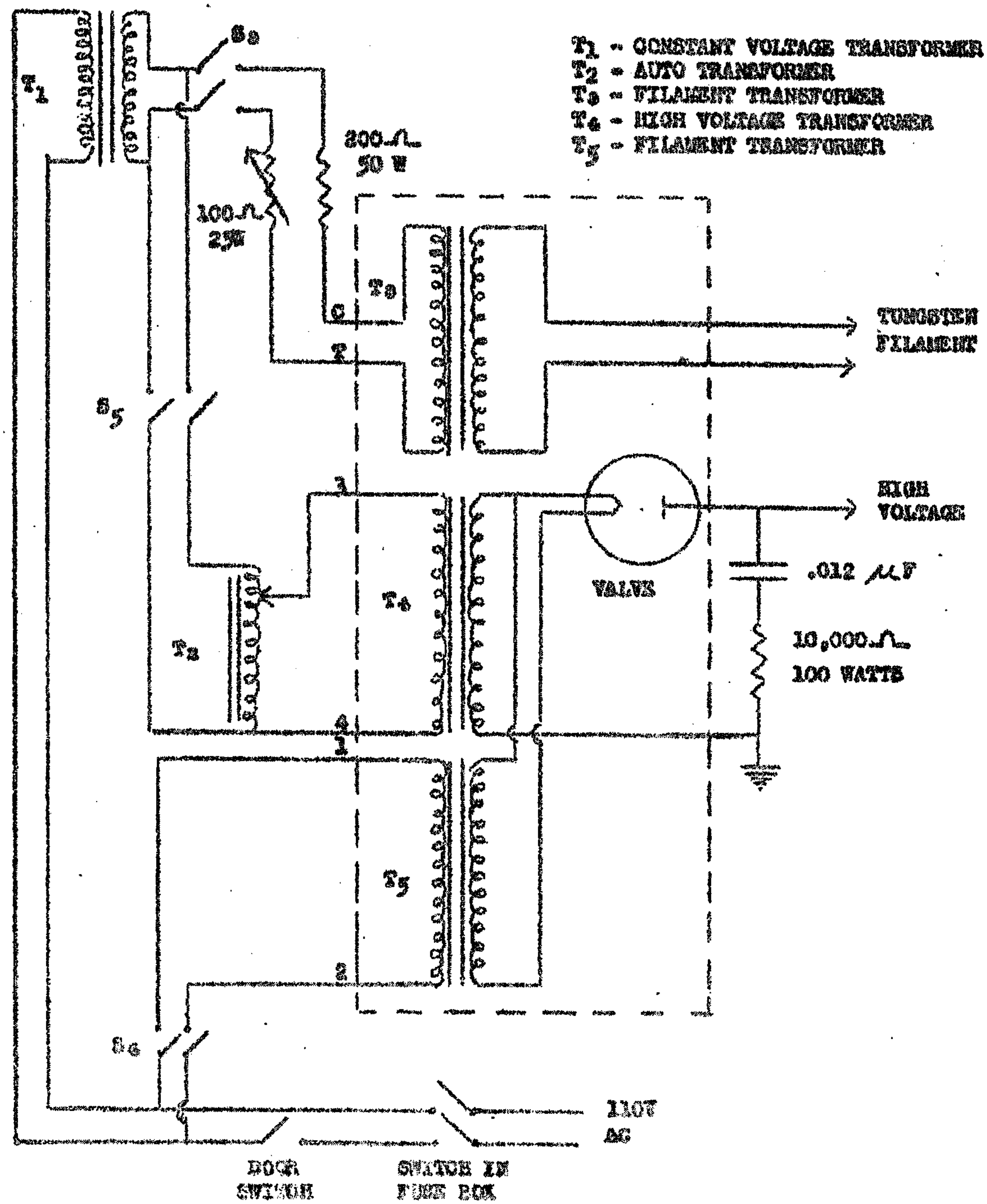


FIG. 11 - HIGH VOLTAGE SUPPLY CIRCUIT

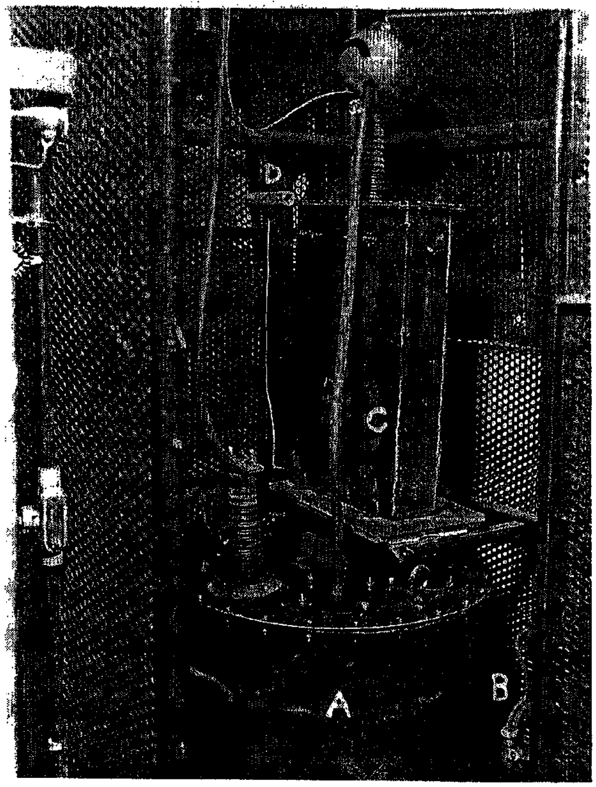


FIG. 12 - HIGH VOLTAGE EQUIPMENT

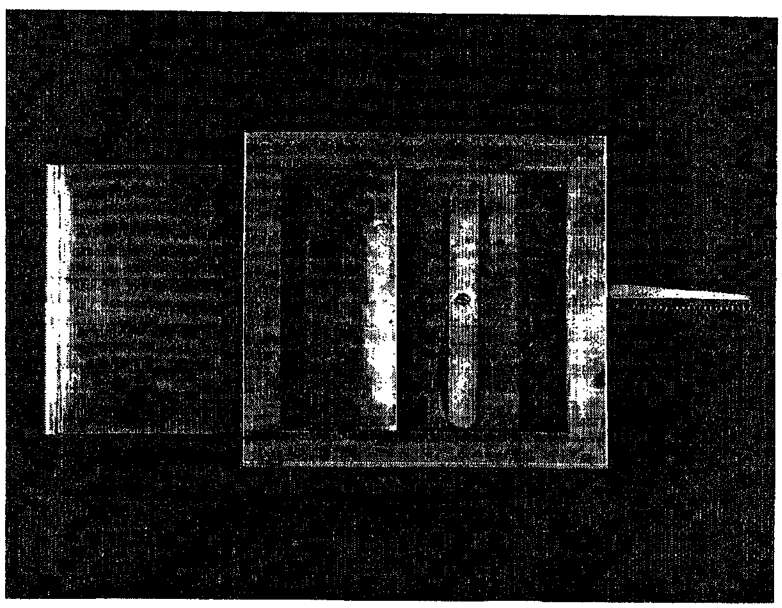


FIG. 13 - PLATE HOLDER

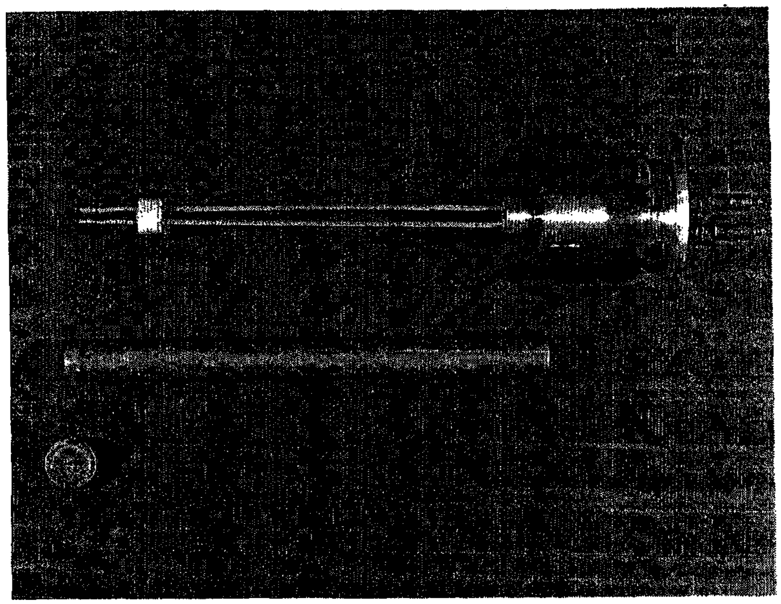


FIG. 14 - OLD ELECTRON GUN

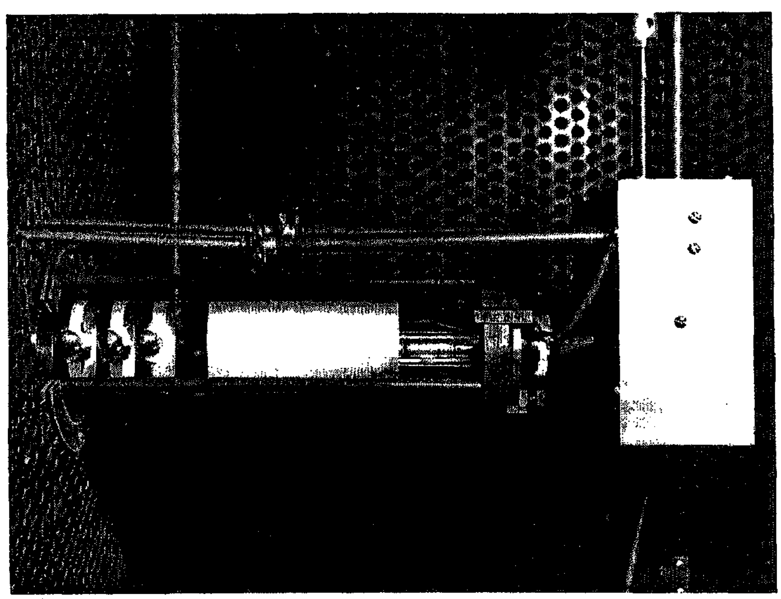
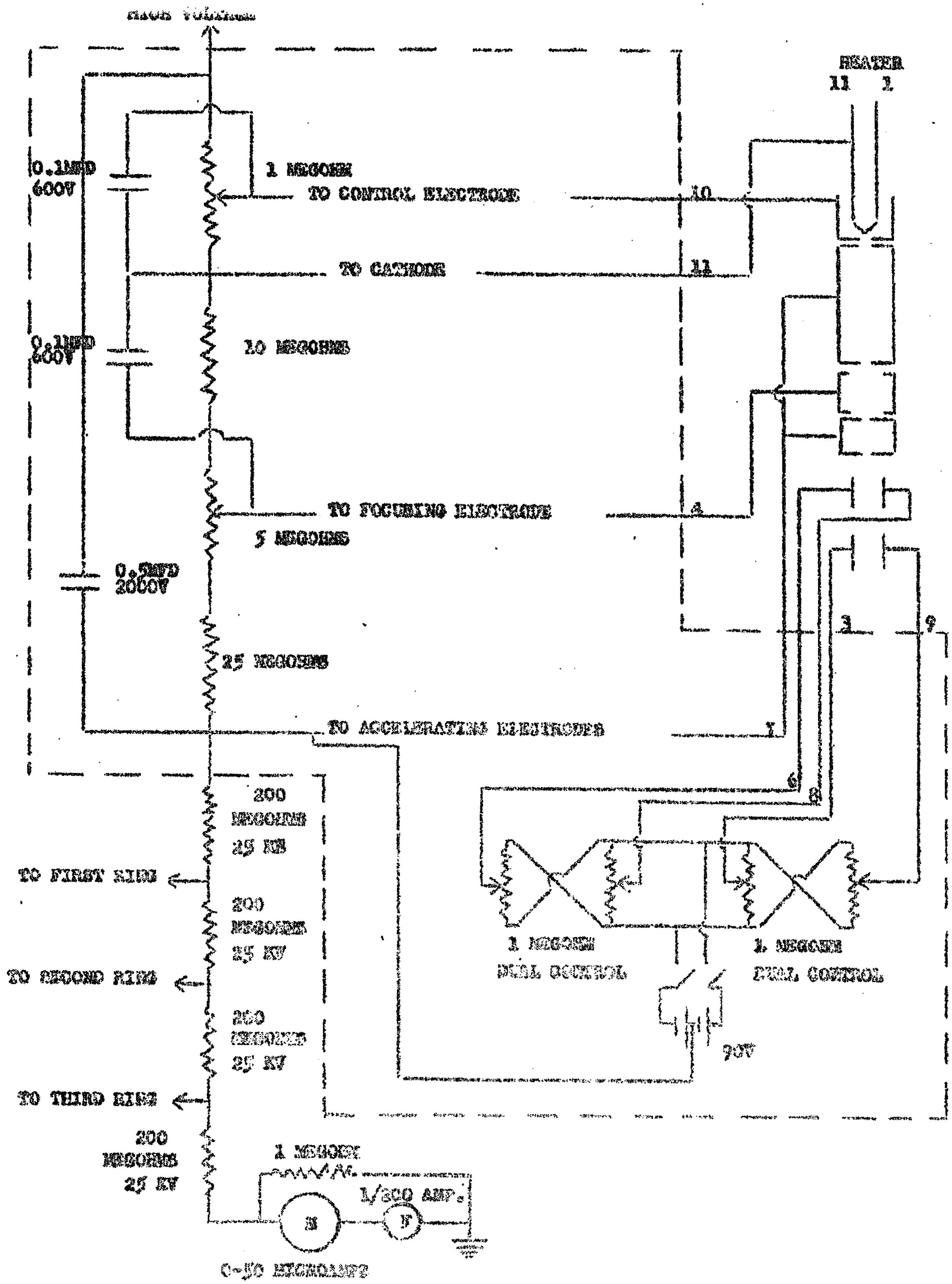
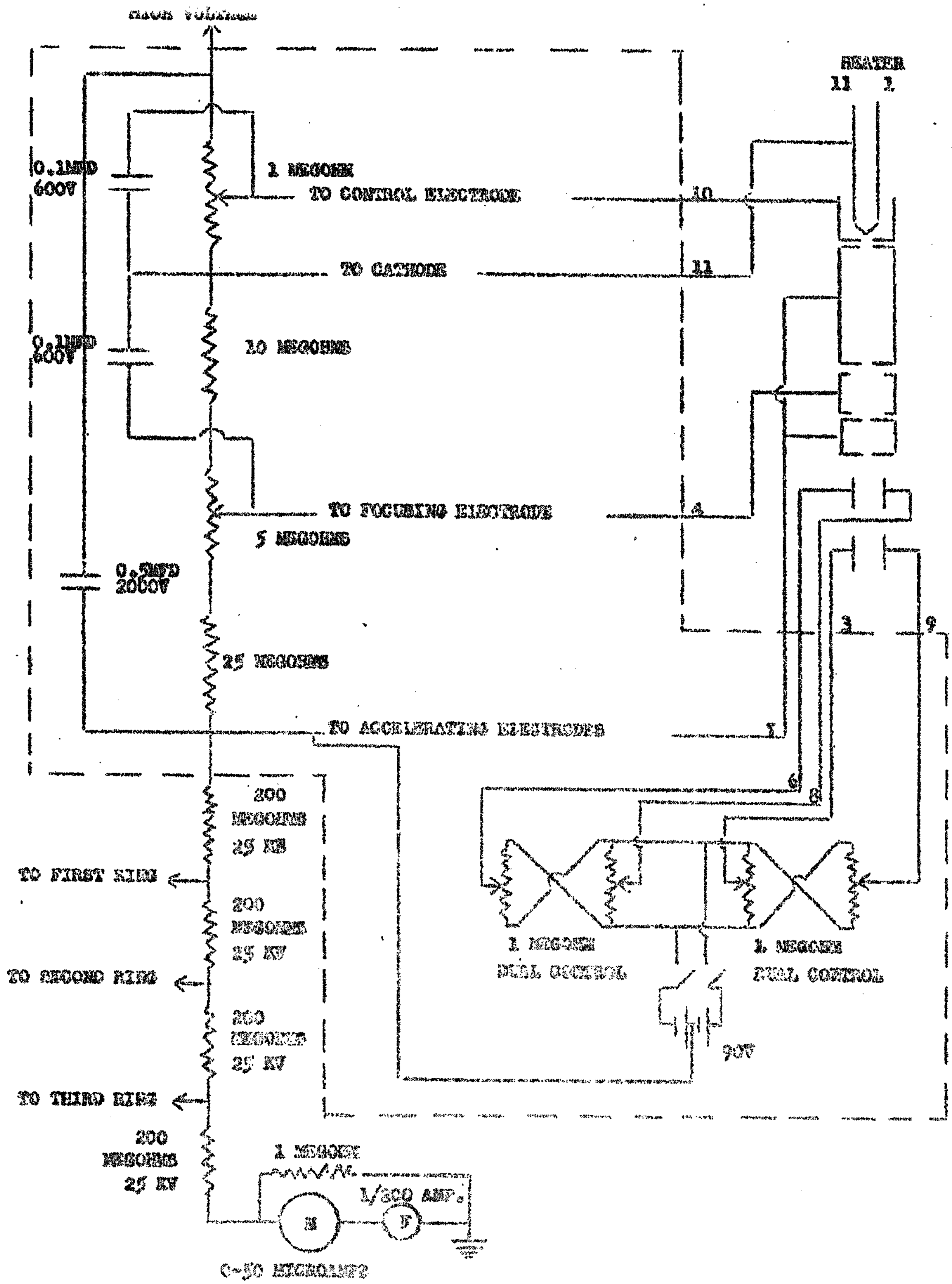


FIG. 15 - NEW ELECTRON GUN


HEATER
11
1
0.1MFD
600V
1 MEGOHM
TO CONTROL ELECTRODE
10
TO CATHODE
11
0.1MFD
600V
10 MEGOHMS
TO FOCUSING ELECTRODE
4
5 MEGOHMS
0.5MFD
2000V
3
9
25 MEGOHMS
TO ACCELERATING ELECTRODES
7
6
8
200
MEGOHMS
25 KV
TO FIRST RING
200
MEGOHMS
25 KV
1 MEGOHM
DUAL CONTROL
1 MEGOHM
DUAL CONTROL
TO SECOND RING
200
MEGOHMS
25 KV
90V
TO THIRD RING
200
MEGOHMS
25 KV
1 MEGOHM
1/200 AMP.
M
F
0-50 MICROAMPS



DUP050150119

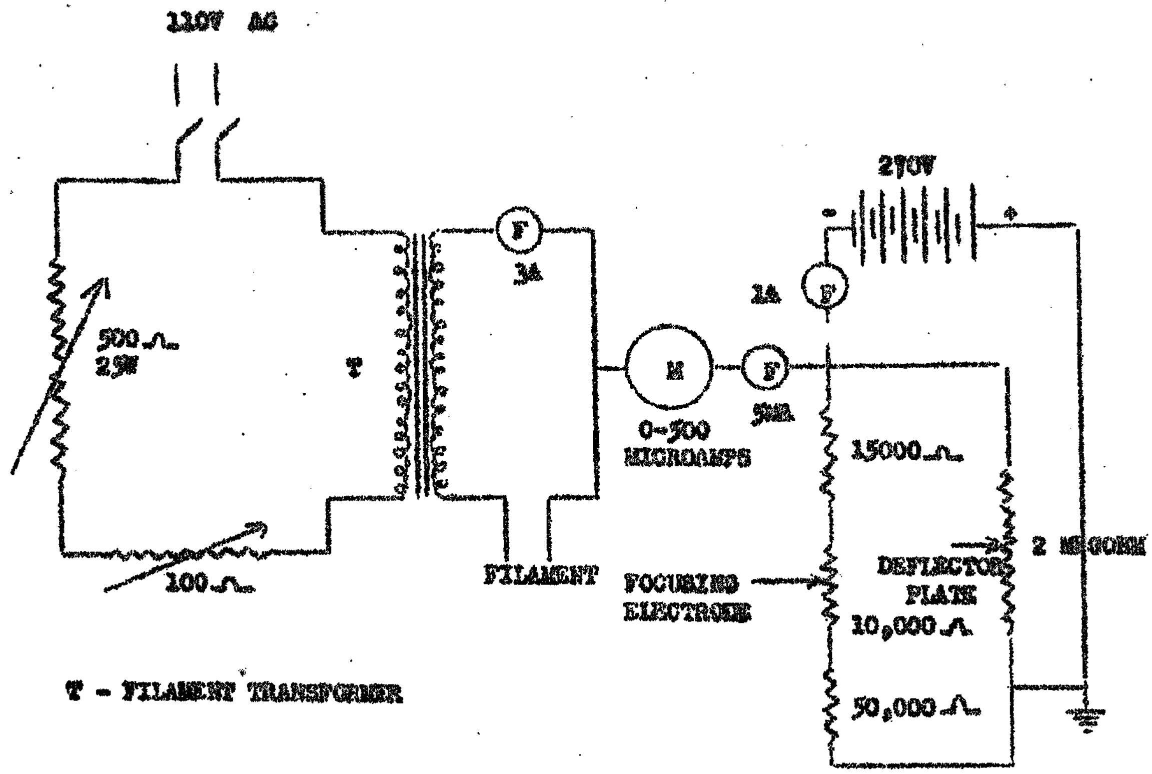


FIG. 17 - LOW VOLTAGE ELECTRON GUN CIRCUIT

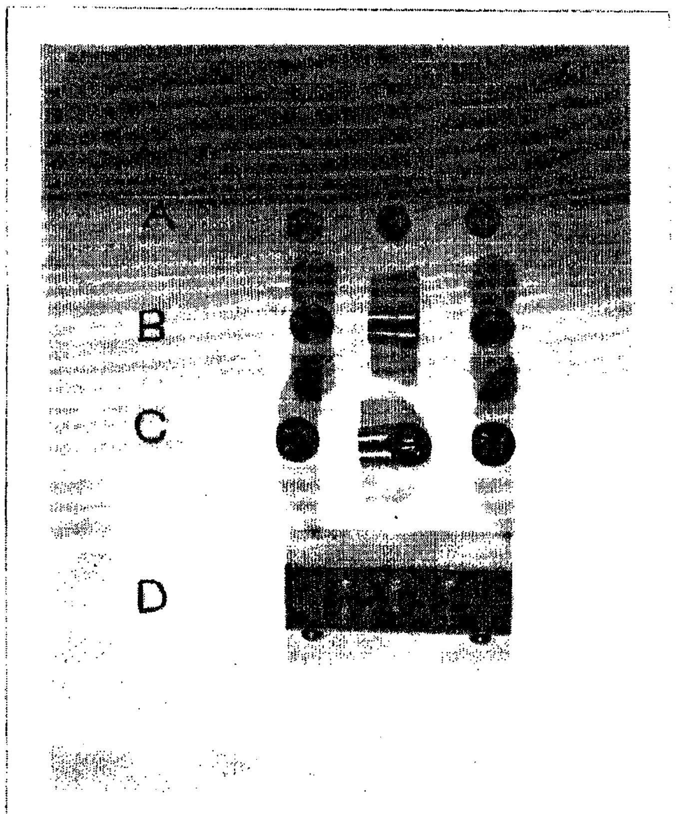
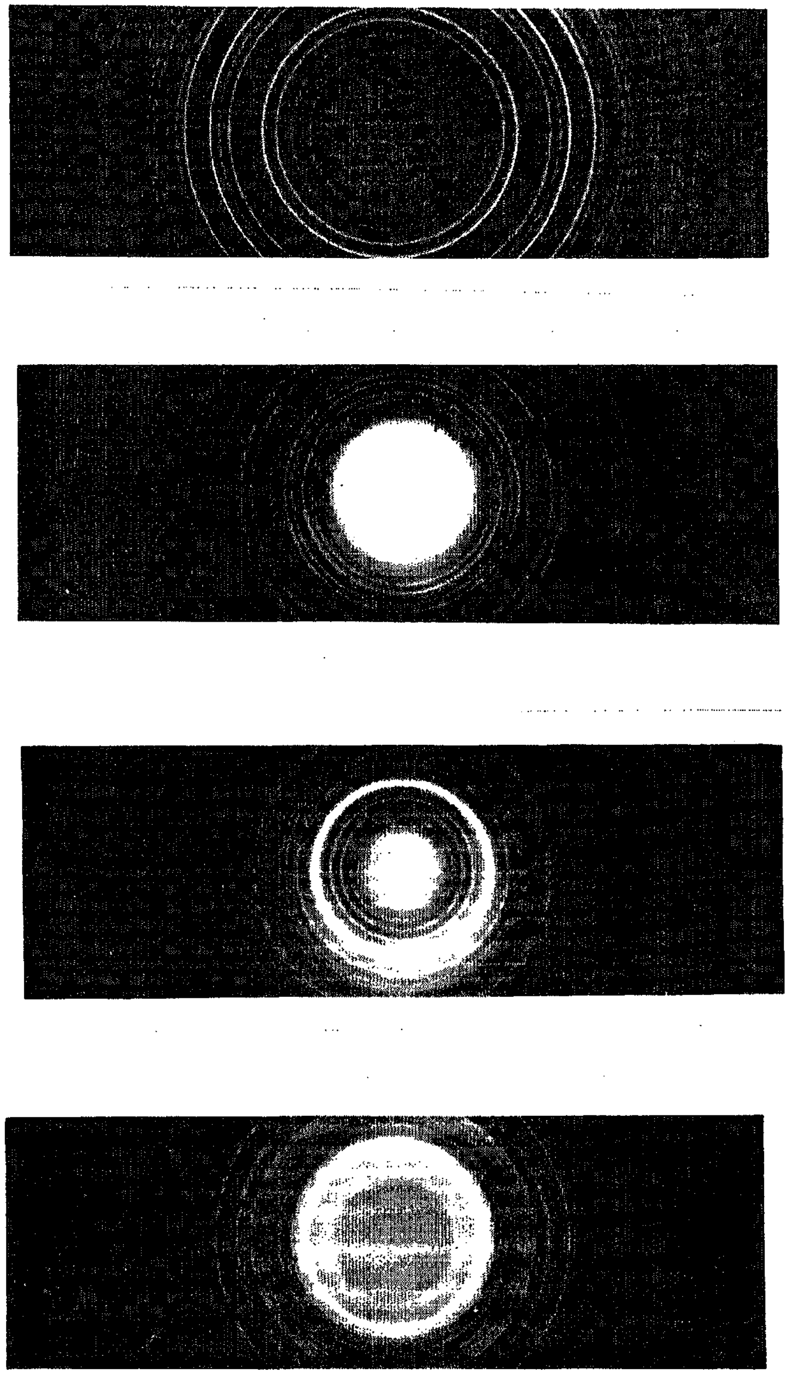


FIG. 18 - SCREENS, SCREEN SUPPORTS & HOLDER



IRON BLUE

MEDIUM YELLOW

B.O.N. RED
TONER

"NAPHTHANIL" RED

FIG. 19 - DIFFRACTION PATTERNS OF PIGMENTS

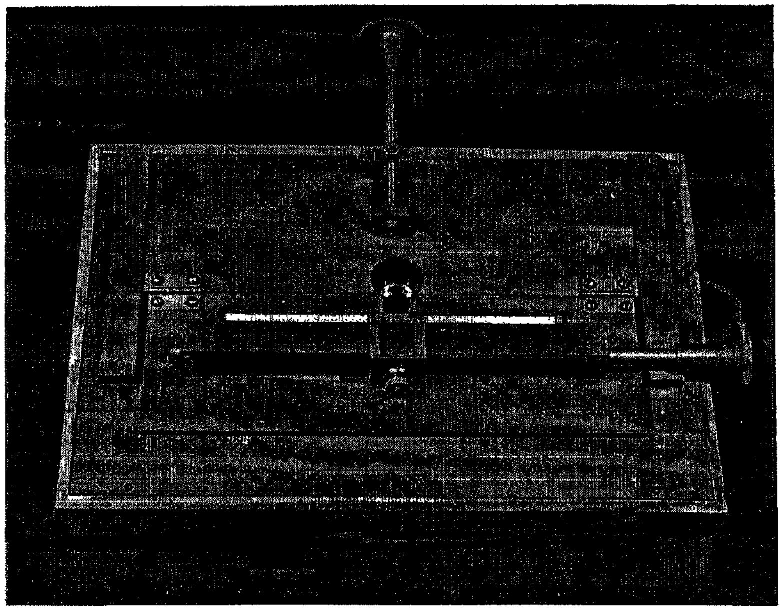


FIG.20 - APPARATUS FOR MEASURING RING DIAMETERS

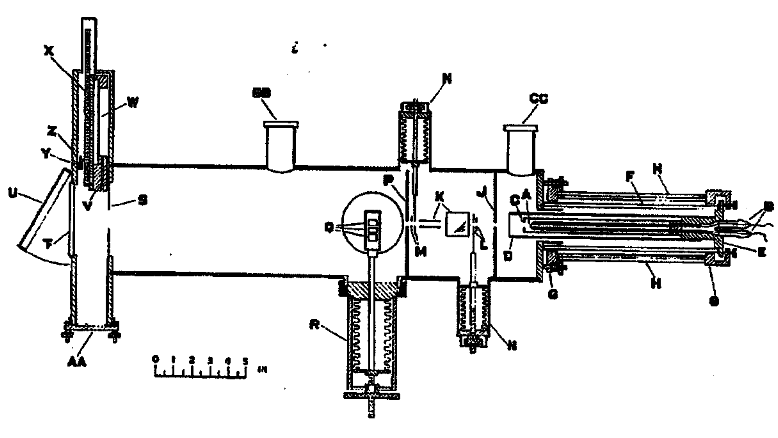


FIG.21 - SCHEMATIC DIAGRAM OF ORIGINAL CAMERA