DP-60

Metallurgy and Ceramics
Instrumentation

42

TRANSFORMATION AND NON-BOND TESTER FOR FLAT ELEMENTS

by

W. L. Blucke
Instrument Development Division

April 1954

[redacted]d

E. I. du Pont de Nemours & Co.
Explosives Department — Atomic Energy Division
Technical Division — Savannah River Laboratory

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INSTRUMENTATION

ABSTRACT

A composite ultrasonic unit was developed to indicate the size and location of non-bonded areas and the presence of non-transformed regions in flat uranium fuel elements clad with aluminum. A two-dimensional recorder was developed to yield instantaneous, permanent records of the non-bonded areas on electrosensitive paper. Panel lights indicate the presence of non-transformed regions that have not received proper heat treatment. Defects 1/8" in diameter are consistently detected at an inspection rate of approximately 50 sq. in./min.

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INTRODUCTION

NON-BOND DETECTOR

The heat generated in the uranium core of a fuel element, during reactor operation, is dissipated through the bonding layer and the aluminum sheathing into the coolant. Localized heating occurs if the aluminum sheathing is not bonded to the core material. These localized "hot-spots" may cause excessive corrosion. This report describes an ultrasonic instrument that detects and records the size and location of non-bonded areas in aluminum-clad uranium fuel elements

TRANSFORMATION TESTER

The most stable form of uranium, under the conditions of pile irradiation, is one with a completely random grain orientation. Uranium is heat treated (transformed) to accomplish this randomness. This report also describes an instrument that is sensitive to the degree of transformation of uranium plates.

SUMMARY

A composite ultrasonic unit was developed to determine the size and location of non-bonded areas in flat fuel elements, and at the same time to indicate the presence of non-transformed regions. Both the non-bond tester and the transformation tester use the ultrasonic transmission principle. A two-dimensional recorder, using electrosensitive paper, was developed to record the size and location of non-bonded areas. Panel lights indicate the degree of transformation. Performance tests show that areas of non-bonding or non-transformation, 1/8" in diameter, can be consistently detected. The instrument scans a fuel element at the rate of 50 square inches per minute.

FUTURE PROGRAM

The future program will be directed toward the design of ultrasonic test units for fuel elements of different composition and different geometry. One objective of the program will be the development of an instrument with a substantially higher scanning rate.

DISCUSSION

THEORY

General Ultrasonic Theory Ultrasonic waves are elastic waves of the same nature as sound waves, but with frequencies above the audible range (20kc). These waves may be propagated in the form of longitudinal, transverse, and surface waves. In an aqueous transmitting medium, only longitudinal waves need be considered since shear waves cannot be propagated in a liquid. Longitudinal waves obey refractive laws in a manner analogous to light waves. Thus, ultrasonic waves may be focused or collimated.

The velocity of the waves is dependent upon the density and modulus of elasticity of the medium. The velocity of a longitudinal wave in a solid is given by Eq. 1

$$v = \sqrt{\frac{E}{\rho} \frac{(1-\sigma)}{(1+\sigma)(1-2\sigma)}} \qquad \text{Eq. (1)}$$

v = longitudinal velocity (cm/sec)
E = Young's Modulus (dynes/cm^2)
ρ = density (gm/cm^3)
σ = Poisson's ratio

The fundamental relation between wave length, frequency, and velocity is given in Eq. 2.

$$\text{velocity} = \text{frequency} \times \text{wave length} \qquad \text{Eq. (2)}$$

For example, a 5 megacycle beam of ultrasound travels through aluminum at the rate of 6.22×10^5 cm/sec and has a wave length of 0.124 cm.

Piezoelectric transducers are employed for the generation of ultrasonic waves. The transducers operate on the inverse piezoelectric effect whereby quartz crystals change their size when an electric field is applied. Maximum radiation occurs when the quartz crystal vibrates at its resonant frequency which is determined by the thickness of the crystal. The beam intensity, of the ultrasound, is proportional to the acoustic resistance of the surrounding medium and to the square of both the applied voltage and operating frequency.

Conversely, a piezoelectric transducer can be used to detect ultrasonic waves. An ultrasonic wave, incident on the face of such a crystal, produces an electrical charge directly proportional to the applied pressure. Thus, quartz crystals can be used to both generate and receive ultrasonic waves.

Further information can be found in ultrasonic texts (12-16).

Non-Bond Theory When an ultrasonic wave encounters an interface between two different materials, part of the wave is transmitted and part is reflected. The amplitude of the reflected wave, as related to the incident wave, is dependent upon the specific acoustic impedances of the two materials as shown in Eq. (3).

$$\text{reflection coefficient} = \frac{\text{reflected energy}}{\text{incident energy}} = \left(\frac{\rho_1 c_1 - \rho_2 c_2}{\rho_1 c_1 + \rho_2 c_2}\right)^2 \qquad \text{Eq. (3)}$$

ρ_1, ρ_2 = Respective densities in each material (gm/cm^3)
c_1, c_2 = Respective ultrasonic velocities in each material (cm/sec)
ρc = Specific acoutic impedance (gm/cm^2-sec)

This equation shows that a non-bonded area acts like a perfect reflector. Since the density of air is small (approx. 10^{-3} gm/cm^3), compared to the density of a metal, the reflection coefficient approaches unity. Thus, ultrasonic waves cannot be transmitted through an air gap in metal since the intensity of the reflected wave is practically 100%. This principle makes it possible to detect non-bonded areas, at the interface of the cladding and uranium, in flat-fuel elements. Bonded areas transmit ultrasound whereas non-bonded areas do not.

Transformation Test Theory The most stable form of uranium, under the conditions of reactor irradiation, is one with a completely random grain orientation. To achieve this randomness, the uranium is heated into the beta-phase and then quenched to room temperature. Heat treatment or transformation results in an increase in grain size. Typical values of the average grain size are 30-50 microns for as-rolled uranium and 150-250 microns for the transformed.

Ultrasonic waves experience partial scattering or reflection in passing through uranium. The amount of scattering is proportional to grain size and the wave length of the ultrasonic wave. Thus, the ultrasonic transmission method can be employed to determine indirectly whether a uranium plate has been sufficiently transformed by measuring the degree of attenuation of an ultrasonic beam in passing through the 0.18" thick uranium plates. When the ratio of ultrasonic wave length to grain size is greater than 3, the attenuation follows the Rayleigh fourth-power scattering law, and is proportional to the grain volume. When the ratio of ultrasonic wave length to grain size is 3 or less, the transmission process is analogous to the propagation of a heat wave and the attenuation is inversely proportional to grain diameter. The wave length of a 5 megacycle ultrasonic wave in uranium is approximately 0.67 mm. The ratio of wave length to grain size, for as-rolled uranium, is approximately 16.8 at this frequency. The ratio of wave length to grain size for transformed uranium is approximately 3.3. Therefore the attenuation of ultrasound is approximately 1.5 times greater in transformed uranium than in as-rolled uranium.

The transformation tester operates on a comparative basis and does not measure absolute grain size directly. It compares the attenuation of a test plate to that of a plate with known grain size.

INSTRUMENT DESIGN

The transformation and non-bond tester (Fig. 1) is a composite ultrasonic unit to detect non-bonded areas and measure the degree of uranium transformation. The tester operates on the pulsed-ultrasonic transmission principle. A collimated beam of ultrasound is electronically generated and transmitted through the test sample. The transmitted beam of ultrasound is converted into electrical pulses, amplified, and fed into detection units. The actuation of the indicating devices, by the detection units, is dependent upon the amplitude of the transmitted pulse. Permanent records of the size and location of non-bonded areas are obtained instantaneously on a two-dimensional recorder using electrosensitive paper. Panel lights indicate the presence of untransformed regions in the uranium core of the fuel element.

The tester (Fig. 2) consists of a pulser, wide band amplifier, non-bond detection unit, transformation detection unit, two-dimensional recorder, and motor control unit with associated scanning and translational mechanisms.

[redacted]

Pulser The purpose of the pulser (Fig. 3) is to generate the ultrasonic pulses. High-voltage pulses, applied to opposite faces of an X-cut quartz crystal, cause the crystal to change dimensionally, generating ultrasonic pulses. Pulses are employed, rather than a sinusoidal excitation voltage to avoid the interference of standing waves. Each wave packet is generated and sent through the test sample, to the receiving transducer, before the next pulse is generated. All multiple reflections disappear before the next pulse is generated.

The high voltage excitation of the quartz transducer is accomplished by capacitor discharge current. A pulse generator triggers a thyratron (3C45), dropping the plate potential from 3000 V. to approximately ground, thus discharging the capacitor in the plate circuit. The 3000 volt pulses that are applied to the quartz piezoelectric transducer permit the examination of thicker samples of uranium than has previously been possible with commercial equipment.

The number of wave packets generated per second is determined by the pulse rate generator. The pulse rate generator consists of an 884 thyratron pulser and a univibrator (6SN7 twin triode). The repetition rate is controlled by the 1 megohm pot located in the plate circuit of the 884 thyratron. The pot is mounted on the pulser chassis adjacent to the thyratron. A 22-1/2 volt battery is used to supply the necessary negative bias to the thyratron and an unregulated power supply provides the plate voltage to the thyratron and the univibrator.

The piezoelectric transducer is a 5 megacycle, X-cut quartz crystal. If a high voltage pulse is applied to a quartz crystal, the crystal continues to vibrate at its natural frequency after the removal of the applied voltage because of the inherently high "Q" of the crystal. By mechanically damping the crystal, small packets of waves with a duration of approximately one microsecond can be obtained. The damping is achieved by mechanically bonding the crystal to the micarta transducer assembly. In order to achieve the maximum efficiency in the electrical-ultrasonic conversion, the transducer assemblies are constructed with an air pocket on the unexposed face of the crystal so that acoustic loading is concentrated on only one face of the crystal.

Since ultrasonic waves are highly directional, a collimating nozzle is placed over the 3/4-inch diameter quartz crystal. The collimator restricts the ultrasound to a 1/4-inch diameter beam. If the diameter of the ultrasonic beam is decreased, more time is required to scan the sample. Accordingly, a compromise must be reached between resolution and scanning time.

[redacted]

The beam of ultrasound is transmitted through water normal to the surface of the test sample. The piezoelectric transducers are never in contact with the test sample and there is no danger of marring the fuel element surface.

Wide Band Amplifier The amplifier unit consists of a wide-band pulse amplifier (Fig. 4) developed by M. H. Goosey of this laboratory, and a receiving transducer assembly. The beam of transmitted ultrasound is converted into electrical pulses by a 5 megacycle quartz crystal. The electrical pulses, generated by the rigidly mounted X-cut quartz crystal, are amplified by the wide-band amplifier and fed to the detection units. The amplifier has a nominal gain of 5000 with a maximum output pulse of 20 volts. The amplifier has been tuned to an operating frequency of 5 megacycles with a band width of 1.2 megacycles. Pulse rise time of the amplifier is 0.5 microseconds. The amplifier has five stages of amplification (6AH6 pentodes) followed by a cathode follower (12AT7 twin triode). Gain of the amplifier is controlled by the negative bias (0 to 22-1/2 volts) at the second and fourth stages of amplification. The gain control is a ten-turn Helipot located on the detection unit.

The pulse amplifier is constructed in accordance with radio frequency techniques to prevent objectionable interactions between the stages. The amplifier was carefully tuned to the desired operating frequency and should require no further adjustment.

The regulated power supply, filament supply, and negative bias supply for the wide band amplifier are located on the detection unit chassis.

Detection Units The two detection units utilize the pulses from the wide-band amplifier to operate indicating devices. Both the non-bond detection unit (Fig. 5) and the transformation detection unit (Fig. 6) are basically the same, differing only in indicators. The non-bond detection unit supplies the recording current to the two-dimensional recorder. The transformation detection unit operates panel lights.

When ultrasound is transmitted through a fuel element, pulses are impressed on the grid of a 2050 thyratron in the non-bond detection unit causing the tube to conduct. The two-dimensional recorder is connected in series with the cathode of the thyratron so that, when the tube conducts a current of approximately 100 ma flows through the electrosensitive paper. The electrosensitive paper is darkened by this current. When a non-bonded area interrupts the ultrasonic beam, the thyratron no longer conducts and the recorder stops printing. Accordingly, non-bonded areas appear as white areas on the recorder paper.

The transformation detection unit also employs a 2050 thyratron to indicate areas of non-transformation. The gain control is adjusted so that the transmitted ultrasonic beam causes the thyratron to just conduct when an as-rolled uranium sample is between the transducers. The intensity of the ultrasonic beam transmitted by a transformed sample of uranium will not be sufficient to cause the thyratron to conduct with the same gain setting. When the transmitted beam is sufficient to cause conduction of the 2050 thyratron, a voltage is developed across the cathode resistor. This voltage causes the 6SC7 pentode to conduct and close the Sigma relay (4R-10000S) in the plate circuit. A slight reduction in the amplitude of the transmitted signal causes the relay to open. The relay controls red and green indicator lights mounted on the front panel. The presence of a non-transformed area turns on the red indicator light.

The negative bias on the 2050 thyratron is fixed at 3 volts by a battery. Thus, only one gain control is required on the panel for adjustment of sensitivity. Beneath this control is a test jack so that the output of the wide band amplifier can be viewed on an oscilloscope.

Scanning Equipment The scanning equipment (Fig. 7) associated with the ultrasonic tester was developed by L. E. Goodwin of this laboratory. It translates the test sample, reciprocates the transducer assembly, and drives the two-dimensional recorder.

A feeder translates the sample between the two transducer heads. The feeder consists of two banks of rubber-faced rollers with a pair of pressure drive rollers at the end of each bank. The two sets of drive rollers are geared together and are operated by a variable speed DC shunt motor mounted directly above. The feed is controlled by a Speed Control adjustment on the motor control unit. A switch on the motor control unit actuates the feeder.

The reciprocating mechanism sweeps the transducers back and forth as the test sample passes between the transducer heads. The reciprocation of the transducers is accomplished by a piston operated by compressed air. Electrically controlled solenoid valves reverse the direction of motion. The length of the sweep is controlled by two microswitches. An R.F. filter is included to prevent transients from the microswitches from entering the recording system. The rate of reciprocation is controlled by an air valve on the input line to the piston. The reciprocating mechanism is turned on or off with the same switch that controls the feeder.

Both the feeder and reciprocating mechanisms are directly coupled to the two-dimensional recorder. The chart drive of the recorder is geared to the D.C. motor of the feeder so that the recording paper translates at the same rate as the fuel element. The reciprocating action of the transducer assembly is mechanically coupled to the printing arm of the recorder. For every complete traverse of the test sample by the transducers, the printing arm makes an equivalent traverse of the recording paper.

Recording Equipment A recorder (Fig. 8) was developed to give interpretable two-dimensional records of the fuel element bonding. The recorder maps the ultrasonic transmission of the fuel element on electrosensitive paper so that non-bond indications correspond in size and location to those of the fuel element. To give permanent records, the recorder utilizes electrosensitive paper manufactured by the Alfax Paper and Engineering Co., Westboro, Mass. Printing is achieved by the direct action of the electric current on the paper and no fixing or heating is required. The amount of power necessary to darken the paper is proportional to the writing speed of the recorder. A few milliwatts are sufficient at writing speeds of a few inches per minute. Several watts are required for writing speeds of 2800 inches per minute.

The electrosensitive paper is fed between the printing arm and a negative electrode at the same rate that the fuel element is translated. The printing arm of the recorder is directly coupled to the reciprocating transducer assembly so that the arm sweeps back and forth across the recorder paper. Darkening of the paper occurs when current flows between the printing arm and the negative electrode. An interruption of the ultrasonic beam by a non-bonded area causes a white spot to appear on the recording trace. The positive electrode on the printing arm is a stainless steel wheel, 1/8" wide, which rolls back and forth across the paper. The negative electrode is a stainless steel bar, 1/2" x 4", clad with a layer of nichrome.

Tests with the recorder showed that the size of a non-bonded area is accurately recorded. The recorder does not limit the scanning rate and is well suited for rugged use since it contains no delicate mechanical or magnetic movements.

Motor Control Unit The Motor Control Unit (Fig. 9) contains the master switch which operates all electronic and scanning equipment. The speed control adjustment for the DC motor which controls the feed and recorder paper translation is also on this unit. A push-button located on the motor control unit permits the operator to halt both the reciprocating and translating mechanisms without interrupting the operation of the electronic equipment. Facilities are also provided for microswitches that automatically halt the scanning mechanisms once inspection of a fuel element has been completed.

PERFORMANCE

Tests made on over a hundred sample plates indicated that areas of non-transformation and non-bonding 1/8" in diameter could be consistently detected at a scanning rate of approximately 50 square inches per minute.

To achieve good correlation, the SENSITIVITY control, which determines the writing threshold level of the recorder, must be properly set. The apparent area of non-bonded regions grows larger as the sensitivity is increased. This fact is demonstrated in Figure 10 which shows the records of a single fuel element scanned at three different SENSITIVITY settings. The correct setting can be maintained in terms of a "standard plate" which is checked periodically.

To establish a "standard plate", it is necessary to find two plates which give similar test patterns at all SENSITIVITY settings. Destructive examination of one of these plates will then determine which SENSITIVITY setting should be used with the remaining "standard".

A sample test pattern taken of a SRL fuel element with "manufactured" non-bonded areas is shown in Figure 11. The ends of this plate were not bonded, as shown in the recording. The symbols which appear on the recording correspond accurately to deliberate non-bonded areas created by painting "-WA7-" on the uranium surface with Aquadag prior to cladding.

The size and location of two non-bonded areas detected in an experimental fuel element are shown in Figure 12. The uranium core is outlined on the recording due to diffraction phenomena.

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Instrument Development Division

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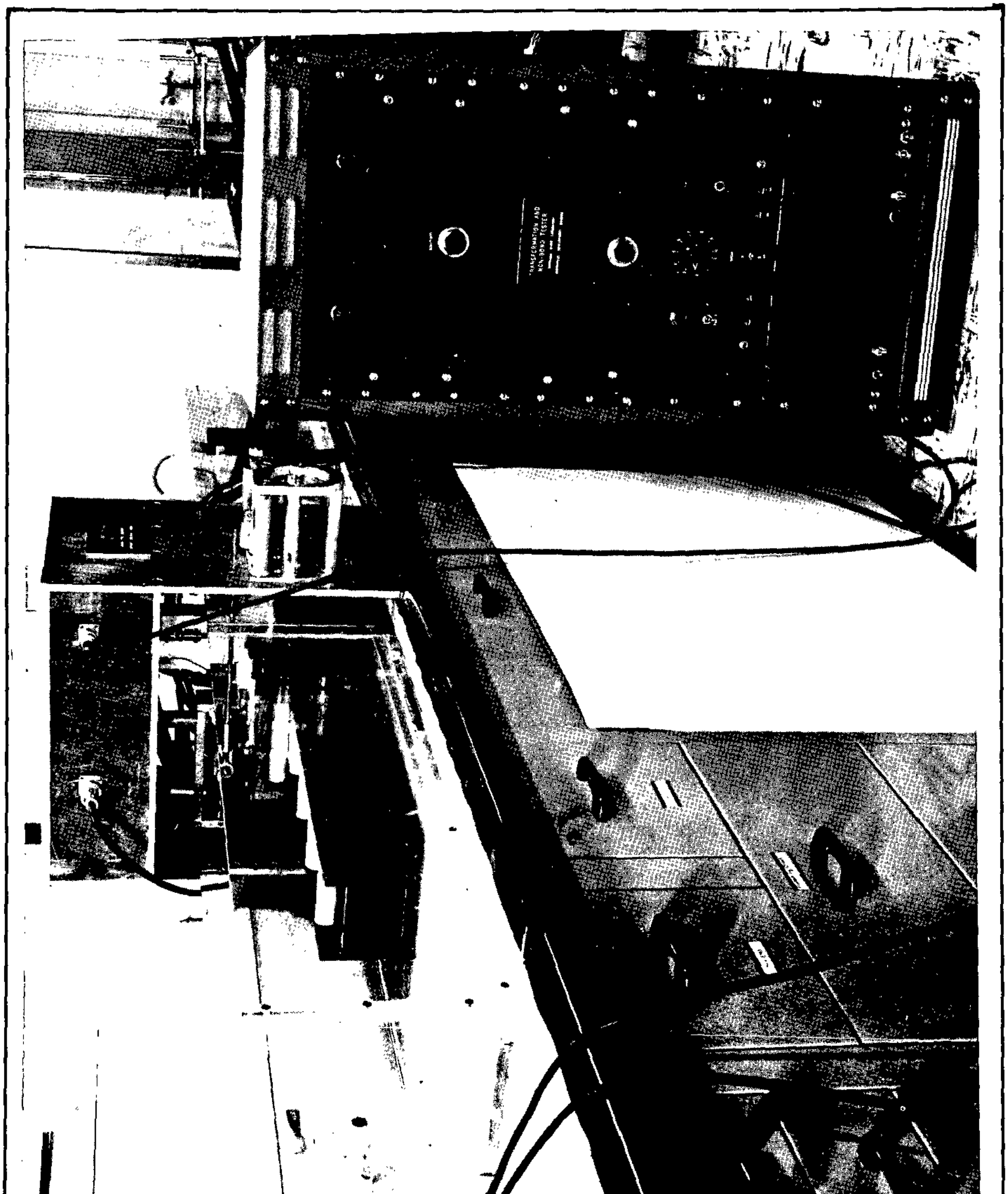
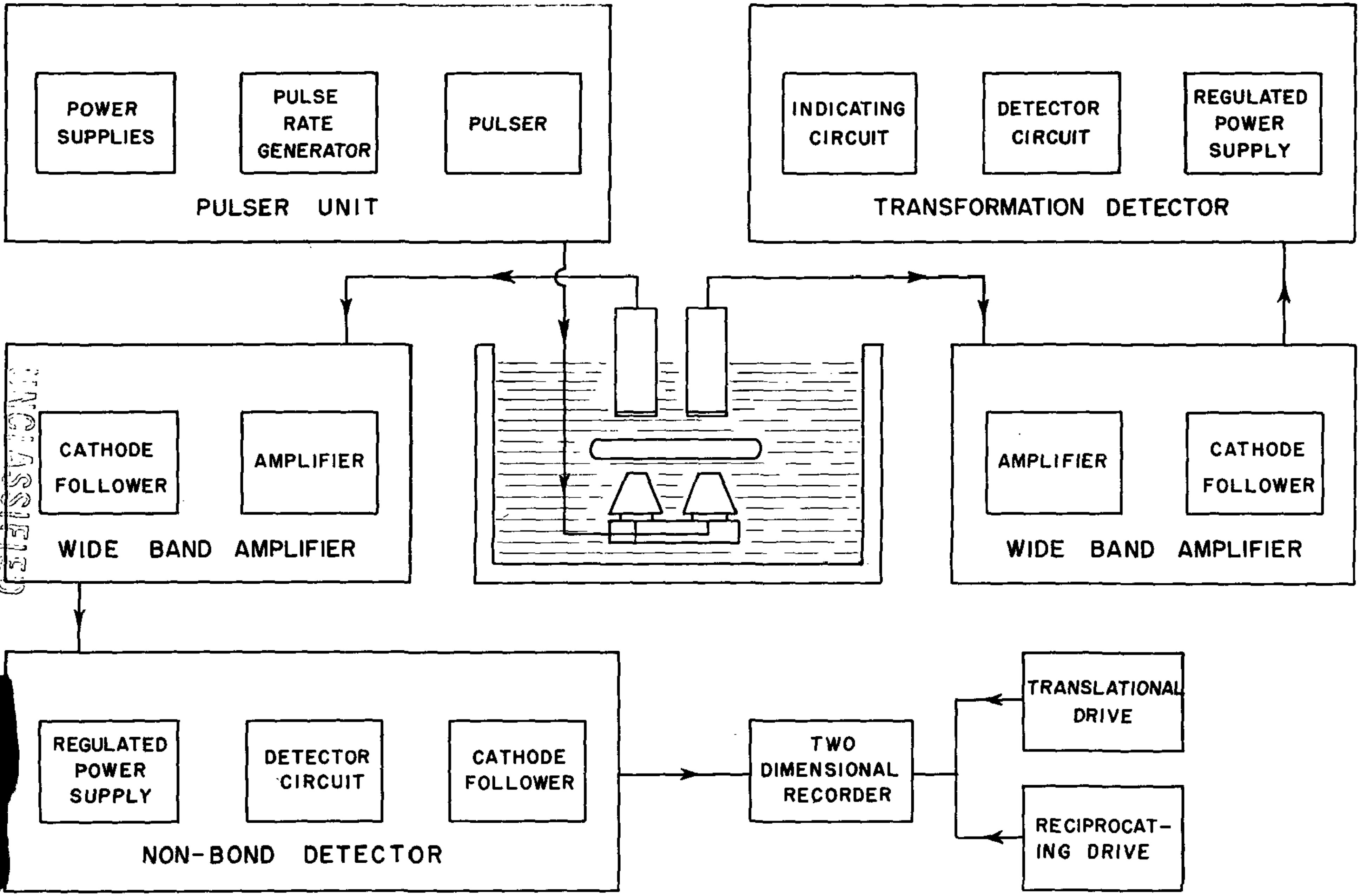


TRANSFORMATION AND NON-BOND TESTER

[redacted]

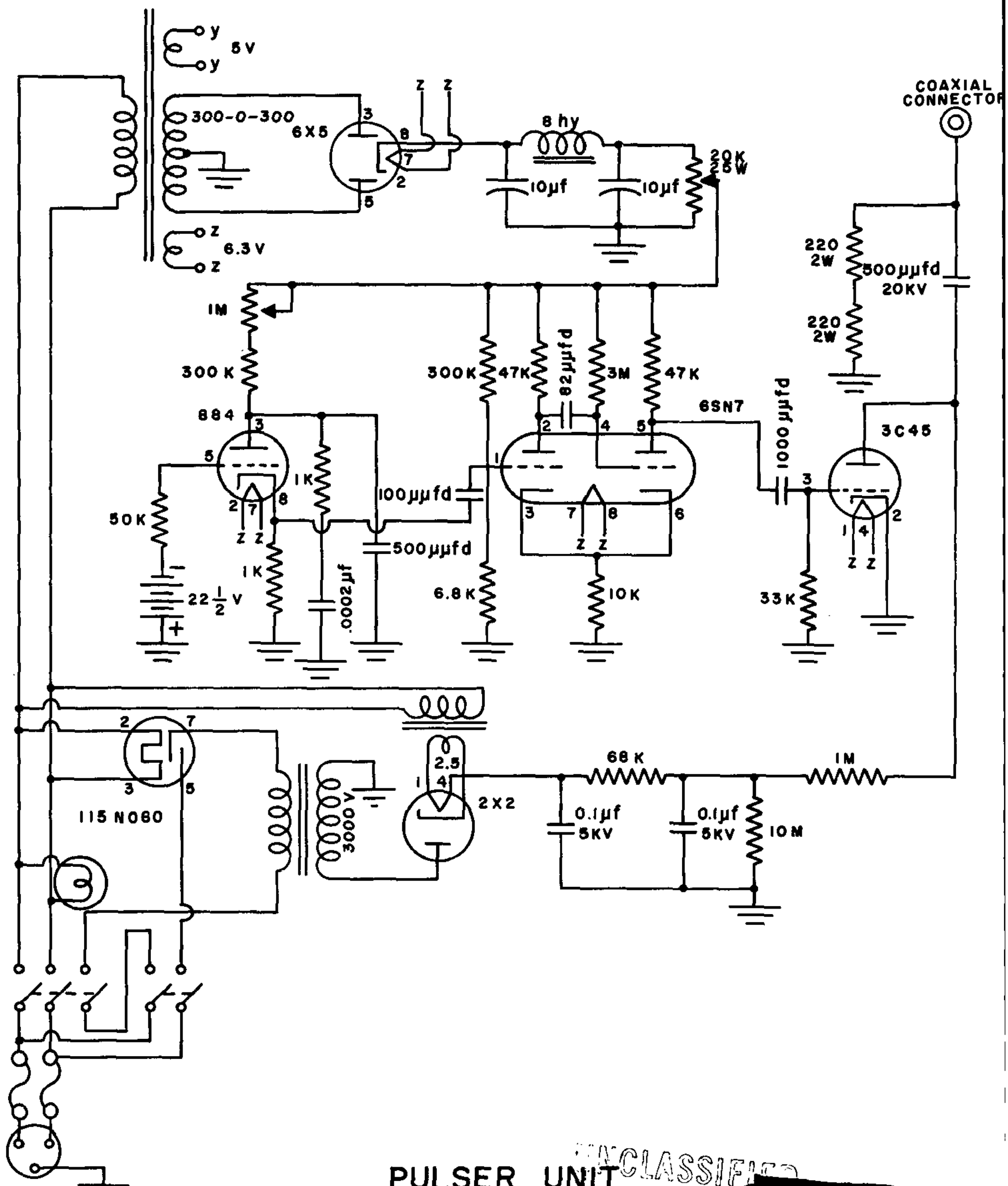
Figure 2

[redacted]



BLOCK DIAGRAM OF ULTRASONIC UNIT

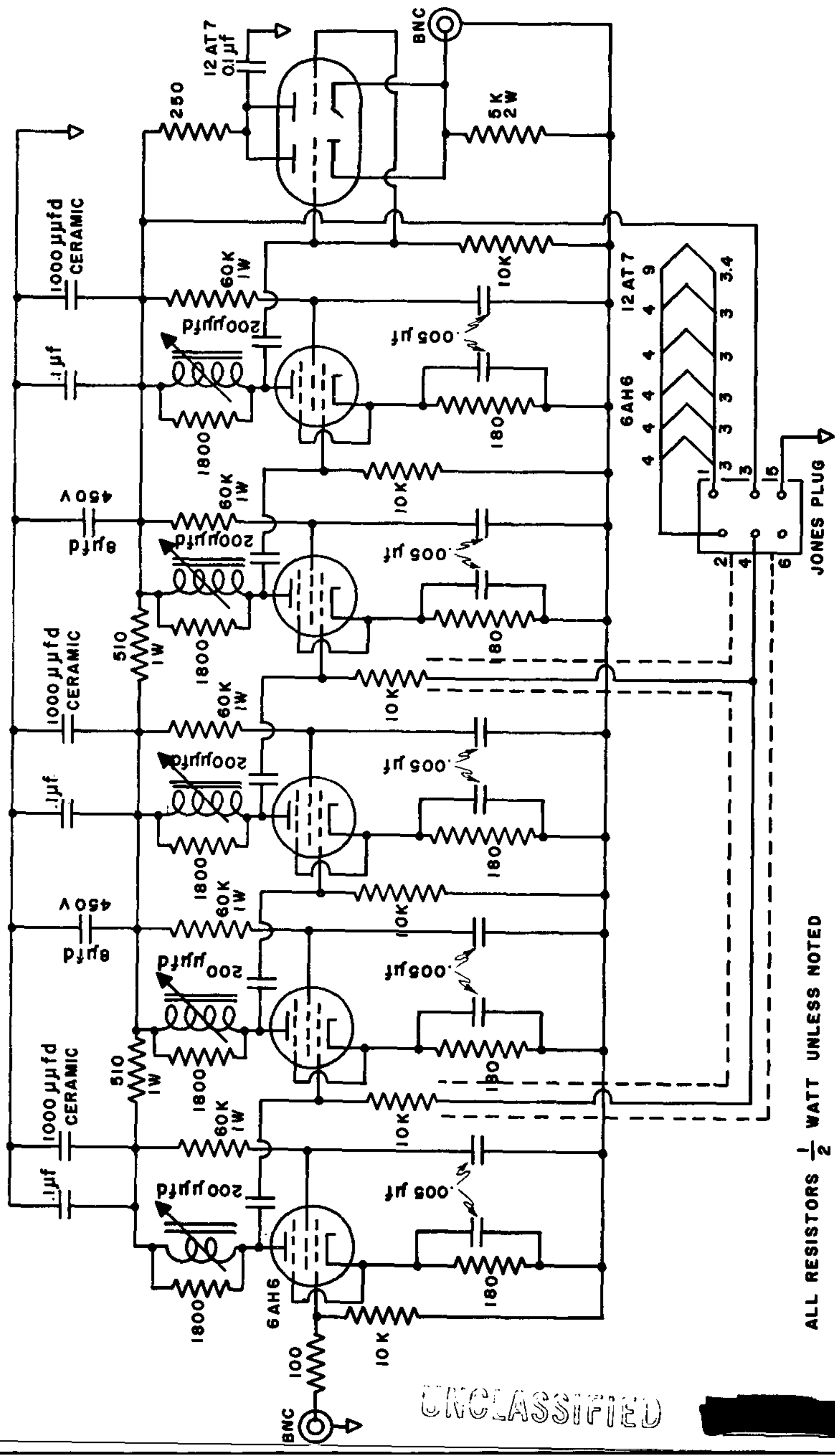
[redacted]



PULSER UNIT

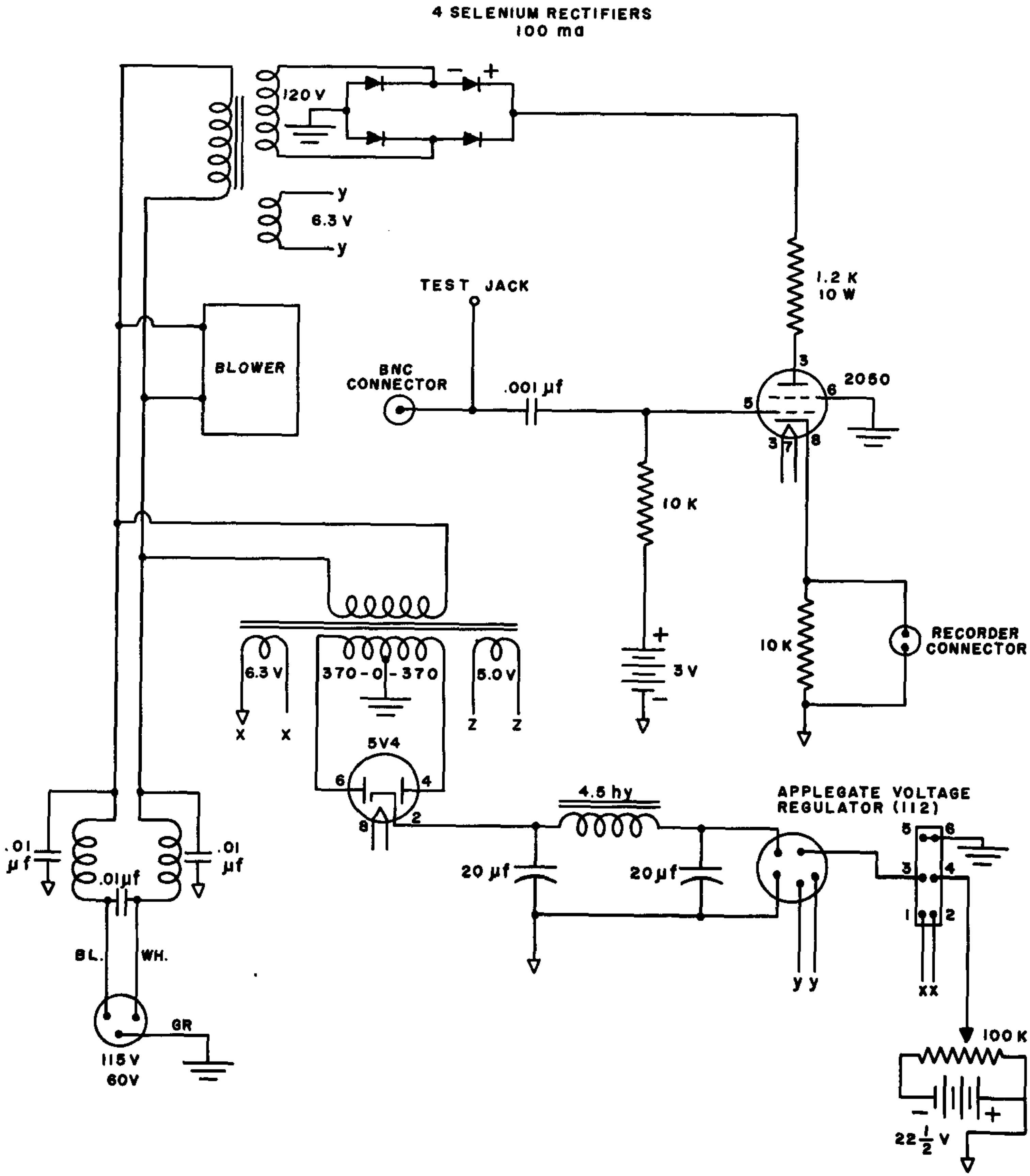
[redacted]

[redacted] Figure 4 UNCLASSIFIED

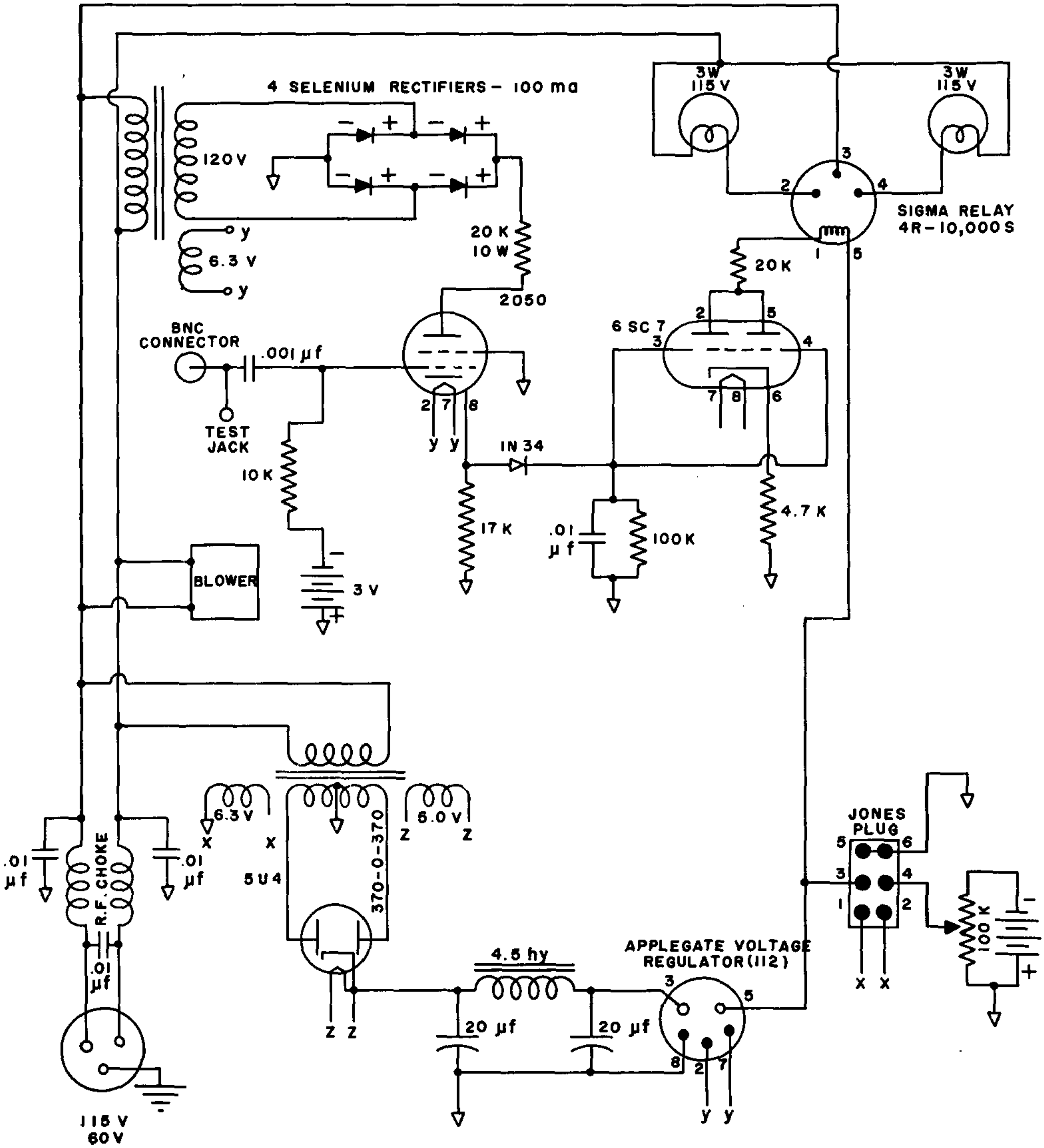


WIDE BAND CARRIER AMPLIFIER

UNCLASSIFIED [redacted]



NON-BOND DETECTION UNIT [redacted]

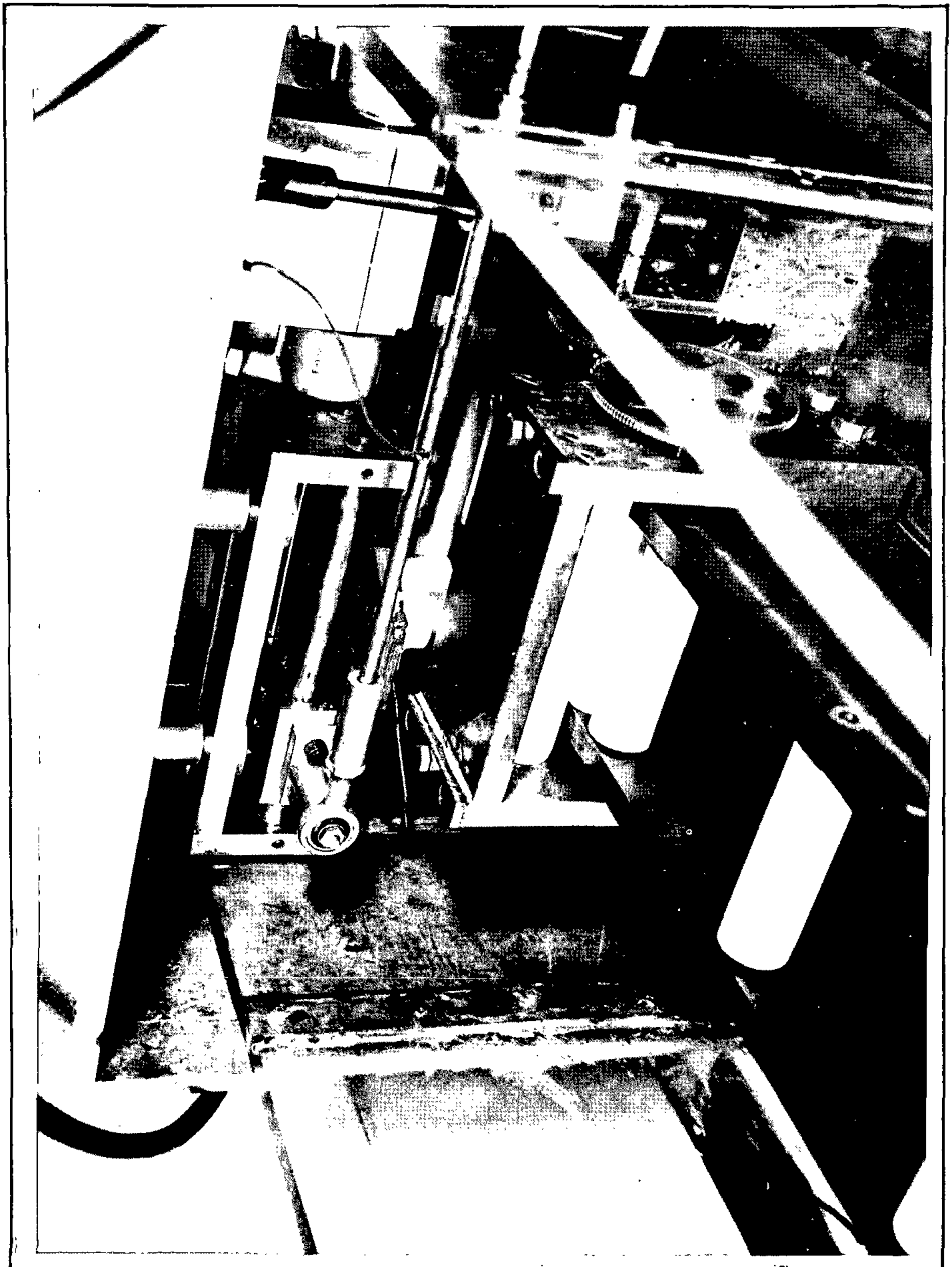


TRANSFORMATION DETECTOR UNIT

[redacted]

Figure 7

UNCLASSIFIED



SCANNING EQUIPMENT

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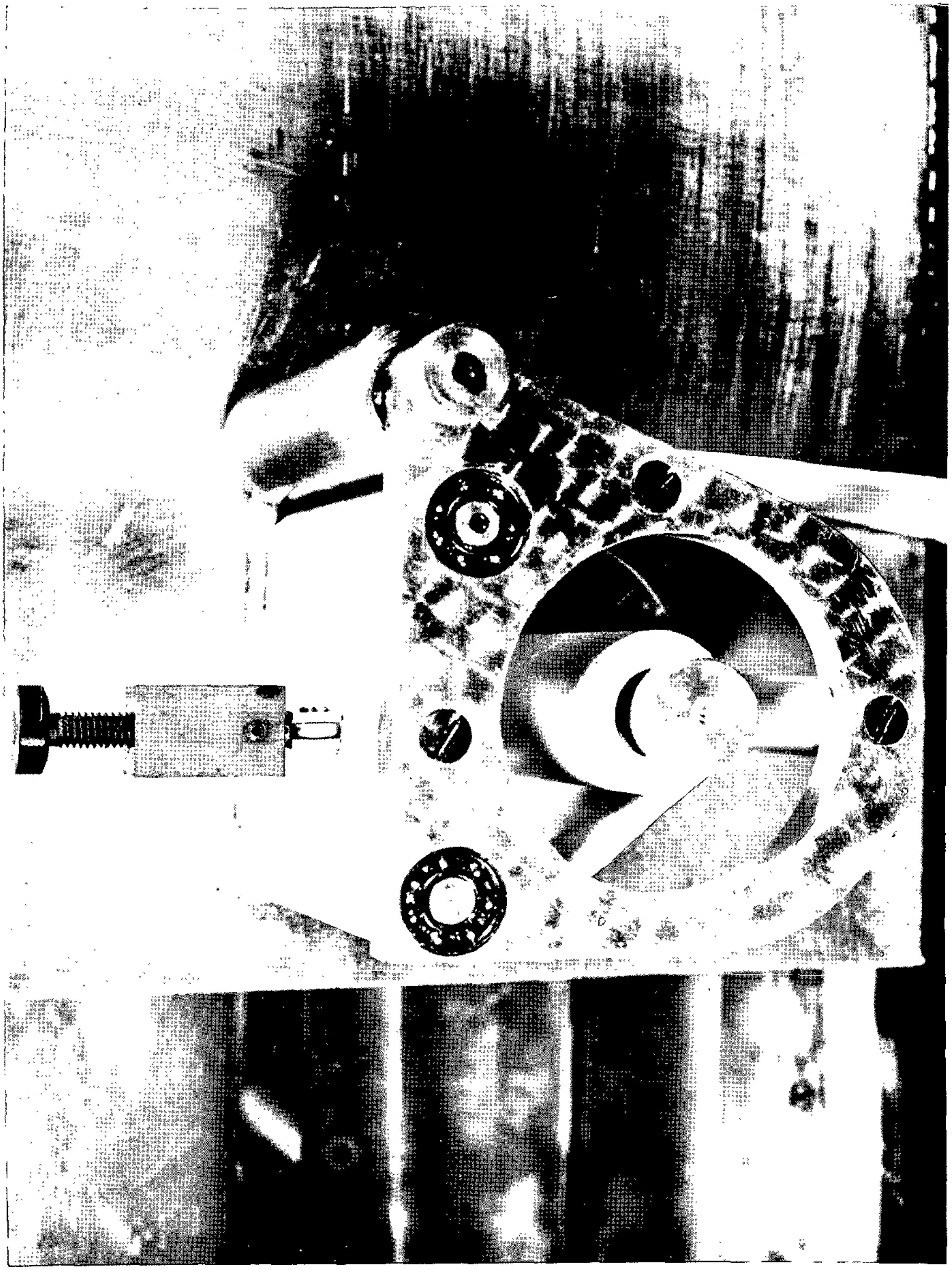
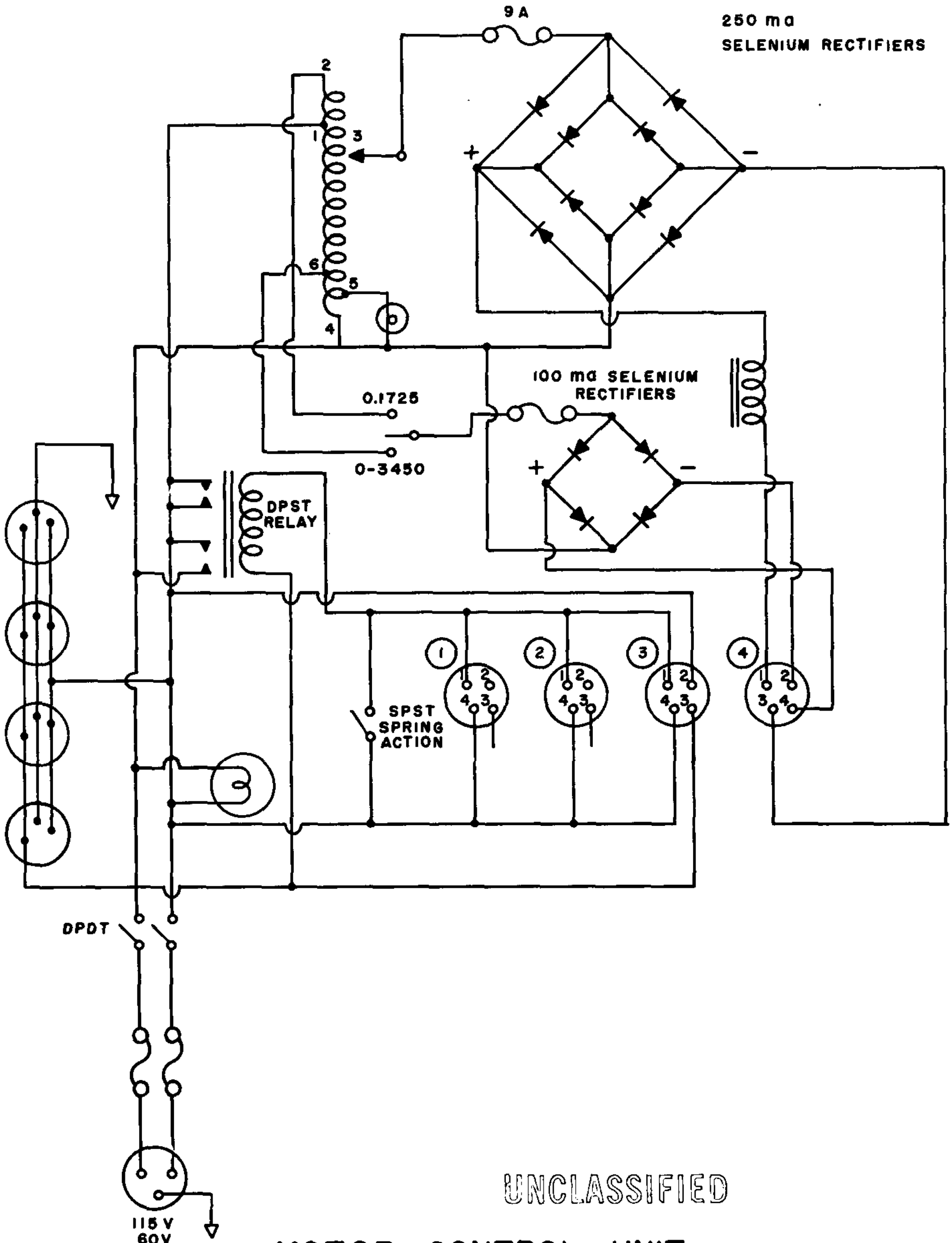


TWO DIMENSIONAL RECORDER



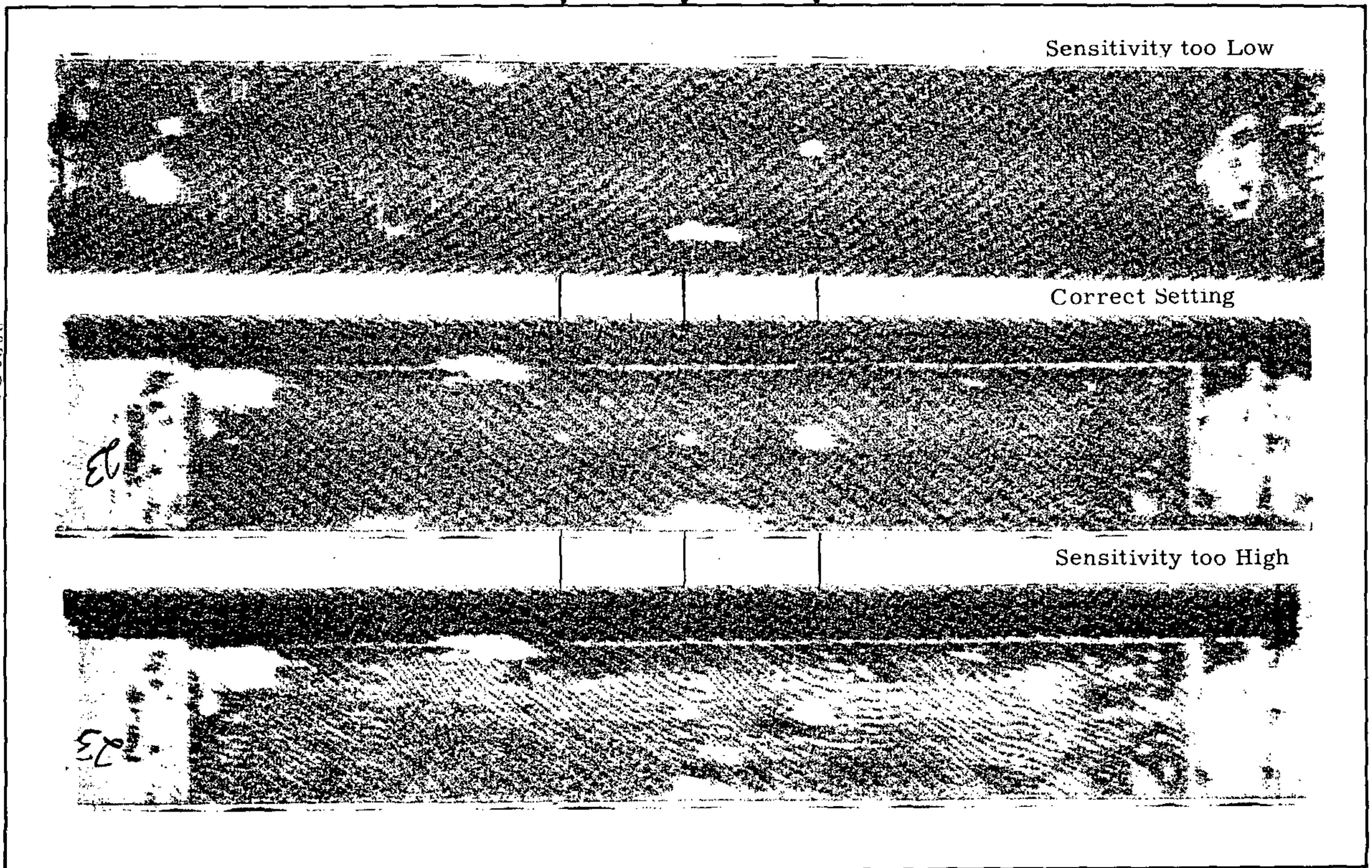
MOTOR CONTROL UNIT

[redacted]

THREE MANUFACTURED NON-BONDED AREAS

Diameters

1/8" 1/4" 1/2"



AREA DETECTED vs SENSITIVITY SETTING

[redacted]

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Figure 10

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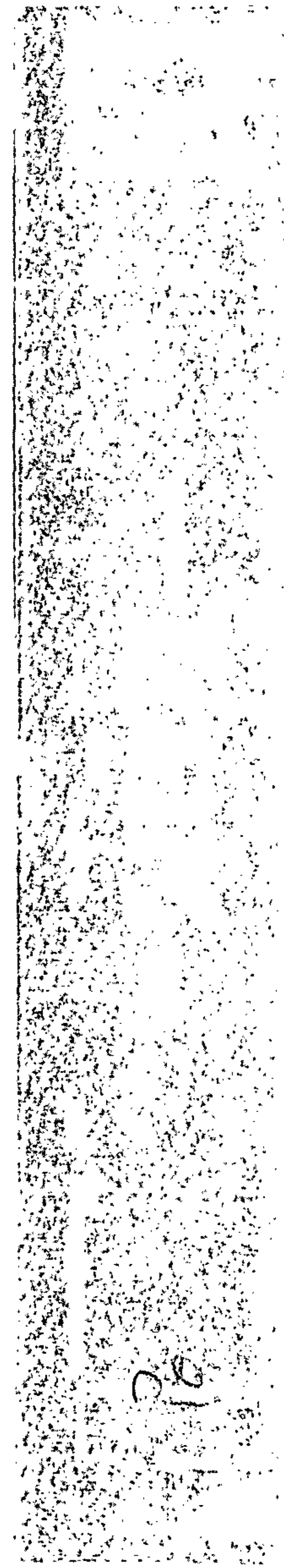
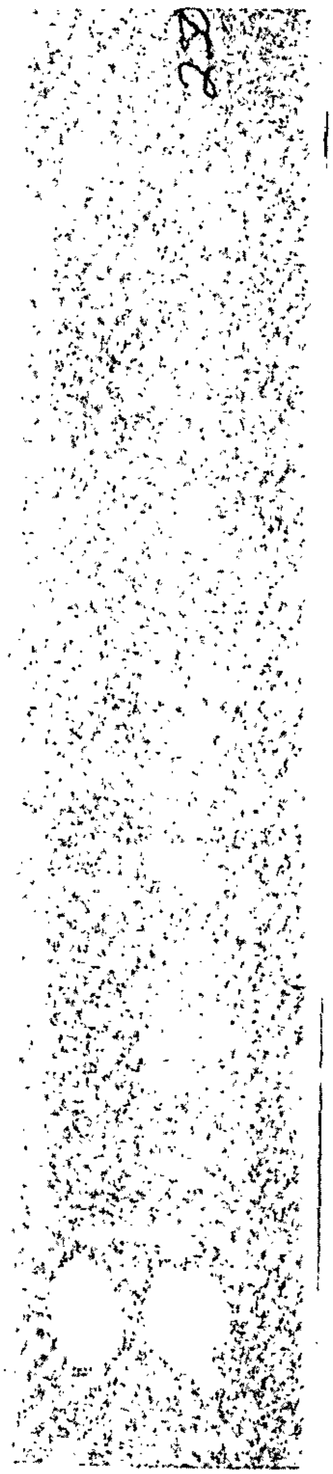


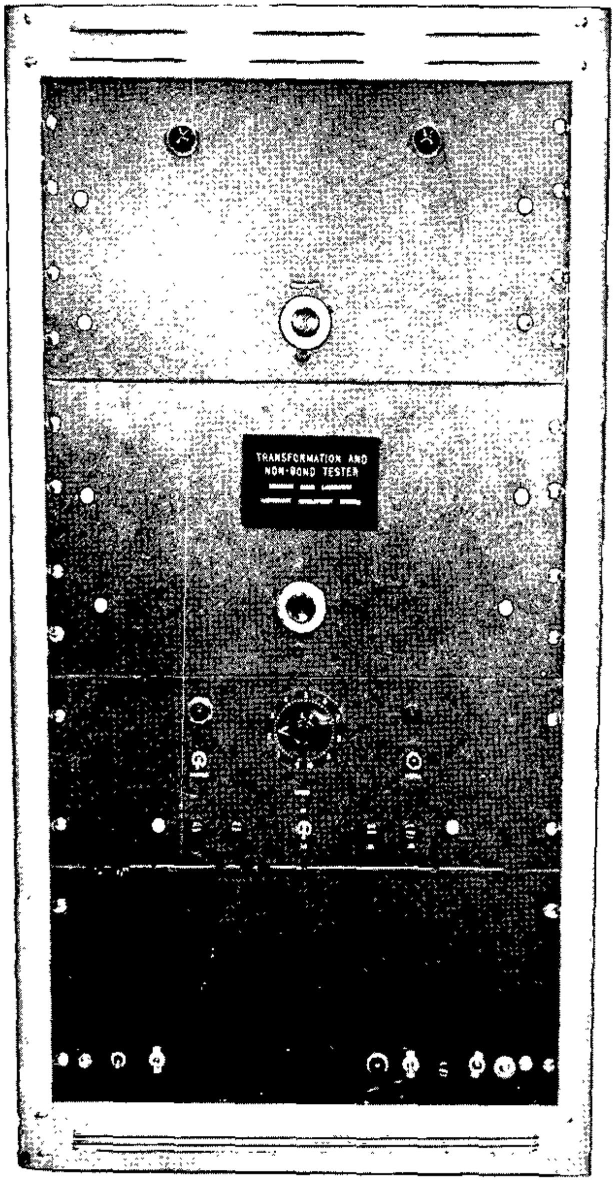
ULTRASONIC TEST PATTERN "WA7"

Figure 11



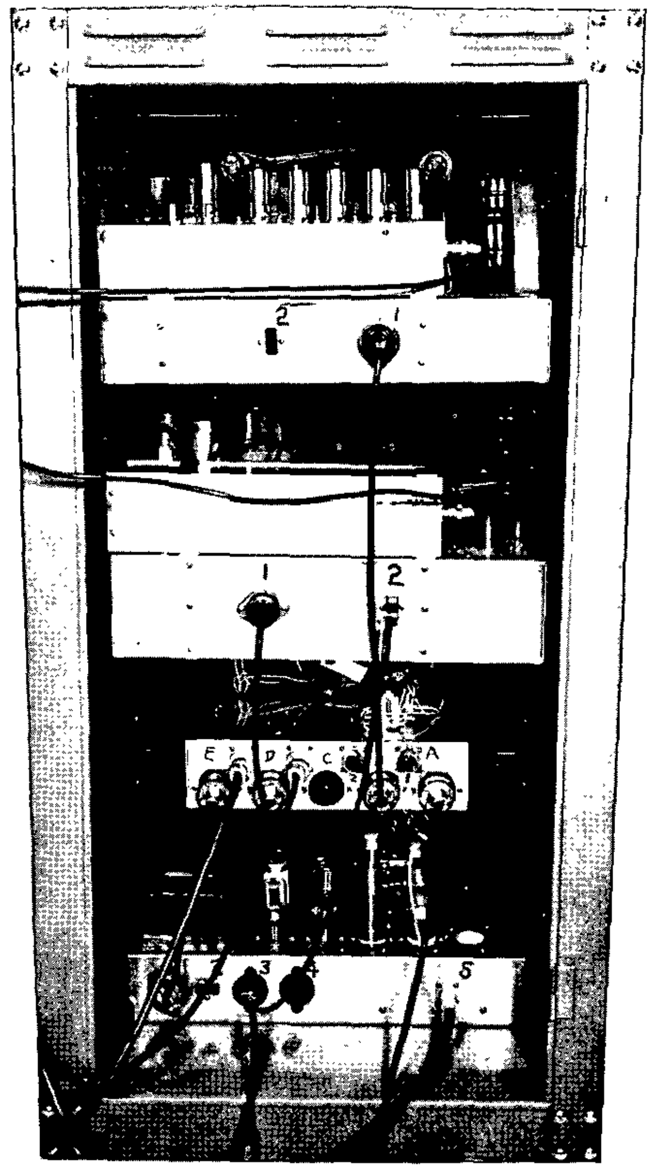
ULTRASONIC TEST PATTERN

Figure 12



FRONT PANEL
ARRANGEMENT

Figure 13



REAR CHASSIS
ARRANGEMENT

Figure 14

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APPENDIX

OPERATING INSTRUCTIONS

Reference should be made to Figures 9, 13, and 14 when following operating instructions.

1. Connect 110-120 volt, 60-cycle line to the male instrument plug no. A on the motor control unit.

2. Connect instrument plug no. B on motor control unit with motor plug no. 2 on the detection unit.

3. Connect instrument plug no. E on the motor control unit with the instrument plug no. 1 on the pulser unit.

4. Connect the 4-prong connector no. 4 on the motor control unit to the 5-prong connector on scanning mechanism.

5. Connect the 4-prong connector no. 3 on the motor control unit to the 3-prong connector on the scanning mechanism.

6. Connect the Jones plug no. 1 on the non-bond detection unit to the Jones plug no. 3 on the pulser unit and in turn to the 3-prong connector on the scanning mechanism.

7. Connect the RG-11/U cable from the transmitting transducer to the Amphenol connector no. 5 on the pulser unit.

8. Connect the BNC connectors, adjacent to the 12AT7 tube on both wide band amplifiers, to the BNC connectors adjacent to the voltage regulators on both detection units.

9. Connect the 6-prong Jones connectors on both wide band amplifiers to the 6-prong Jones connectors on both detection units.

10. Connect both of the RG-62/U cables from the receiving transducers to the respective BNC connectors on the ends of both wide band amplifiers.

11. Connect the instrument plug no. C on the motor control unit to the instrument plug no. 1 on the transformation detection unit.

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12. Turn on the master switch on the motor control unit front panel. This switch controls all operations of the ultrasonic unit.

13. Turn off recorder switch on the pulser unit. Recorder switch is turned on only when recording trace is desired.

14. Turn on power switch and pulser switch on the pulser unit. A built-in time delay will prevent the pulser from operating until a minute has elapsed. BE SURE TO TURN OFF PULSER SWITCH WHEN MAKING ADJUSTMENTS. DANGER, HIGH VOLTAGE.

15. Adjust the sensitivity control on the non-bond detection unit until sharp distinct pulses are seen with an oscilloscope attached to the test jack. Interrupting the ultrasound beam will cause the pulses to disappear from the scope face.

16. Connect air hose to air valve mounted on the scanning mechanism.

17. Press the motor switch button on the motor control unit to start and stop the scanning mechanism. Adjust the air valve for the desired rate of reciprocation. Adjust the speed control so that the recorder yields a solid color trace.

18. Turn on the recorder switch to record on the electrosensitive paper. Adjust the sensitivity control until the recordings of typical standard fuel elements indicate proper operation.

19. Adjust the sensitivity control on the transformation detection unit so that the green panel light is lit when a transformed standard is inserted between the transducers and the red light is lit when a non-transformed portion is inserted.

20. For grain size measurements, an oscilloscope should be attached to the test jack on the detection unit and the pulse heights measured for each sample tested.

21. A water softener should be added to the water to prevent the formation of air bubbles on the test sample.

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MAINTENANCE GUIDE

The localization of malfunctions of the ultrasonic fuel element tester should follow the same general procedure used in trouble-shooting other electronic equipment. The method depends upon the symptoms which generally fall into two broad categories. There may be (1) complete failure of the instrument or a component unit, or there may be (2) erratic operation or low sensitivity.

Complete failure of the instrument is usually due to a failure in the power supplies. Following normal trouble-shooting techniques, a check should be made of line fuses and rectifier tubes (Pulser Unit, check 6x5 and 2x2 tubes; Detection Unit, check 5V4 tubes). Blown line fuses can be caused by: (a) excessive line voltage; (b) shorted rectifier tubes; (c) defective transformers; (d) defective filter capacitors; (e) defective filter chokes; and (f) any defective component or tube that would cause abnormal current drain.

Defects of the second classification are not as simple to locate as those of the first. The various units of the instrument will be covered in detail, but tube checks should be made first.

Pulser Unit HIGH VOLTAGE IS USED IN THE PULSER UNIT (3000 VOLTS). OBSERVE SAFETY PRECAUTIONS AT ALL TIMES. TURN OFF PULSER SWITCH BEFORE MAKING ADJUSTMENTS.

Defective operation of the Pulser Unit is usually characterized by loss of sensitivity and little or no transmitted pulse. While any component in the circuit can cause trouble if defective, the major cause is usually the thyratron tube (3C45) or a defective transmitting transducer assembly. Under normal operating conditions, the pulser tube has a characteristic audible hum. Failure to hear this hum immediately localizes the defect to the pulser unit. If water gets into the transmitting transducer assembly, the ultrasonic signal will be weakened. If the pulse rate generator fails to produce a triggering pulse, the voltage of the bias battery for the 884 thyratron should be checked.

Wide Band Amplifier Amplifier failure will ordinarily be caused by one or more defective 6AH6 tubes. The presence of faulty 6AH6 tubes is characterized by a loss of gain. If the amplifier is operating properly, tube noise can be seen on an oscilloscope connected to the test jack, with the gain control turned in the extreme clockwise position and no input signal to the amplifier. If the wide-band amplifier oscillates at full gain, a slight reduction of the gain is required. If the amplifier is carefully tuned initially, it should need no further adjustment.

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Detection Units A failure in the detection units is characterized by a lack of gain control or failure to detect known defects. The major cause of failure will probably be improper firing action of the 2050 thyratron resulting from (1) a faulty 2050 tube; (2) weakened bias battery; or (3) stray pick-up from the transmitted pulse. The transducer assembly and electrical circuitry must be carefully shielded to prevent high voltage excitation pulses and microswitch transients from feeding through to the grid of the 2050 thyratron. Under normal operating conditions, pulses will not be seen on a CRO attached to the test jack when a non-bonded area interrupts the ultrasonic beam. If the thyratron is triggered when the beam of ultrasound is interrupted, additional shielding is required.

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Maintenance Guide

Symptom	Test Procedure
1. Lack of pulser hum. Failure to obtain pulses at test jack.	(a) Check for open or shorted coaxial cables. (b) Check or replace the 3C45 thyratron in pulser. (c) Water in transducer assemblies. Resistance between coaxial connector and ground should be above 1 megohm.
2. Recorder prints continually, with or without pulser operating. Red Panel indicator on continuously.	(a) Determine if wide band amplifier is oscillating by attaching oscilloscope to the test jack. (b) Check bias supply on the detection units.
3. Failure of instrument to detect standard defects.	(a) Pick-up from H.V. excitation pulse impressed on detection unit. Indicated by pulses on oscilloscope attached to test jack, with ultrasonic beam interrupted.
4. Lack of control with sensitivity control. Instrument too sensitive. Recorder prints erratically. Panel lights flash erratically.	(a) Test 6AH6 tubes on amplifiers. (b) Test bias supply for wide band amplifier. Should be continuously variable from 0 to 22-1/2 volts with gain control. (c) Test negative bias on 2050 thyratron, 0-3 volts.
5. Reciprocating mechanism inoperative.	(a) Test for open circuited RF filter choke inside scanning mechanism.

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