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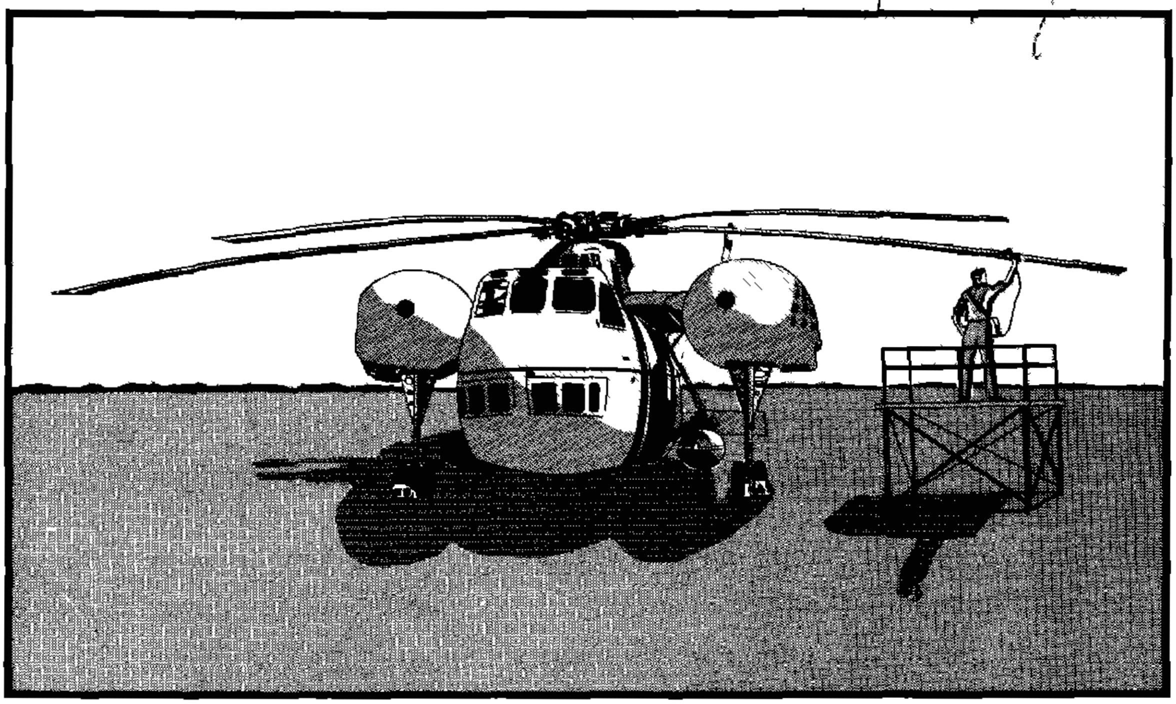

FINAL REPORT

DEVELOPMENT OF GENERAL SPECIFICATIONS FOR A DEVICE FOR INSPECTING HELICOPTER BLADE BONDING

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Prepared by

TEST AND EXPERIMENTATION DIVISION
Atlantic City New Jersey

Development of General Specifications for a Device

For Inspecting Helicopter Blade Bonding

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This report has been reviewed and is approved for distribution.

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ABSTRACT

An experimental helicopter blade bonding inspection device was developed and tested on various representative samples of blade construction. The data accumulated from these tests provided a technical basis upon which the specifications were written for a portable field-type device to detect nonhomogeneity in helicopter blade bonding.

PURPOSE

The purpose of this task assignment was to develop specifications under contract with the Office of the Chief of Army Transportation to form a guide for the construction of a prototype army helicopter blade bonding inspection device.

SUMMARY

This report describes the development of specifications for a practical, nondestructive field testing device for inspecting adhesive-bonded helicopter rotor blades and other similar adhesive-bonded aircraft structures.

An experimental device called a Flawmeter was developed to determine the practicability of such an instrument, and to obtain technical background information which could be used for preparing specifications for prototype equipment. The universally used coin-tapping method of locating flaws in adhesive-bonded structures formed the basis for the development of the Flawmeter. Coin-tapping is simple and fairly reliable, but it is limited to use in quiet locations, and the results are only qualitative.

The difference in the coin-tap sound for good and for poor bonds, so readily distinguished by the human ear, was analyzed. From this analysis, a precision, electronic tapping device with a meter indicator or Flawmeter was designed and built.

In a series of tests using the experimental Flawmeter on seven representative structural test panels, not only were the poorly bonded areas correctly indicated, but the vagaries of adhesive flow and differences in structural solidity were clearly indicated, thereby demonstrating the practicability of using the Flawmeter as a field testing instrument.

INTRODUCTION

Under contract with the Office of the Chief of Army Transportation dated December 11, 1956, the Civil Aeronautics Administration (CAA) Technical Development Center (TDC) undertook the development of specifications for a field-type device for inspecting helicopter rotor blade bonding. A three-phase program was established (1) to investigate methods for nondestructive testing, (2) to develop specifications for a testing device, and (3) to develop a prototype testing instrument. This report covers the second phase of the program. The first phase of the program is described in a previous report.[1]

The investigation conducted in the first phase of the program revealed that there were two practical methods of testing adhesive bonds: (1) by means of ultrasonics, and (2) by coin tapping.[2] These methods are not readily adaptable to field use. The ultrasonic equipment is large and the indication of areas of poor bonding is complex. The coin-tapping method is dependent on aural interpretation and therefore, is subject to sound interference and differences in individual hearing and judgment. To produce a usable field testing device, it appeared that the most practical approach would be to develop a device based on the coin-tapping method but which can present reproducible, precise indications of the bond quality

The requisites for such indications are (1) at least one discrete difference in the tap sound between a good bond and a poor bond or void area, (2) exact reproducibility of the tap sound at a sufficiently high rate to give the effect of a periodic or continuous sound, thereby giving a steady response on a meter-indicator, and (3) to be practical for field use, the device should be rugged and

[1]Robert C. Mulvey and Marion J. Arvin, "Some Methods for Inspecting Adhesive-Bonded Joints in Helicopter Rotor Blades," Technical Development Report No. 371, September 1958.

[2]Ultrasonic test devices use an oscilloscope display of differences in waveform, reflected from a crystal probe held against the surface to be tested, to indicate bond quality. Coin-tapping inspection is done by tapping the surface over the bond with the edge of a half-dollar or similar object. The difference in the tap sound over good and poor bonding is distinguishable.

compact, have low power drains, and be relatively free from effects of extraneous noise

In undertaking the study, it was decided first to determine the difference in tap sounds over good and poor bonds, and secondly, to determine the reproducibility of the sound waves From these data, it was believed possible to develop a circuit for distinguishing or indicating the quality of the bond.

CHARACTERISTICS OF TAP SOUNDS

In the first phase of this program,[3] seven test panels were built with known areas of poor bonding or voids to provide accurate, known conditions of bonding or lack of bonding in various types of structure. See Fig. 1, where the areas of poor bonding in several structures are outlined. The most prominent areas of poor bonding or voids under thin cover sheets could be located readily by coin-tapping. These panels were used in the investigation and development of the experimental device described in this report Panels 2, 4, and 5 were used to provide clear-cut indications of bond quality.

During the first phase of the program, tests were conducted with electrically driven, continuous but erratic, tapping devices. The sound caused by the tapping was picked up by a microphone, amplified, and fed to a voltmeter that indicated the amplitude of the sound These tests showed that there was some, but evidently unreliable, relation between the amplitude or loudness of the tap sound and the condition of the bond. Therefore, it was decided to investigate the exact difference in tap sounds as heard and interpreted by the ear between areas of good and poor bonding. For this purpose, it first was necessary to devise a means of producing taps of exactly the same impact force and of exactly the same duration of the tapper dwell or contact time on any surface being struck. An approximation of tapper dwell time, in hand coin-tapping, was found to be 54 milliseconds.

An electronically controlled, single-tap device was designed and built See Fig. 2 With this device, the tap force and the duration of tap dwell could be controlled by adjustment of the timing capacitor, as shown in Fig. 3 A tap was produced for each push on the control-switch button. In operation, the button was released to discharge the

[3]Mulvey and Arvin, op cit.

capacitor before another tap was produced Starting with the 54-millisecond value, it was found that the tapper dwell time should be as short as practicable. The sound of the single taps of the device was picked up by a microphone and fed to an oscilloscope. The oscilloscope trace was triggered by the tapper control switch, so that pressing the switch button started both the trace and the tap simultaneously.

The oscilloscope displays of typical sound waves as shown in Fig 4A and 4B illustrate tap sounds over good bonding, Fig. 4A, and over poor bonding, Fig. 4B. It will be noted that the trace in Fig. 4A shows an essentially constant frequency of 2,500 cycles per second (cps), whereas the frequency of the trace in Fig. 4B decreases as the wave dies away. The trace pattern over a void area, as shown in Fig. 4B, indicates a beat between a low frequency and the higher impact frequency, thereby producing the notched appearance to the sound wave. The readily measurable amplitudes of the sound wave of a nondestructive tap are seen to have a duration of approximately 8 milliseconds. The difference in sound between the waves in Fig. 4A and 4B, as heard by the human ear, is that the sound caused by poorly bonded or void areas causes an admixture of lower tones to follow the initial impact sound. The resulting damped sound waves were reproduced precisely with each tap. It was apparent that a tapper driven to strike at the end of the decay of each preceding tap sound wave, that is, every 8 milliseconds (125 taps per second), would produce a periodic train of damped waves which could be analyzed, and with suitable circuitry, indicate the difference between good and poor bonds or void areas.

An experimental tapping device suitable for operation at the desired frequency of 125 taps per second was designed and built using a tuned steel reed carrying a hammer. A rectangular wave driver was used to provide a sudden application and release of the hammer. The rectangular wave for the driver was derived from a transistor multivibrator, amplified, and applied to the coil of the reed-type tapper. See Fig. 5A. This tapper was improved by substituting wheels for the back skids, and a nylon foot in place of the screw, as shown in Fig. 5B. The precise drive and resulting exact duplication of the sound waves, obtained with the electronically driven tapper, are shown in the three separate exposures, taken 1 minute apart, in Fig. 6. The pulse that drives the reed is applied after the reed hammer has struck the surface. This phase shift gives the most vigorous reed swing. The exact time of each wave train is

7.8 milliseconds, with power on for 3.5 milliseconds. Each division in Fig. 6 represents 2 milliseconds.

The hammer dwell time for the reed-type tapper is shown in Fig. 7A and 7B. Fig. 7A illustrates the short dwell over a firm structure (No. 5 panel), the dwell time being approximately 0.8 millisecond. Fig. 7B illustrates the dwell time over a loose surface facing within the square area of the No. 5 panel. The hammer dwell time increased, due to yielding of the metal, to approximately 3 milliseconds.

INDICATOR

The characteristic difference in the sound waves between good and poor bonds was shown to be an admixture of lower frequencies of relatively high amplitude as the bond deteriorated. Over a good bond, the resulting sound consists of short (approximately 2-millisecond) bursts spaced approximately 6 milliseconds, but over a poor bond, the sound wave will be almost continuous due to the low frequencies of high amplitude that follow the impact. This would indicate the need for an indicator circuit in which the output current or voltage developed by tne damped sound wave input would be proportional to the decrease in frequency.

The circuit developed for the Flawmeter makes use of the difference in the amount of sound fill-in of the 8-millisecond time intervals. A microphone converts the sound into electrical pulses, and the current is fed to an electric meter. Over a good bond, there is only the tap impact sound, followed by 6 milliseconds of silence. This condition will give a very low total average current for the time period, but over a poor bond, the sound is almost continuous, giving a large total average current for the time period. A circuit is arranged to integrate or average the sound.

The circuit used in the experimental Flawmeter is illustrated in Fig. 8, where C and R form an integrating circuit. The diodes, D1 and D2, serve as an automatic switch, sending the plus polarity half-pulses to ground through D2 and the negative polarity half-pulses charge capacitor C through D1. Capacitor C can discharge only through the resistance R and the small resistance of the base-to-emitter of the transistor VT1, thus causing the meter M to deflect in accordance with the average charge and discharge current of C Hence, over a good bond, when the sound waves are composed of pulses separated by about 6 milliseconds, the meter will read low, whereas over a poor bond with almost continuous sound pulses, the meter will read full scale.

The requisite for use of the integrating circuit is that the amplitude, or volume, variation of the sound must be eliminated as much as possible so that only the frequency or pulse difference remains. The sound received at point A of Fig. 8 is shown amplified in Fig. 9A, however, the amplification is not as great for Fig. 9A as it is in Fig. 9B, as will be noted by the difference in the indicated limiting levels. The sound is both amplified and limited, in amplitude, in the transistor amplifier of Fig. 8, as shown in Fig. 9B. The sweep rate for the oscilloscope writing beam for the pictures of Fig. 9 was 5 milliseconds per centimeter, which is the distance between the grid lines.

Fig. 10 illustrates the meter used to indicate the conditions of the bonding. Sector 0 - 3 of the meter is colored green for good, sector 3 - 6 is colored orange for poor, and the final sector, 6 - 10, is colored red for very bad. The larger the reading, the poorer the bonding. Any upscale movement of the meter needle indicates a decrease in bond quality. Over box-type structures, the needle reads higher because of the open or void condition of the box; however, the meter will indicate a poor bond over such a box section by a slight rise above the basic reading for the good box section.

An investigation of a direct frequency comparison circuit also was made. The circuit is shown in Fig. 11A. The component values were assigned for a frequency difference of 2,000 to 500 cycles per tap sound. The test setup for the circuit is shown in Fig. 11B.

A level of 12 volts was maintained at the input, and the frequency was varied from 4,000 cycles down to 200 cycles, and the output voltage read on the vacuum tube voltmeter

Frequency (cps)	Volts Output
4,000	2.8
2,000	2.9
1,000	3.35
500	3.95
400	4.1
200	4.95

The results obtained with the circuit of Fig. 11A, as compared to the counting type of indicator circuit actually used in the Flawmeter, produced a more sharply defined indication on test panel No. 5 (Fig. 1) but not as good an indication when used on the heavy steel test panel, No. 2. It has been noted that both the impact and lower following frequencies over poor bonding on test panel No. 2 were higher in frequency than those obtained on test panel No. 5. The direct frequency comparison circuit should be investigated further.

CONSTRUCTION OF A PRACTICAL TEST DEVICE

a. Reed-Type Tapper: The original reed-type tapper, shown in Fig. 5A, was evolved from a Mallory autoradio vibrator, which is designed to vibrate at 115 cycles or 115 taps per second. The vibrator was dismantled, the contacts removed, and the drive coil was rewound with the coil insulated from the frame, using Mallory specifications of 2,788 turns of No. 35 enameled copper wire. The insulating reed support stack was replaced with steel to give a better magnetic circuit. A clamping plate was used on both sides of the reed, as a crude adjustment for the active reed length, to tune the reed for the best swing. A flathead, 1/8-inch by 1/2-inch, anodized, aluminum rivet was bonded to the center of the reed weight, and the small end of the rivet slightly rounded off as a hammer face. A hole was punched in the reed to allow the tap sound to impinge directly on the microphone.

The original three-skid-type supports gave squeaks which were eliminated by using wheels at the rear and a Teflon skid 1/2-inch behind the hammer. The skid being so near the hammer slightly damps the higher frequency impact sound of the hammer but does not interfere seriously with the total sound. The close location of the skid to the hammer was found to be necessary to allow the hammer to follow concave surfaces.

b. Driving Circuit: The transistor multivibrator and driver circuit were developed empirically. Formulations for such circuitry have not yet been developed A Type 2N109 transistor was chosen for its high current rating, necessary for quick switching and good rectangular waveform. The CK722 coupling transistor reduces the load on the multivibrator and provides the base current necessary to drive the 2N270 output transistor.

The accuracy of the Flawmeter depends on the precisely spaced taps. This precision is obtained from a resistancecapacitance tuned multivibrator, the tuned steel reed, and proper adjustment of the length of the drive pulse. The resistance values of the multivibrator were adjusted to the point where any combination of two out of six 2N109 transistors could be used. The coupling capacitors were chosen for their low temperature coefficient.

It was found that the apparent limits for the spacing of the taps was 7 to 10 milliseconds. Although one speed change was caused by a transistor failure and several interruptions were caused by steel particles, picked up by the reed and magnet, very little trouble was encountered with the tapper. For the final field device, the multivibrator circuitry will need revising to provide for temperature stabilizing of the transistors.

c. Microphone: A suitable, very small, directional microphone to pick up the sound of the taps proved a difficult problem, not only did it have to be small, but also capable of being mounted near the hammer so as to exclude extraneous noise and pick up only the tap sound. The answer to this problem was the use of a dynamic-type earphone from a hearing aid, mounted in foam rubber.

The magnetic field of the driver coil affected the microphone, until it was mounted above a steel plate over the frame of the vibrator. See Figs. 12 and 13. The dynamic-type microphone is preferred to a crystal, as it is much more weatherproof.

d. Amplifier It was decided to build a compact hand-held device for the test work. This limited the space available for the amplifier-voltmeter. Only half-watt size resistors and 1N38A diodes were available for the initial work. The rather large size of these units further restricted the space and necessitated the most simple form of circuitry. A suitable limiting transistor amplifier was empirically designed, using an oscilloscope to determine the resistance values required to give the necessary amplification and limiting. The values chosen gave the required action, but operated the transistors at such low current and voltage values as to give trouble. Some investigative work had been done on properly stabilized transistor circuits but the required limiting action was difficult. The output of a simple transistor-balanced voltmeter circuit was used to drive the indicating meter. Details of the experimental assembly are shown in Figs. 14 and 15.

One amplifier may not cover the range of light to heavy panels without some form of volume or sensitivity control. The amplifier might be placed in the carrying case, but this requires a multiwire cable with the microphone wires shielded. Therefore, all of the circuitry was built into the tapper-indicator unit and only batteries are located in the carrying case. The complete experimental Flawmeter including the carrying case is shown in Fig. 16.

TEST RESULTS

The seven test pannels shown in Fig. 1 were constructed to duplicate the various types of structure used in helicopter blades. The areas outlined in white were intended as known areas of no bonding, however, the bonding material, being a viscous paste, flowed into some of the areas where no bond was intended. The bonding material is transparent to X-rays. Therefore, in hidden places, there is no sure way to ascertain the exact boundaries of the unbonded areas. Where the unbonded areas can be seen or probed from the outside, the readings of the Flawmeter check correctly. Therefore, the Flawmeter readings should be considered as being correct in all places. The characteristic of the Flawmeter is that it indicates the relative solidity of the structure beneath the hammer

All test readings were made with the test panels lying on foam rubber 1 inch thick. The foam rubber insulates the test panel from the sound absorption of a hard bench top. It is not necessary to use the foam rubber when the structure being tested is suspended as a helicopter blade would be. Successful tests also were run on a blade section lying on corrugated cardboard box material.

a. Panel No. 1. Panel No. 1, Fig. 17, was prepared to determine the depth of penetration of any test device. It is constructed of alclad aluminum alloy. In constructing panel No 1, the two facing sheets first were assembled to the ribs. Bonding material was applied to all the surface of the top facing sheet except in the void areas, then a sheet covering the entire area of the facing sheet was laid down. On panel No. 1, the visible part of the first covering sheet is marked step 1. Succeeding sheets, each 1 1/2 inches shorter than its predecessor, were well bonded to the next lower sheet so as to form a series of steps or increments of .018-inch thickness of metal plus the thickness of the bonding material.

The numbers on panel No 1 in Fig. 17 are the Flawmeter readings. The higher the reading, the poorer the bonding or solidity of the structure. Note the horizontal row of figures on step 1. The readings over the hollow structure are much higher than the two readings over the ribs. The upper horizontal row of figures on step 8 shows that the meter indicates a lack of solidity caused by the edge of the structure. The dotted outlines clearly indicate actual void areas in the bonding beneath step 1.

Undoubtedly, the bonding material flowed under pressure, departing from the planned positions shown by the solid outlines The results shown on Fig. 17 indicate that the light tapping experimental Flawmeter is limited to a thickness of six or seven layers of .018-inch aluminum and bonding material.

b. Panel No. 2 (Fig. 18): Test panel No. 2 was constructed the same as panel No. 1 with three exceptions; the ribs of the base are parallel with the steps, the material of the test panel is stainless steel, and adhesive tape was used. Originally, the test panel had eight steps, but the eighth step was ripped off during the first phase of this project. The dotted outline shows the true areas of poor bond. The adhesive tape could not have flown or changed position during construction, therefore, abnormalities, namely, the reading of 4 in the upper right-hand corner of the upper dotted outline, the reading of 9 in the lower right-hand corner of the lower dotted outline, and the two readings of 4 in the center of step 4, all may be due to poor bonding between steps and outside of the intended void areas. The Flawmeter will not differentiate in depth of location of a poor bond or void in multilaminate structures, but it will detect a void.

All of the following panels, Nos 3 to 7, inclusive, were tested with a 120-ohm shunt on the meter to reduce sensitivity

c. Panel No. 3 (Fig 19). The interesting points brought out in the readings on the steel panel, No. 3, are the 10 plus readings, meaning off-scale, obtained over the hollow box structure as compared to the low readings of 2 over well-bonded rib parts. The rectangles marked on the panel show the areas of intended void, no bond condition. Note the intrusion of the bonding material into the lower end of the left-hand vertical rectangle, resulting in the 2.5 reading below the 9. Further, the readings of 10 over the left-hand vertical rectangular void area agree with the same complete lack of bond as is indicated by the 10 plus readings over the hollow box part of the structure.

d. Panel No. 4 (Fig. 20): This panel is of the same construction as panel No. 3 except that it is of 24S-T3 aluminum. Again, the Flawmeter indicates the open box structure by reading 10 plus, or off-scale, at the four points between the ribs. Two unplanned void locations over the ribs are outlined in dots. The plus mark before the upper right-hand 2.5, and before the right-hand 10 plus, are position marks used for good and bad reference during the development of the Flawmeter.

e. Panel No. 5 (Fig. 21). This 24S-T3 aluminum, honeycomb sandwich panel was used more than the other panels in developing the Flawmeter. The intended void areas of circle, square, and tee were determined easily by coin tapping. The single tap sound pictures A and B of Fig. 4 were taken with the tapper striking the spot marked X below the square and the plus in the square, respectively.

The intended void in the tee-shape suffered from flowing of the bonding material. The actual void is in the dotted area. This area was probed from the left edge with a very thin and narrow piece of metal. A small blister in the bonding is noted at the reading 5 near the bottom of the tee.

The circular area was badly dented by some of the earlier mechanical tappers so that the facing metal has been driven down against the core material. The dotted extension of the lower left corner of the square area is an unintended void.

f. Panel No. 6 (Fig. 22): Panel No. 6 is a 24S-T3 aluminum box structure bonded to a heavy 24S-T3 aluminum spar. Flawmeter readings over the open box structure are 10 plus as are the void areas over the ribs. The extreme left vertical column of readings show an edge effect, except for the 10 plus, over a blister above the tee-shaped void. The tee-shaped intended void shows flowing of the bonding material. Compare the edge readings with the readings of 1 over the web of the spar.

g. Panel No. 7 (Fig. 23): Panel No. 7 is a 24S-T3 aluminum box structure with the 24S-T3 aluminum face plates bonded to the inside of the spar flanges. The left-hand spar is 1/4-inch-thick 24S-T3 aluminum and the right-hand spar is 1/16-inch-thick steel. Void areas were intended under both spars, however, the configuration of the Flawmeter, involving the relation of wheel track to wheel-foot spacing, would not permit readings to be obtained over the narrow steel spar. The readings of 2 and 3 over the planned void area under the aluminum spar seem to indicate the existence of a void area though this indication should be classed properly as doubtful. The bonding of the ribs to the upper face sheet is much worse than was intended.

h. Tail Rotor Test (Figs. 24 and 25). The section of aluminum honeycomb sandwich tail rotor shown in Figs 24 and 25 was found to have a poor bond or void condition where it is marked. Note the reading of the meter over the good bonding shown in Fig. 24. Figure 25 illustrates the increased reading on the Flawmeter obtained over the void or poor bond area. Figure 26 shows the appearance and lack of bonding between the face sheet and the aluminum honeycomb. The edge was slotted with a jeweler's saw and the face sheet turned back

GENERAL SPECIFICATIONS

a. Device for Nondestructive Testing of Helicopter Blade Bonding The tapper-meter device generally should consist of three parts assembled together, part No. 1, a precision tapping device, part No. 2, a highly directive microphone, and part No. 3, a sound analyzing circuit, with indicating meter.

Part No. 1: A suitable hammer should be mounted on a steel reed, the reed to be mechanically tuned to the required frequency and driven by a temperature-compensated, precision, electronic circuit, such as a multivibrator and amplifier The frequency or speed of tapping is to be determined by the decay time of the individual tap sound. For light metal structures, it should be approximately 125 taps per second.

Part No. 2: A microphone having an output flat over the frequency range 4,000 down to 500 cycles per second. It should be of small physical size and highly directive in pickup, capable of being mounted so as to pick up the tap sound and exclude extraneous noise.

Part No. 3: A suitable, small, electronic, temperature-compensated amplifier to raise the output level of the microphone to a desirable level should be provided. The amplifier is to be self-limiting or feed a suitable limiting circuit. The limited output is to be fed to either a direct-frequency comparison circuit or a suitable counting circuit. The output of the frequency comparison or counting circuit is to feed an indicating voltmeter circuit. The meter should be similar to a small-size 0-1 milliampere meter.

OBSERVATIONS

1. The experimental Flawmeter not only reveals poor bond conditions not discernible by coin tapping but also has a distinct advantage over the far more complicated supersonic test methods in that the Flawmeter gives scalar values proportionate to the degree of departure from good bond conditions.

2. The analysis of tap sounds and the development of an experimental model Flawmeter opens up a number of possible developments in addition to further expansion of the basic principles of the Flawmeter.

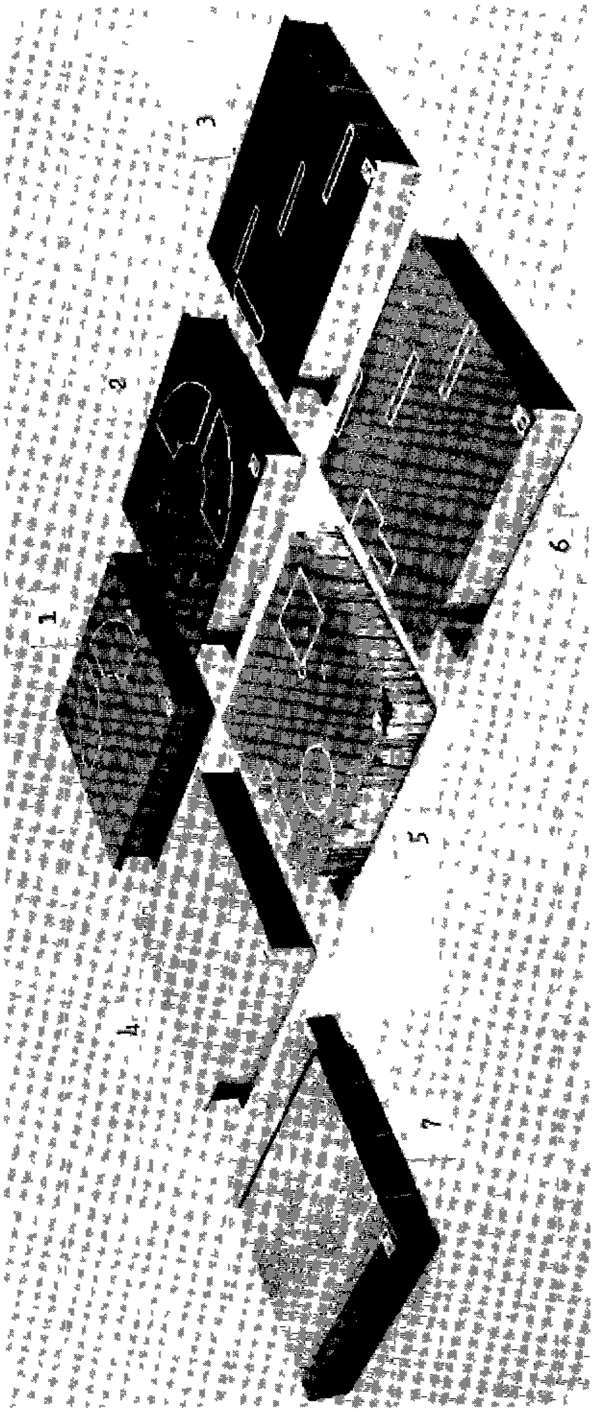
3. Sound analysis of such things as gear-box noises would indicate the type of circuitry needed to give indication of immenent failure or overload conditions.

4. The counting circuitry employed in the Flawmeter to count sound pulses also may be employed to count strains in such structures as rotor blades, wings, and other aircraft parts. The counts may be totalized in extremely small magnetic memory devices, with available read-out at any time, such as periodic inspections, with no disturbance of the total. The entire device could be of very small proportions.

5. Expansion of the basic principles of the Flawmeter may be used to inspect welded steel propellers, storage vessels, and other closed metal devices. The speed of tapping and interpreting circuitry will be determined by the type of tap sound inherent to the article being tested.

RECOMMENDATIONS

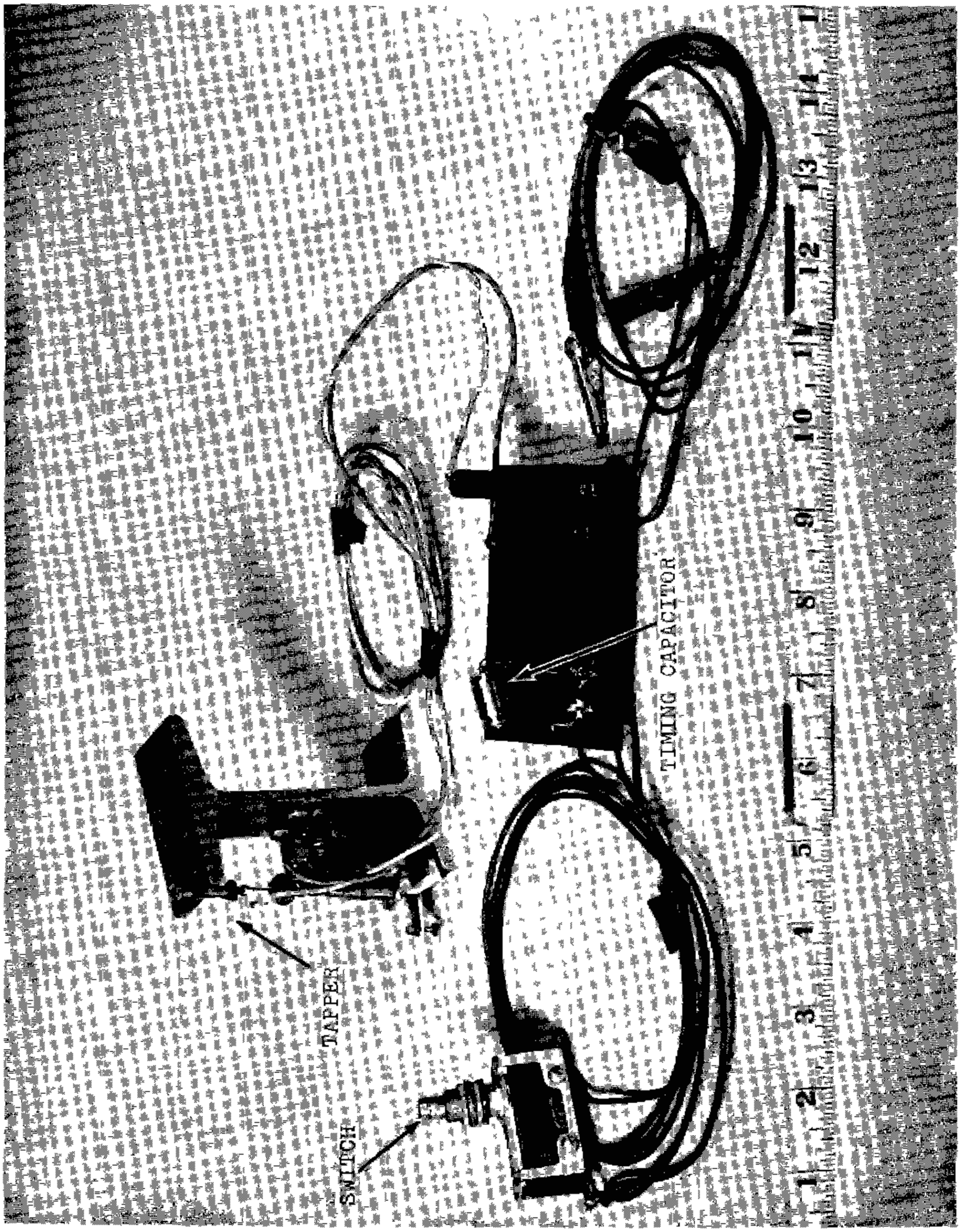
Further development of the Flawmeter should include means to measure the force of the hammer blow and the relation of the strength of the blow to the type of structure being tested. The circuitry will need to be refined, temperature stabilized, and adapted to suit best the particular structure being tested. Some structures may be tested best by using the direct-frequency difference method; other structures may be suited to a total count system.



TEST PANELS

Task No 59-2141

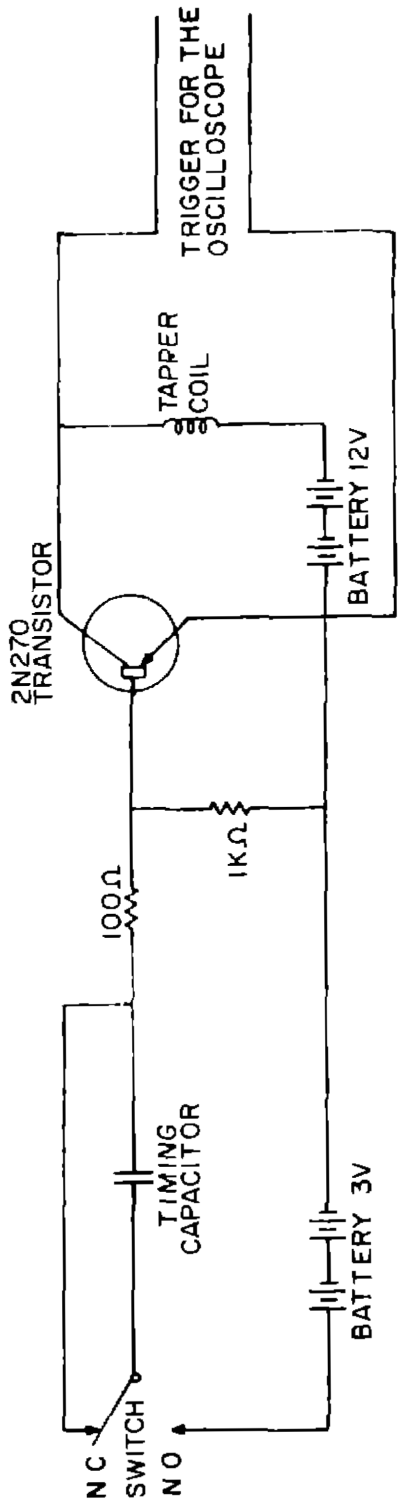
FIG. I



SINGLE TAPPER

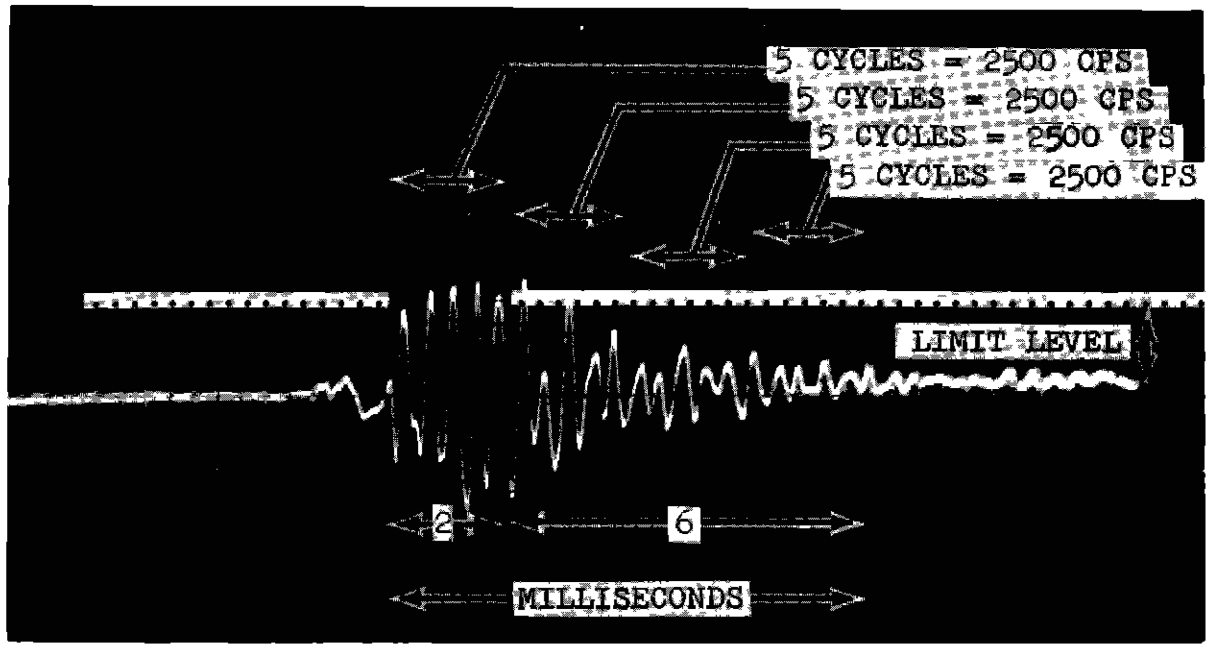
Task No 59-2141

FIG. 2

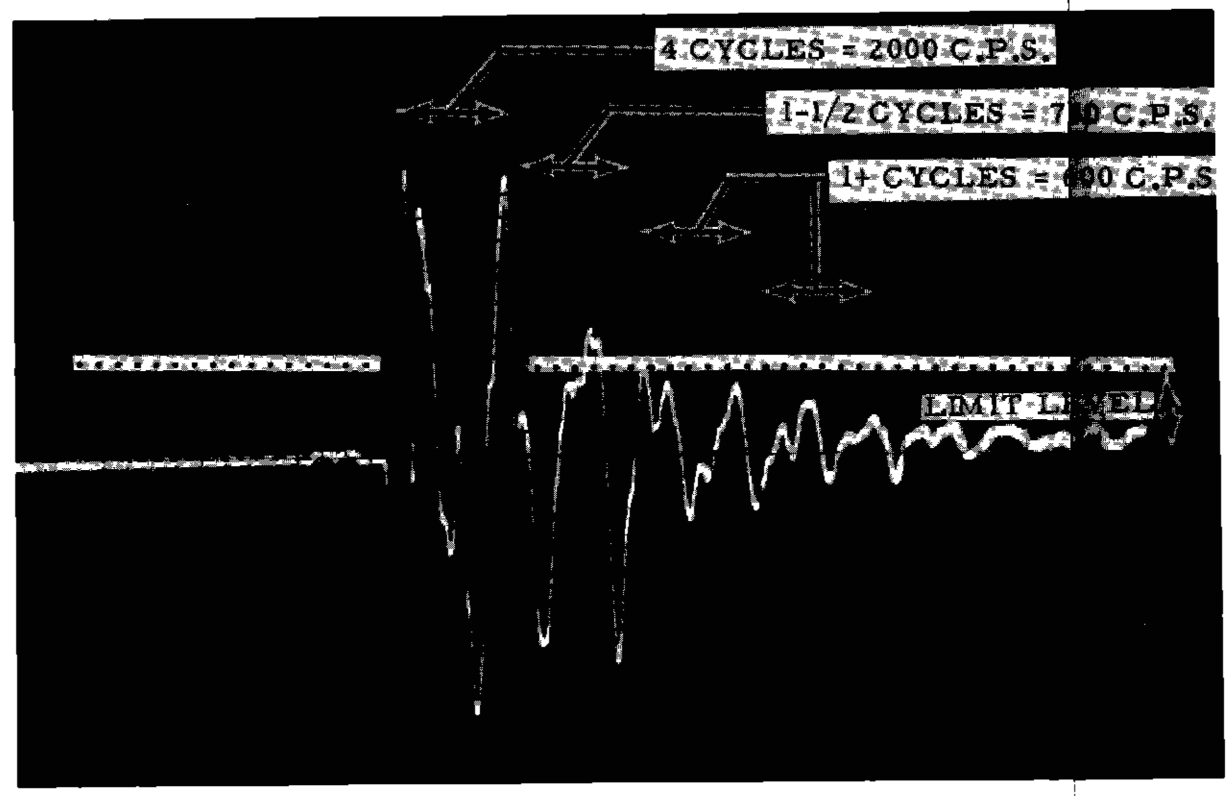


WIRING DIAGRAM FOR THE ELECTRONICALLY CONTROLLED SINGLE-TAP DEVICE

FIG. 3



A

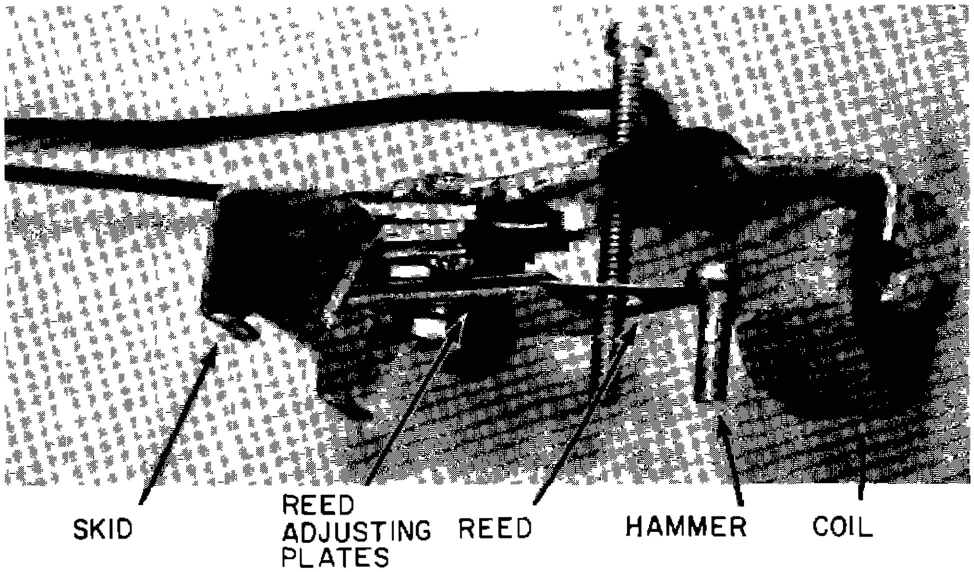


B

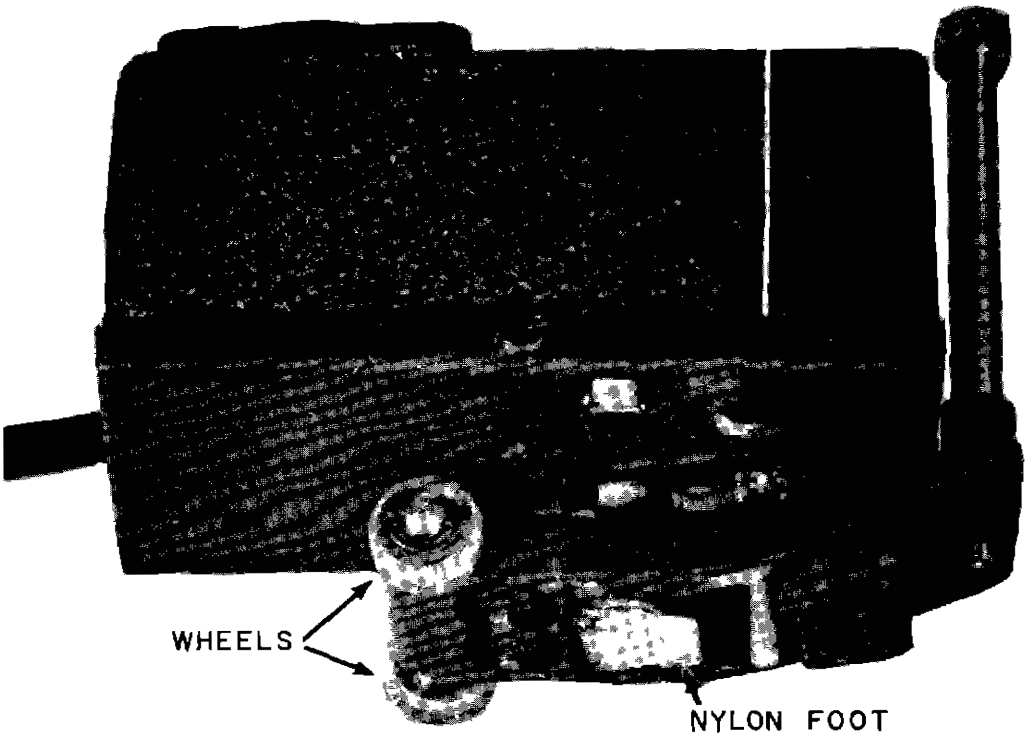
SOUND DIFFERENCE
GOOD AND POOR BOND

Task No 59 - 214 I

FIG. 4



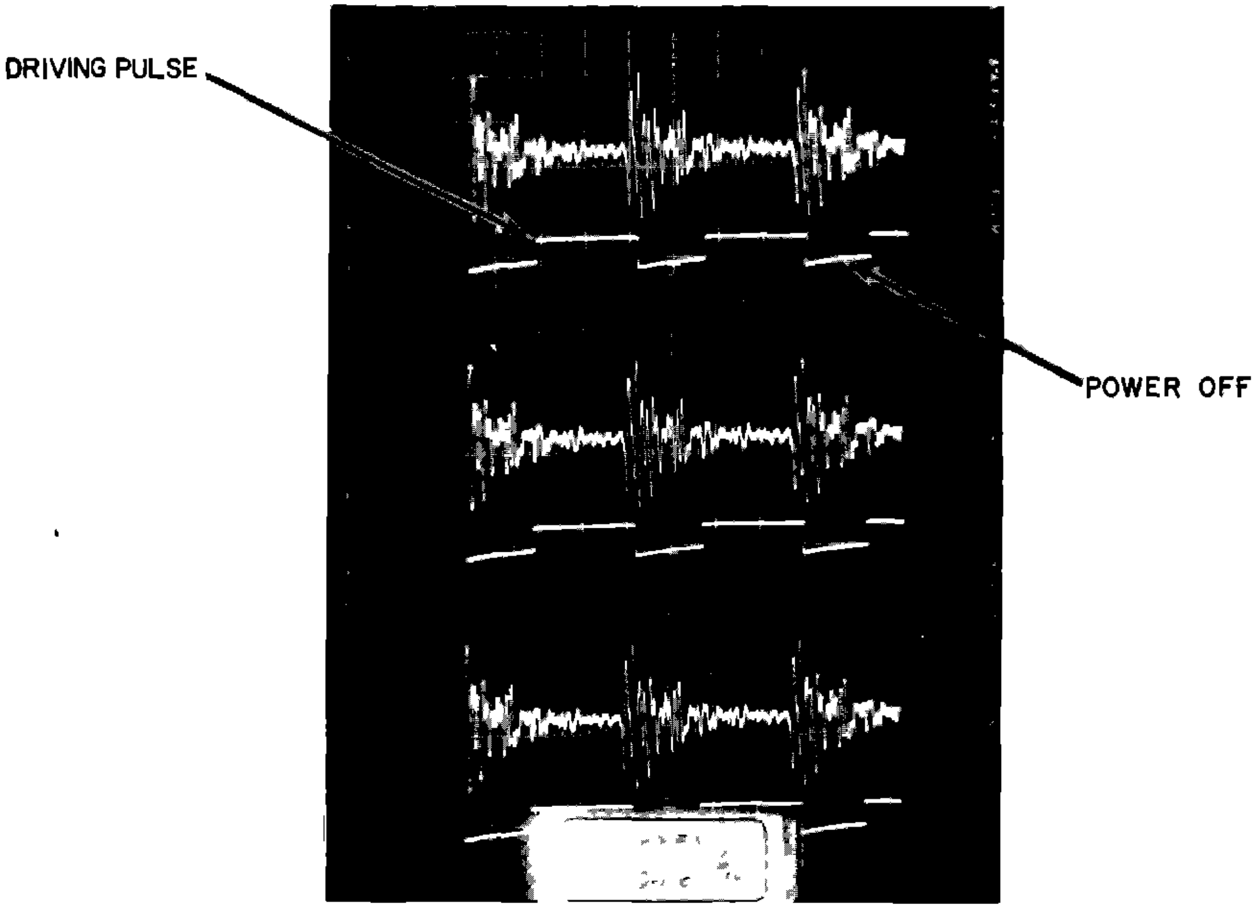
A-ORIGINAL REED TAPPER



B-IMPROVED REED TAPPER

REED-TYPE TAPPING DEVICE

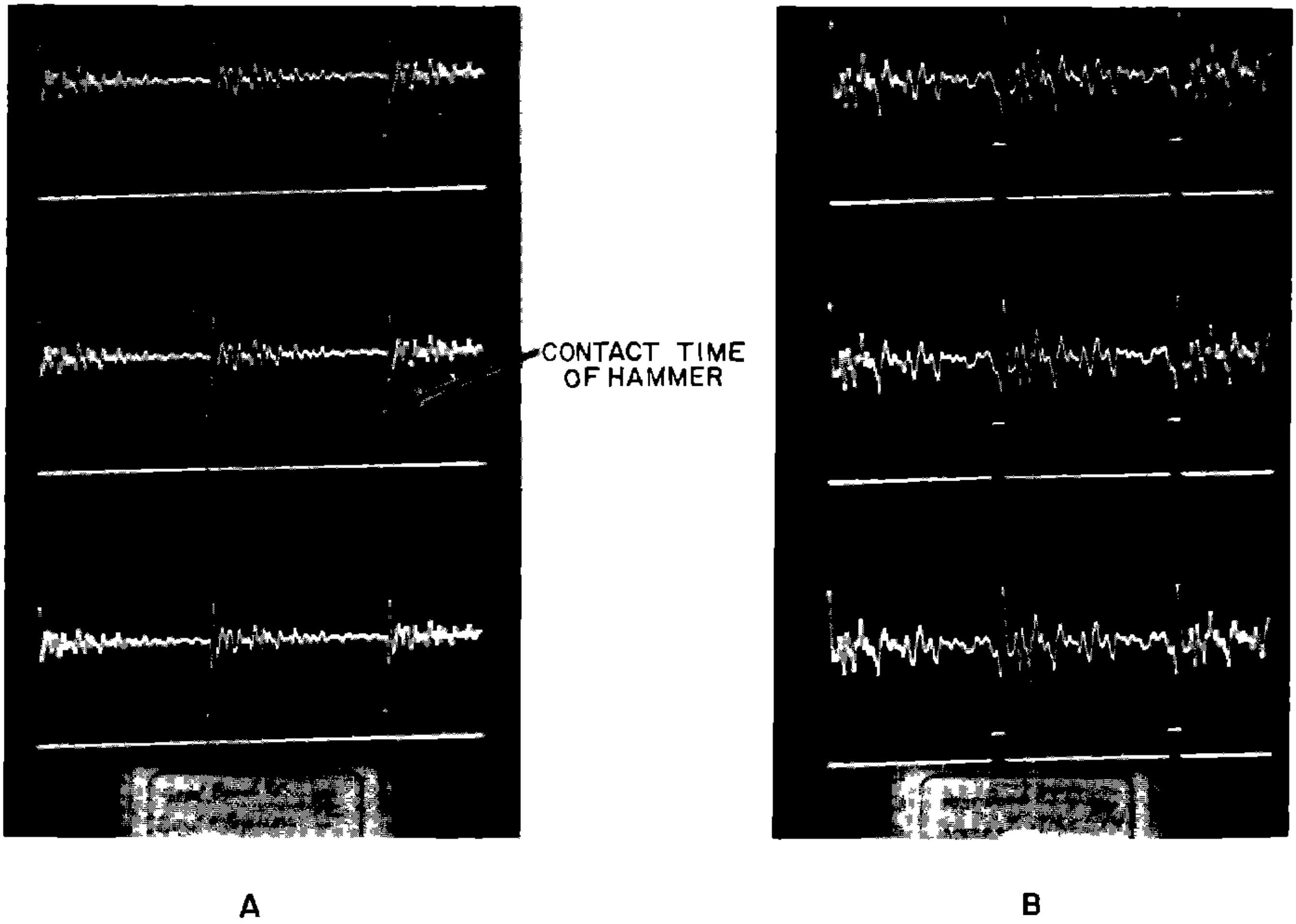
FIG. 5



PRECISION DRIVE AND SOUND REPRODUCTION

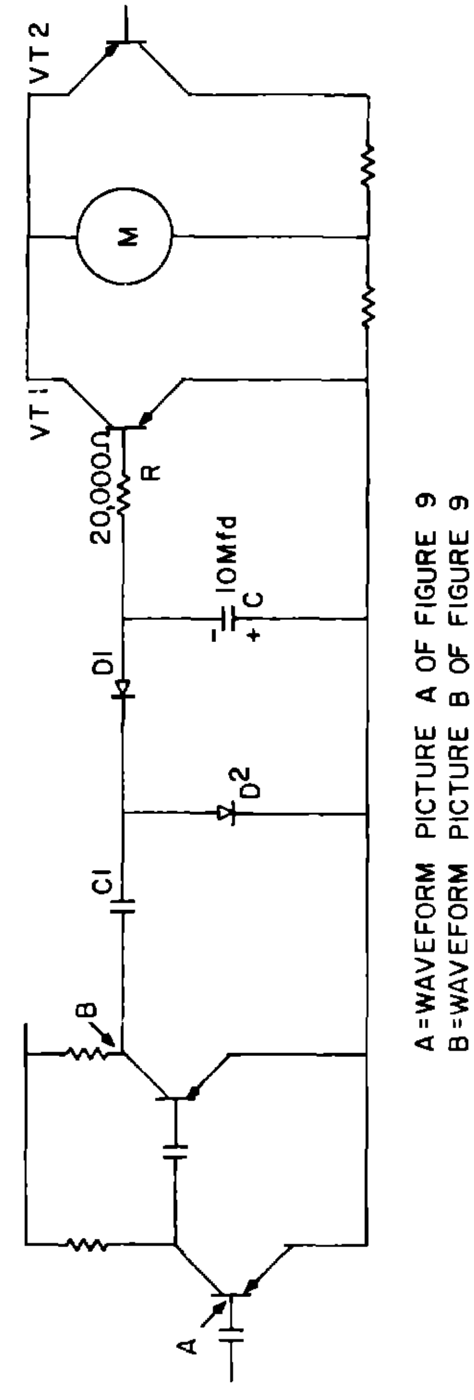
Task No 59-214 I

FIG. 6



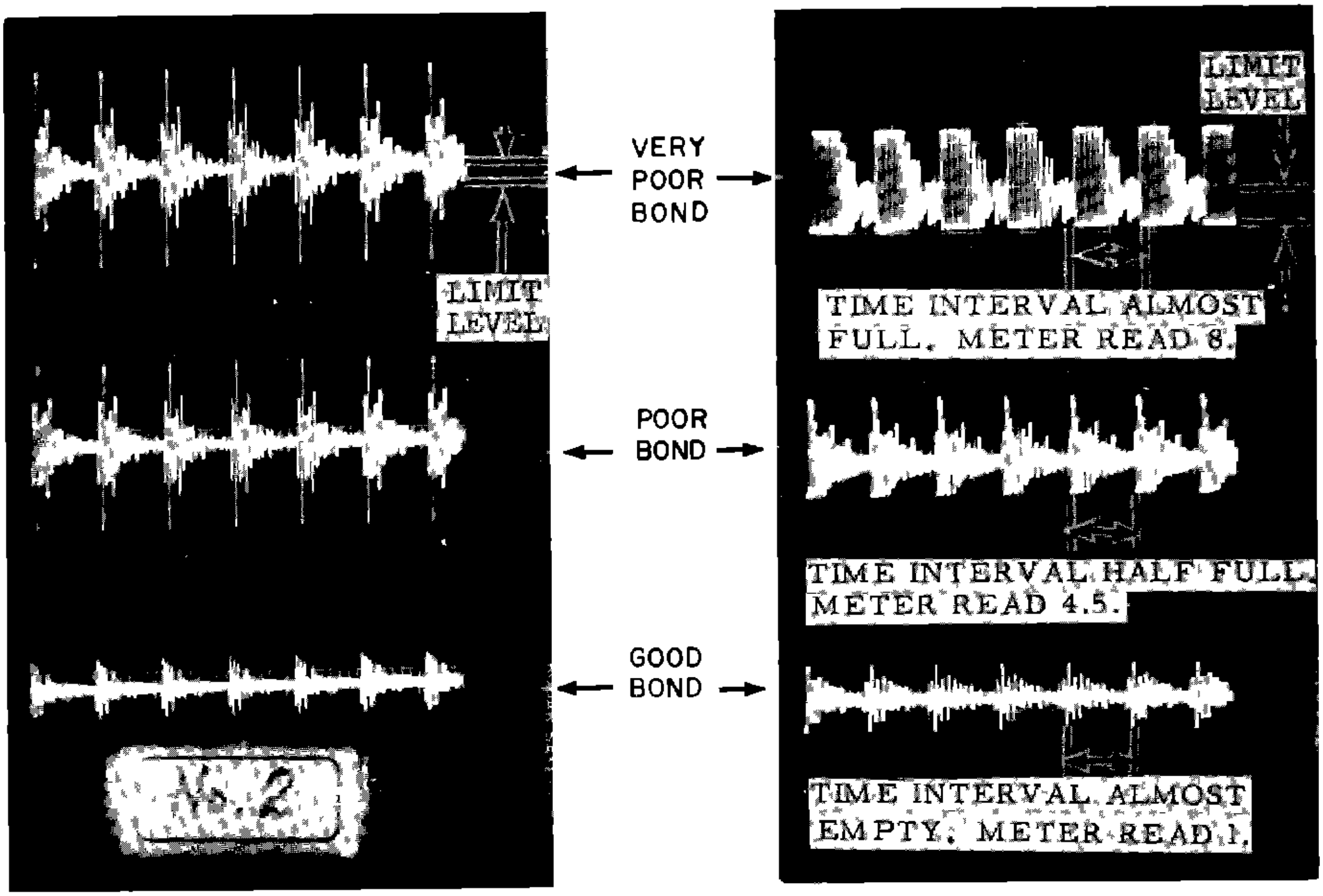
HAMMER DWELL TIME

FIG. 7



INTEGRATING CIRCUITRY

FIG. 8

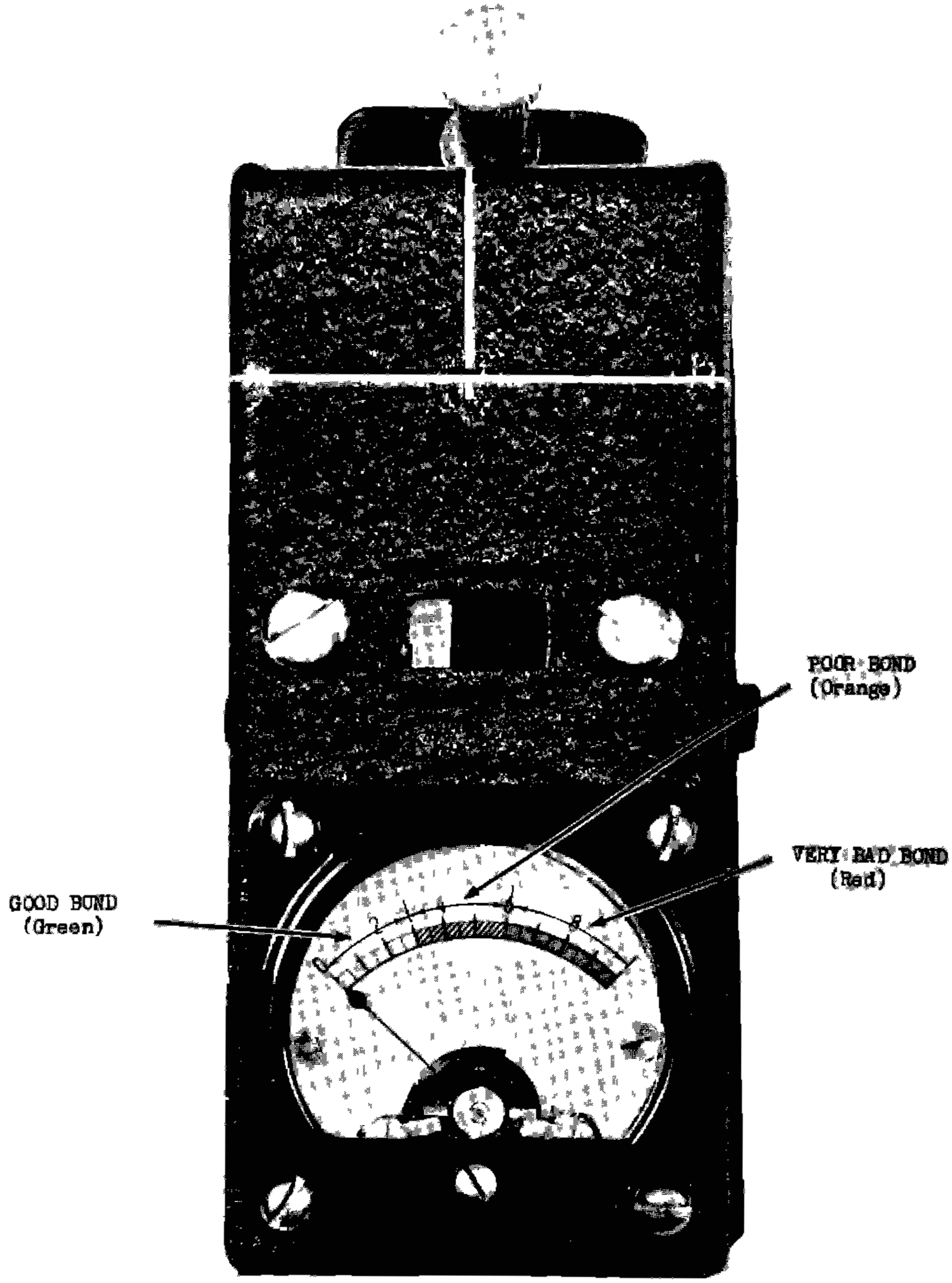


SOUND WAVE AT POINT A, FIG 8

SOUND WAVE AT POINT B, FIG 8

ACTION OF THE CIRCUIT ON THE SOUND WAVE

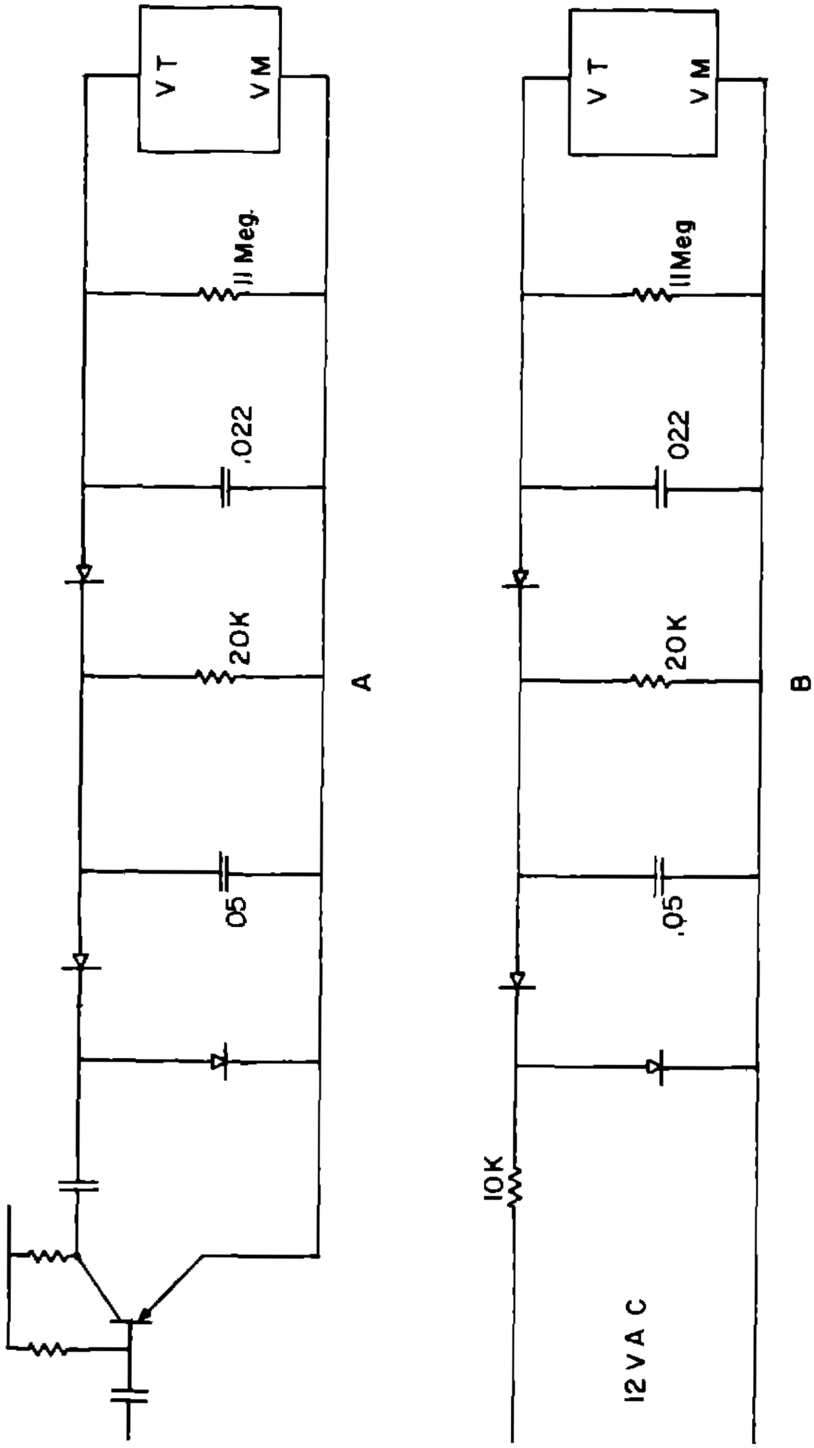
FIG. 9



GOOD, POOR AND BAD
BOND SCALE READINGS

Task No 59-2141

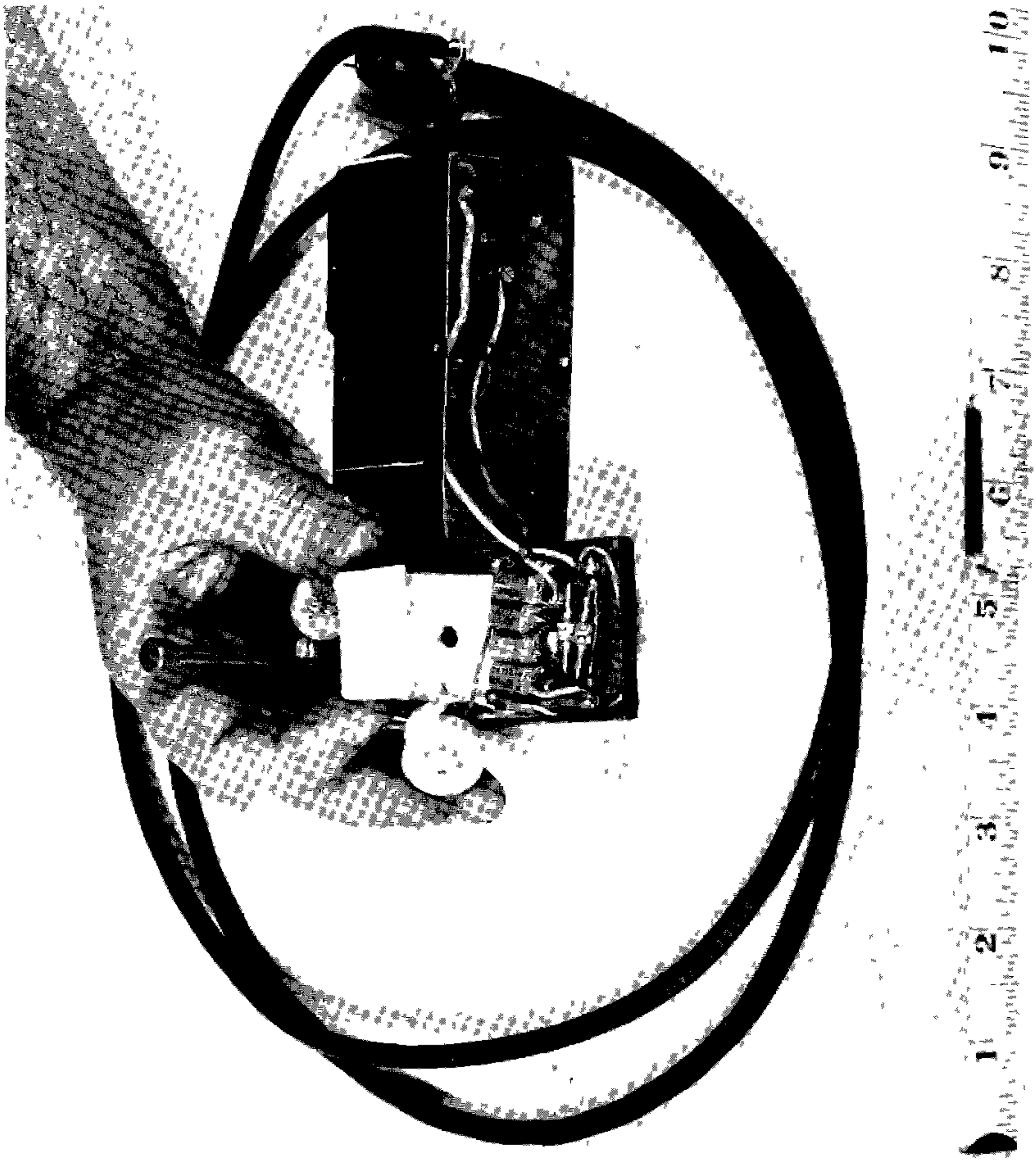
FIG. 10



CIRCUITRY FOR DIRECT
FREQUENCY COMPARISON

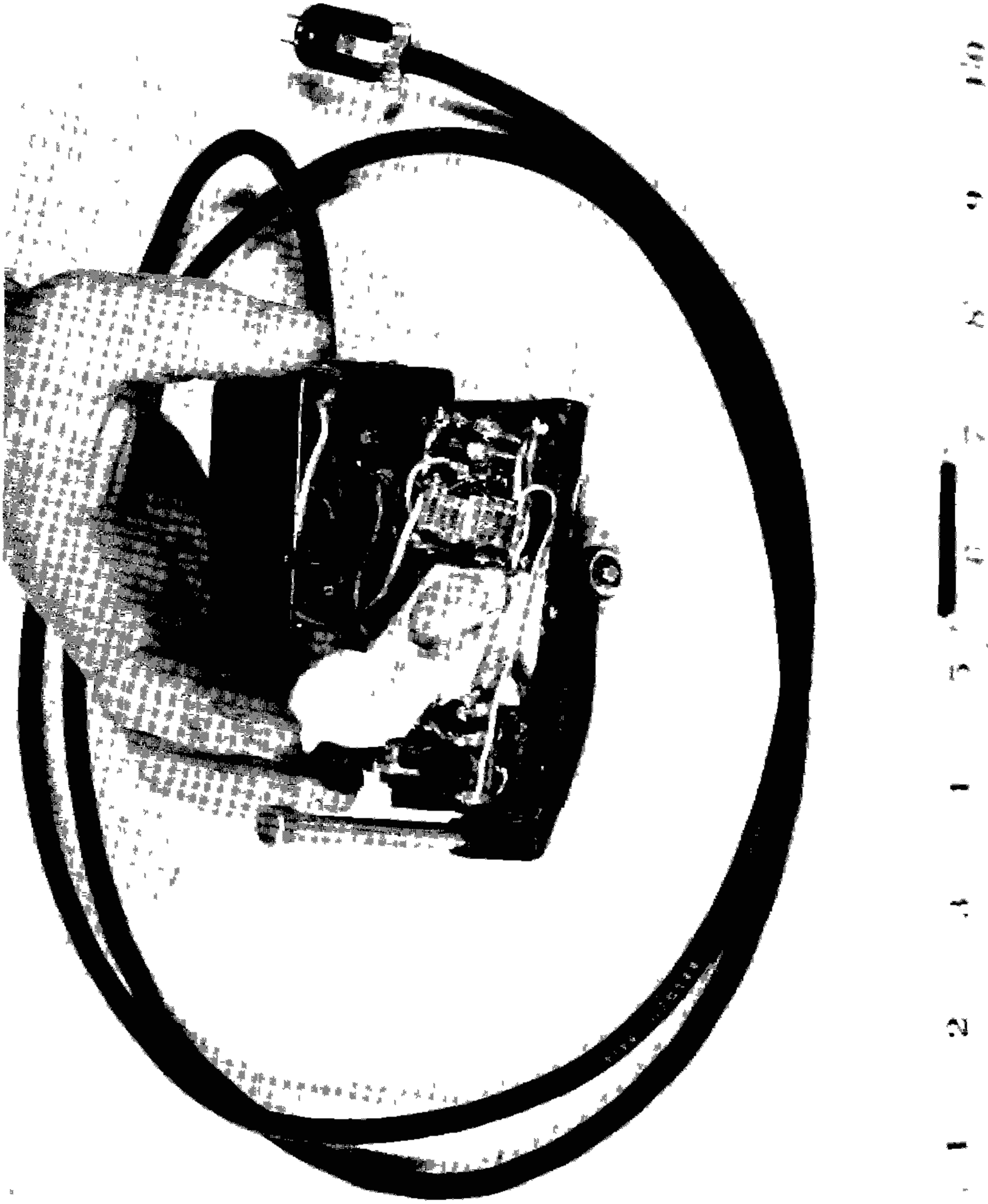
Task No 59-2141

FIG. 11



MICROPHONE AND MOUNTING

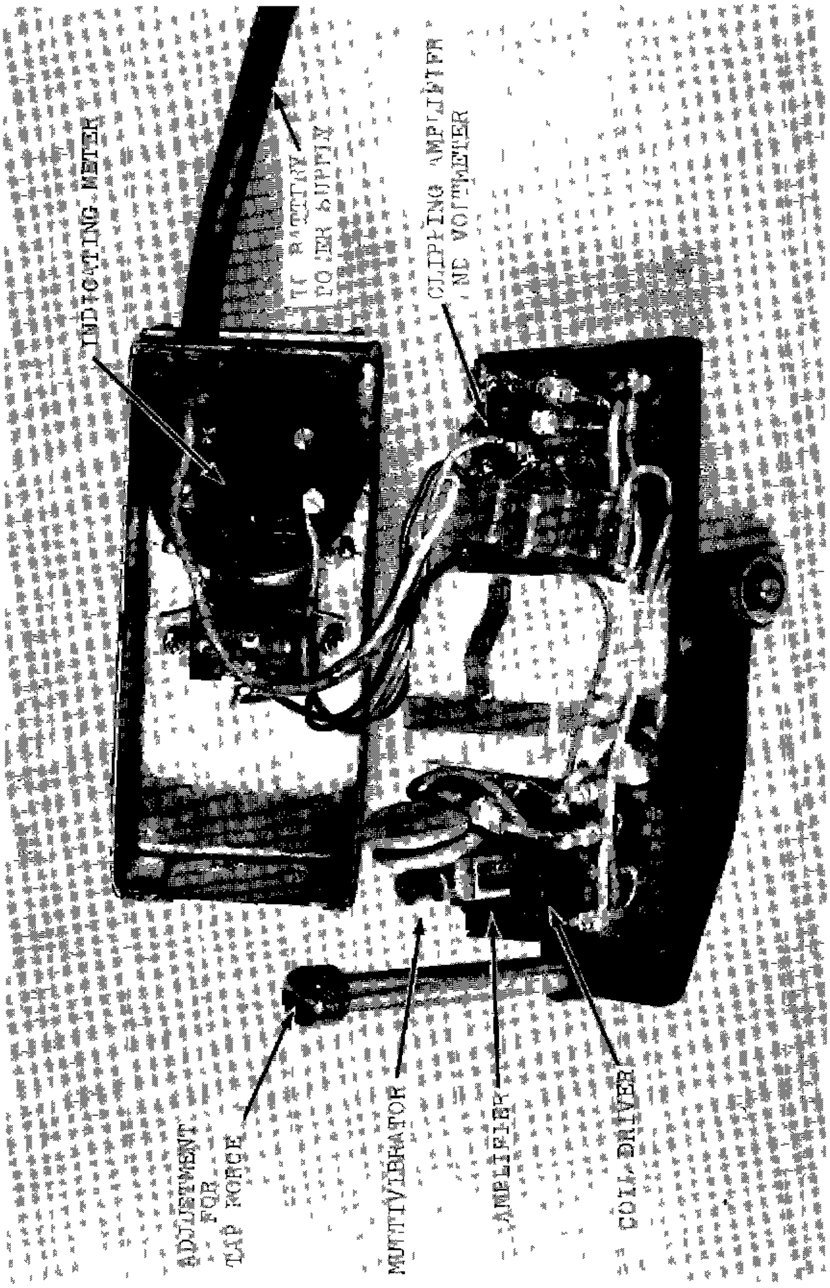
FIG. 12



MICROPHONE AND MOUNTING

Task No 59-2141

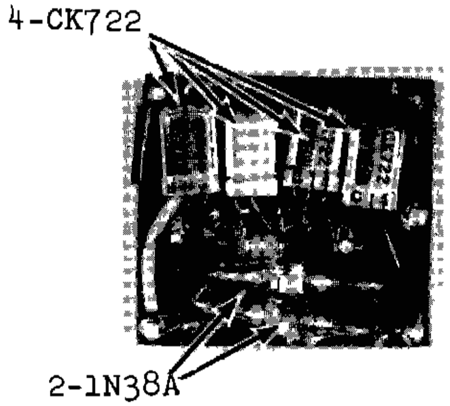
FIG. 13



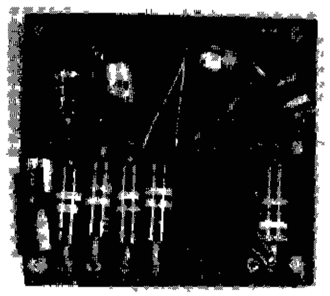
EXPERIMENTAL ASSEMBLY FLAWMETER

AMPLIFIER - METER DRIVE

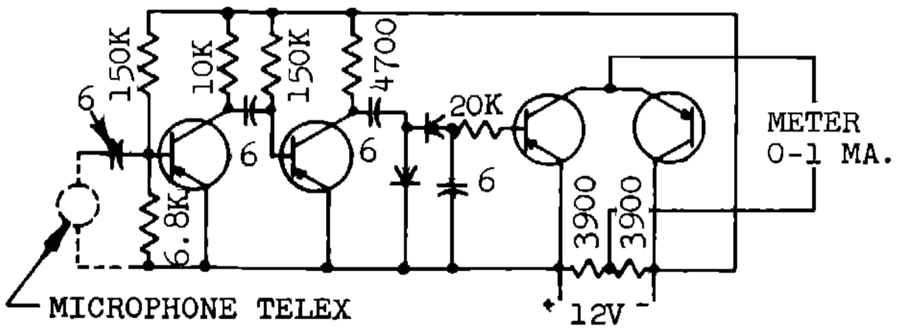
ACTUAL SIZE



TOP VIEW

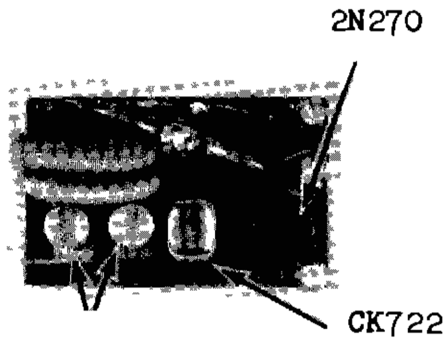


BOTTOM VIEW

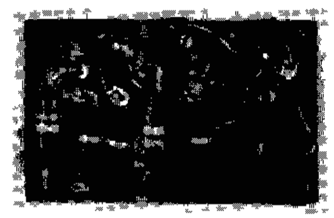


MULTIVIBRATOR HAMMER DRIVER

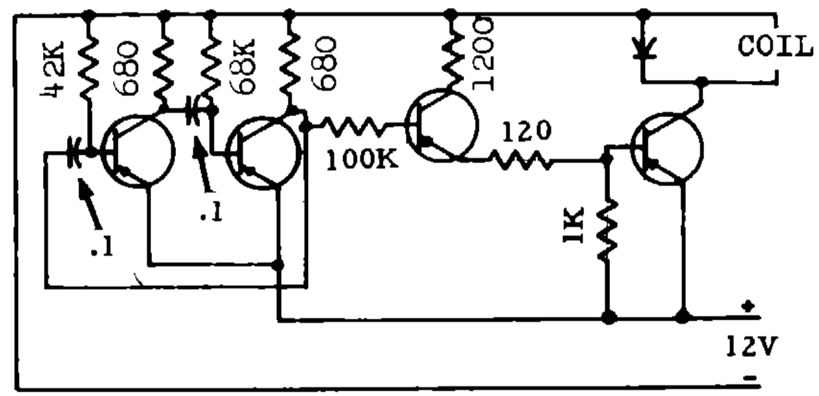
ACTUAL SIZE



TOP VIEW



BOTTOM VIEW



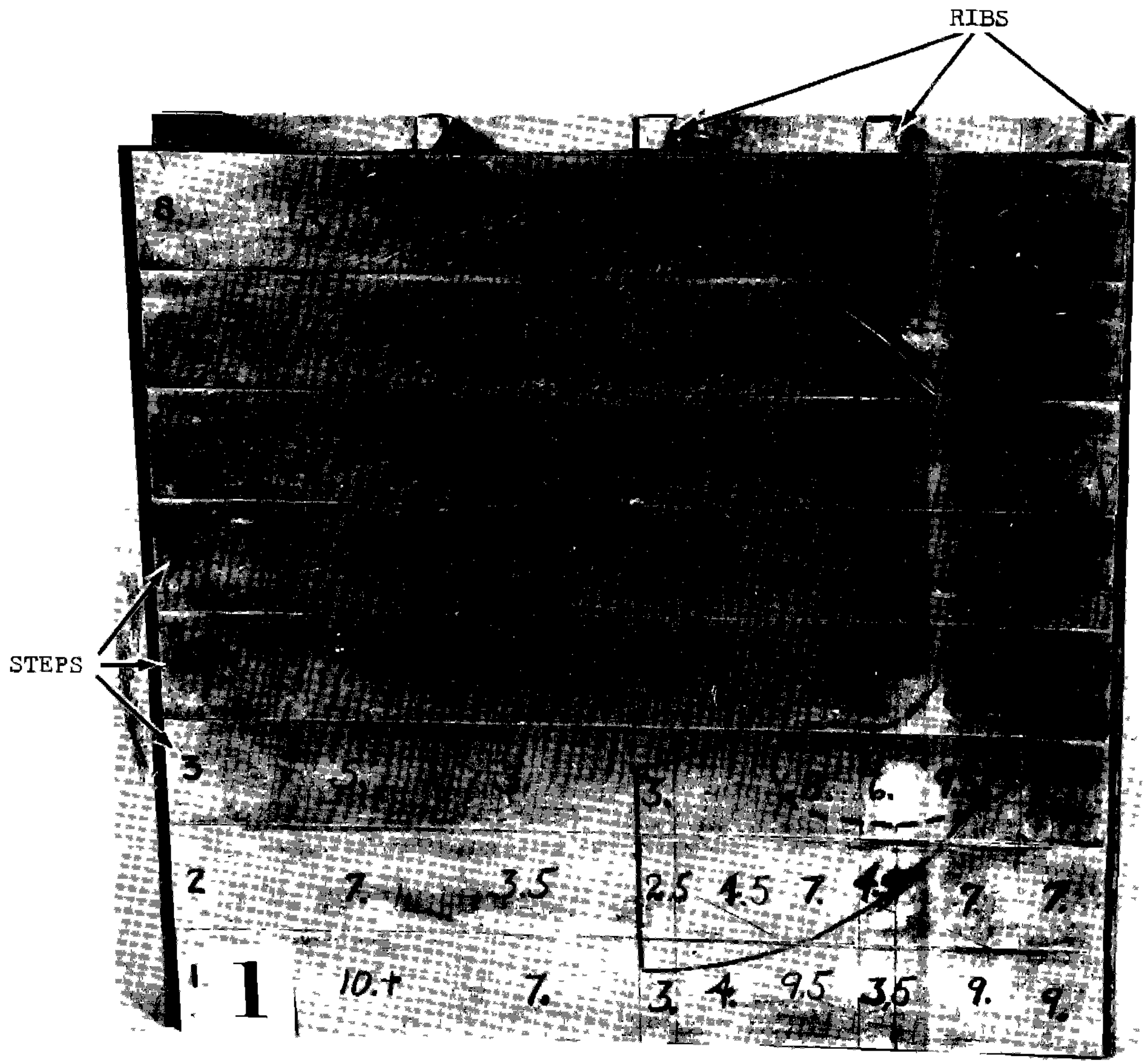
ELECTRONIC ASSEMBLIES OF THE FLAWMETER

Task No 59 - 2141

FIG. 15

COMBINATION BATTERY
AND CARRYING CASE

FIG. 16



SPAR: 2" X 1" X 1/8" X 12"
WT. 1.59 LB.
AISI C1015 - 20 CHANNEL
1 - REQUIRED

RIBS: 2" X 1/2" X .050" X 12"
24S-T3 ALCLAD FORMED CHANNEL
4 - REQUIRED

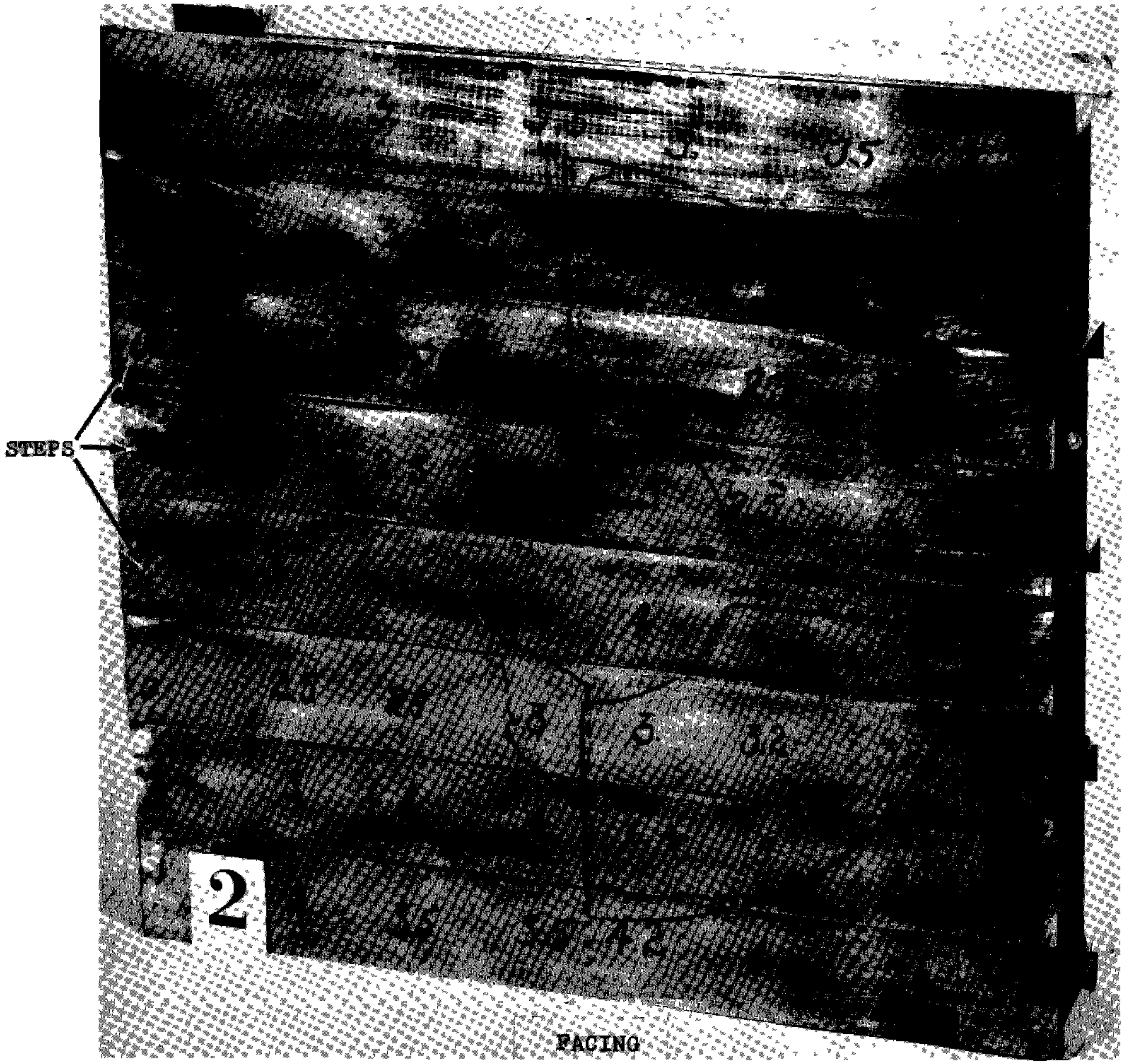
FACING: .032" 24S-T3 ALCLAD SHEET
NO. REQUIRED:
3 - 12" X 12"
1 - 10.5" X 12"
1 - 9" X 12"
1 - 7.5" X 12"
1 - 6" X 12"
1 - 4.5" X 12"
1 - 3" X 12"
1 - 1.5 X 12"

ADHESIVE: PLASTOLOCK 601

TESTS ON PANEL NO. I

Task No 59—214.1

FIG. 17



SPAR: 2" X 1" X 1/8" X 12"
WT. 1.59 LB.
AISI C1015 - 20 CHANNEL
1 - REQUIRED

RIBS: 2" X 1/2" X .016" X 11"
24S-T3 ALCLAD FORMED CHANNEL
5 - REQUIRED

FACING: .018 STAINLESS TYPE 302
NO. REQUIRED
3 - 12" X 12"
1 - 10.5" X 12"
1 - 9" X 12"
1 - 7.5" X 12"
1 - 6" X 12"
1 - 4.5" X 12"
1 - 3" X 12"
1 - 1.5" X 12"

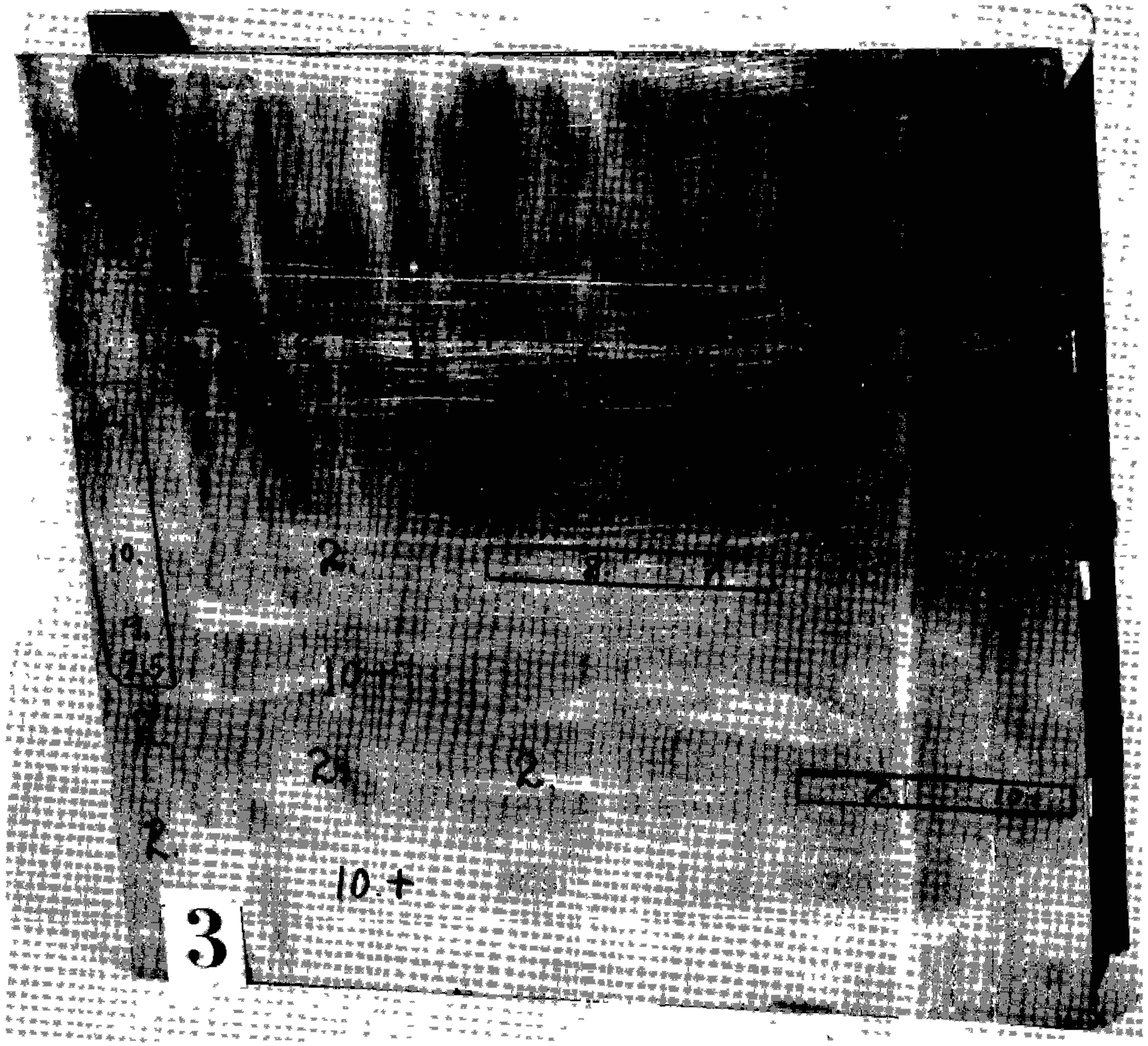
ADHESIVE: FM-47 TAPE

NAT ONAL AVIAT ON

TESTS ON PANEL NO. 2

Task No 59 – 214 I

FIG. 18



SPAR: 2" X 1" X 1/8" X 12"
AISI C1015 - 20 CHANNEL
WT. 1.59 LB.
1 - REQUIRED

RIBS: 2" X 1/2" X .016" X 11"
24S-T3 ALCLAD FORMED CHANNEL
5 - REQUIRED

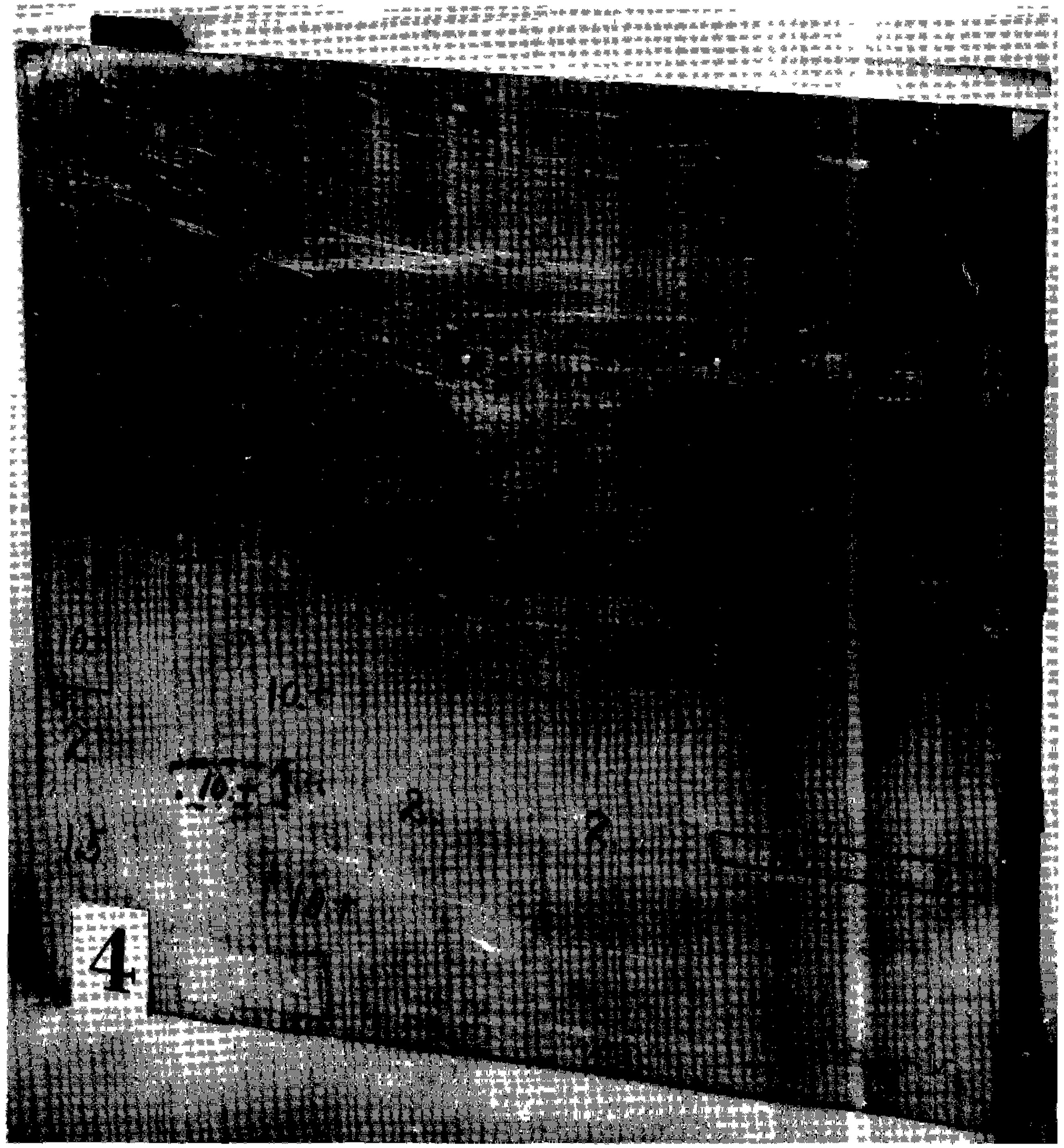
FACING: .018" STAINLESS TYPE 302
MIL - S - 5059
2 - 12" X 12" REQUIRED

ADHESIVE: FM-47 TAPE

TESTS ON PANEL NO. 3

Task No 59 - 214 1

FIG. 19



SPAR: 2" X 1" X 1/8" X 12"
WT. 1.59 LB.
AISI C1015 - 20 CHANNEL
1 - REQUIRED

RIBS: 2" X 1/2" X .016" X 11"
24S-T3 ALCLAD FORMED CHANNEL
5 - REQUIRED

FACING: 12" X 12" X .016"
24S-T3 ALCLAD SHEET
2 - REQUIRED

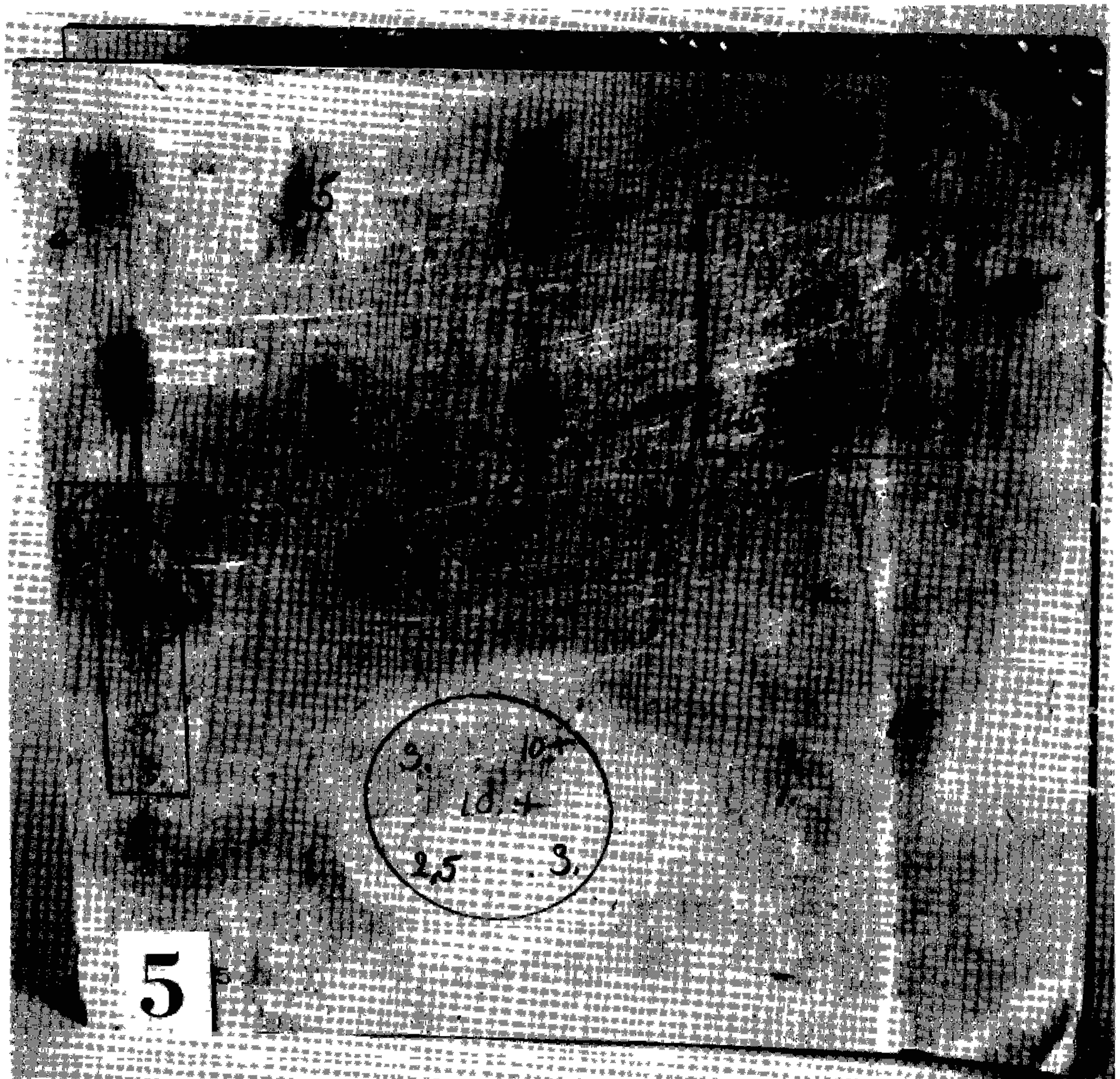
ADHESIVE: SKIN TO RIBS AND SKIN TO CHANNEL
NARMCO METLBOND 4021

NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER
ATLANTIC CITY, N J

TESTS ON PANEL NO. 4

Task No. 59 - 2141

FIG. 20



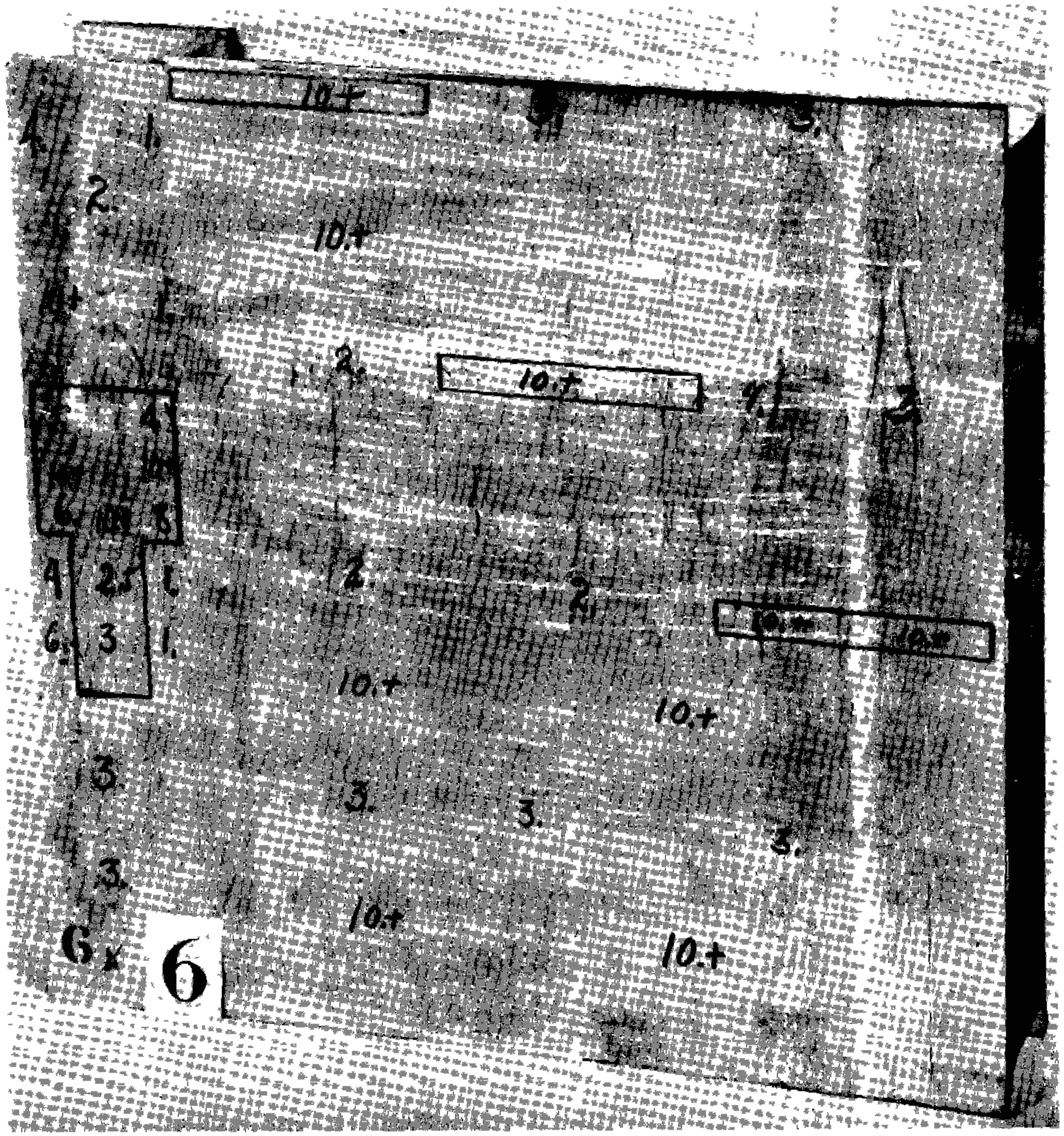
SPAR:	2" X 2" X 1/4" X 12" 62S-T6 ALCOA NO. 892 WT. 1.667 LB. 1 - REQUIRED
RIBS:	10" X 12" X 2" ALUMINUM HONEYCOMB 3/8" CELL 1 - REQUIRED
FACING:	12" X 12" X .016" 24S-T3 ALCLAD SHEET 2 - REQUIRED
ADHESIVE:	HONEYCOMB TO FACING, 3 LAYERS SCOTCHWELD 585; FACING TO CHANNEL, 1 LAYER SCOTCHWELD AF-6 BONDING FILM

NATIONAL AVIATION
FACILITIES EXPERIMENT[illegible]
ATLANTIC [illegible]

TESTS ON PANEL NO. 5

Task No 59 — 214 1

FIG. 21



SPAR: 2" X 2" X 1/4" X 12"
62S-T6 ALCOA NO. 892
WT. 1.667 LB.
1 - REQUIRED

RIBS: 2" X 1/2" X .016" X 10"
24S-T3 ALCLAD FORMED CHANNEL
5 - REQUIRED

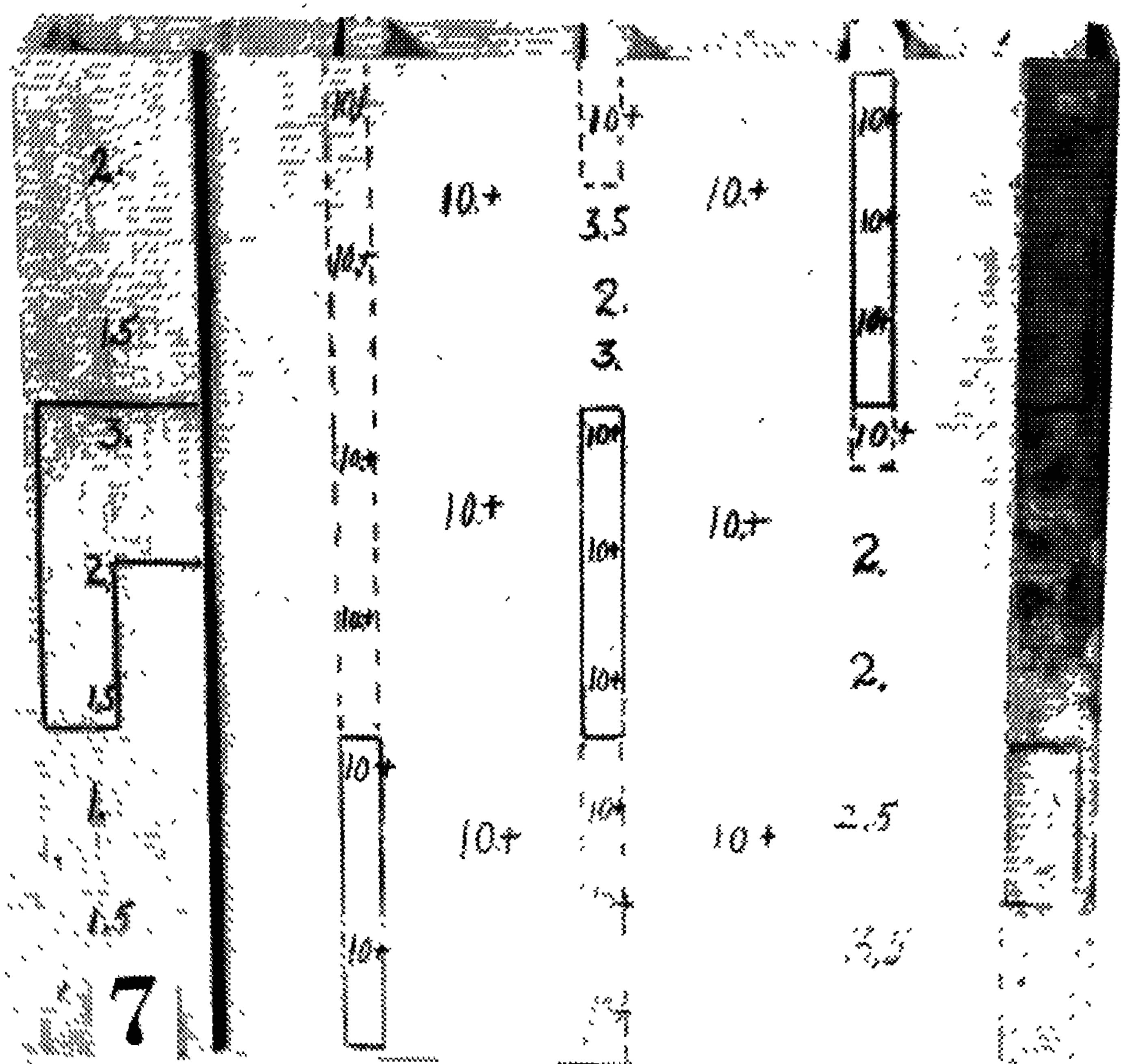
FACING: 12" X 12" X .016"
24S-T3 ALCLAD SHEET
2 - REQUIRED

ADHESIVE: 2 OR 3 LAYERS SCOTCHWELD 585

TESTS ON PANEL NO. 6

Task No 59-2141

FIG. 22



SPAR: 2" X 2" X 1/4" X 12"
62S-T6 ALCOA NO. 892
WT. 1.667 LB. CHANNEL
1 - REQUIRED
SEE SPEC.
2" X 1" X 1/8" X 12"
AISI C1015 - 20 CHANNEL
WT. 1.59 LB.
1 - REQUIRED

RIBS: 2" X 1/2" X .050" X 12"
24S-T3 ALCLAD FORMED CHANNEL
3 - REQUIRED

FACING: 12" X 12" X .032"
24S-T3 ALCLAD SHEET
2 - REQUIRED

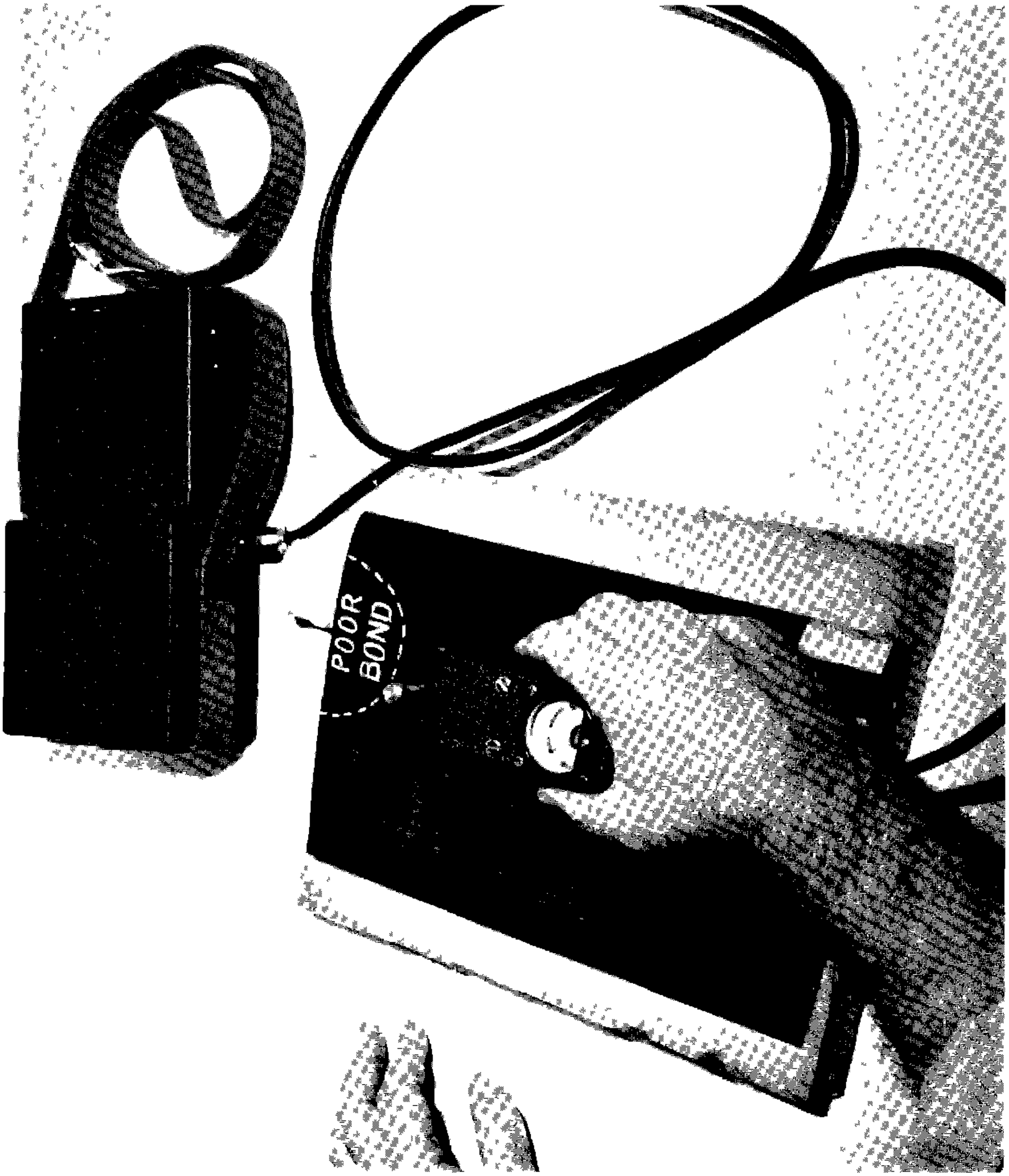
ADHESIVE: PLASTOLOCK 601

NATIONAL AVIATION
[illegible] EXPERIMENTAL [illegible]
ATLANTIC CITY, N.J.

TESTS ON PANEL NO. 7

Task No 59-214 I

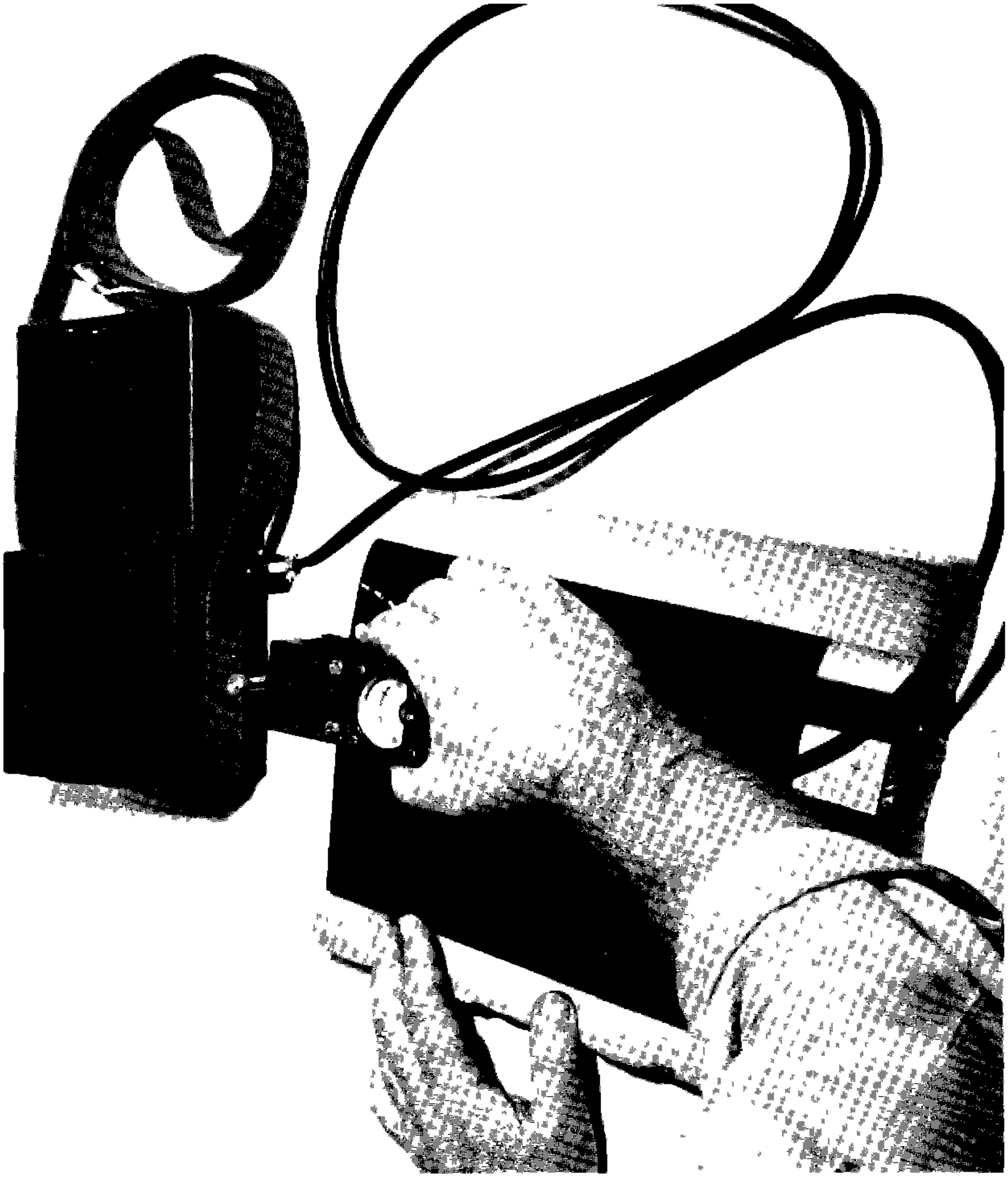
FIG. 23



ACTUAL GOOD BOND READING

Task No 59-2141

FIG. 24



ACTUAL BAD BOND READING

Task No 59-2141

FIG.25

PROOF OF FLAWMETER READING

Task No 59-2141

FIG. 26