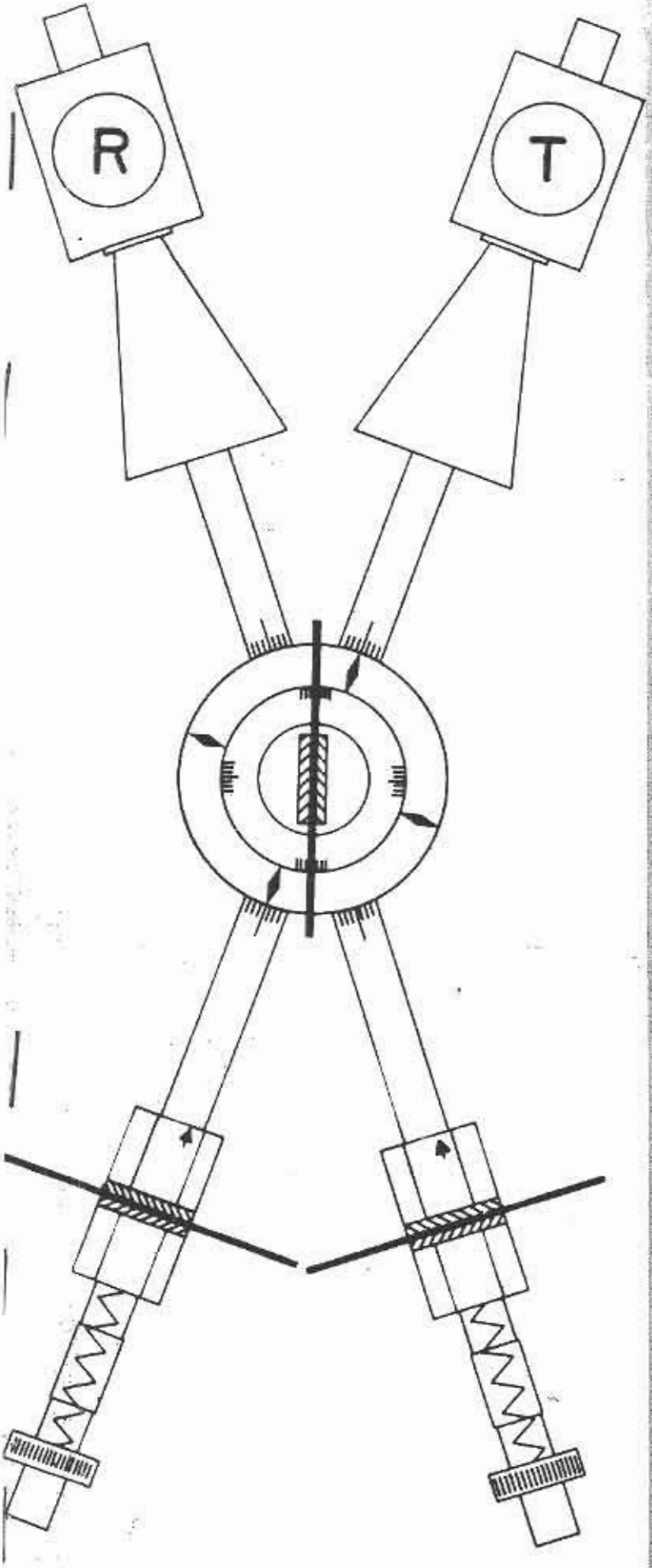

$3.00

OPTICS
LABORATORY

MICROWAVE-OPTICS
MARK II ED-SET®

INSTRUCTION MANUAL
FOR EXPERIMENTS IN
ELECTROMAGNETIC RADIATION
AND
MICROWAVE-OPTICS

BUDD STANLEY CO., INC.

MICROWAVE-OPTICS
MARK II ED-SET®

INSTRUCTION MANUAL FOR EXPERIMENTS IN ELECTROMAGNETIC RADIATION AND MICROWAVE-OPTICS

Budd-Stanley Co. Inc., 175 Eileen Way, Syosset, L. I., N. Y.

Foreword

The Mark II Ed-Set has been specifically designed for use as part of the science curriculum.

This manual has been prepared for the purpose of explaining how to set-up and perform the many experiments for which the Ed-Set was designed. Integrating these experiments with present course material can be readily accomplished.

Included are complete instructions for performance of 15 scientific demonstrations and laboratory experiments, many of which have previously been unavailable to most schools. The detailed diagrams in this manual will aid in realizing the full potential of this fine instrument.

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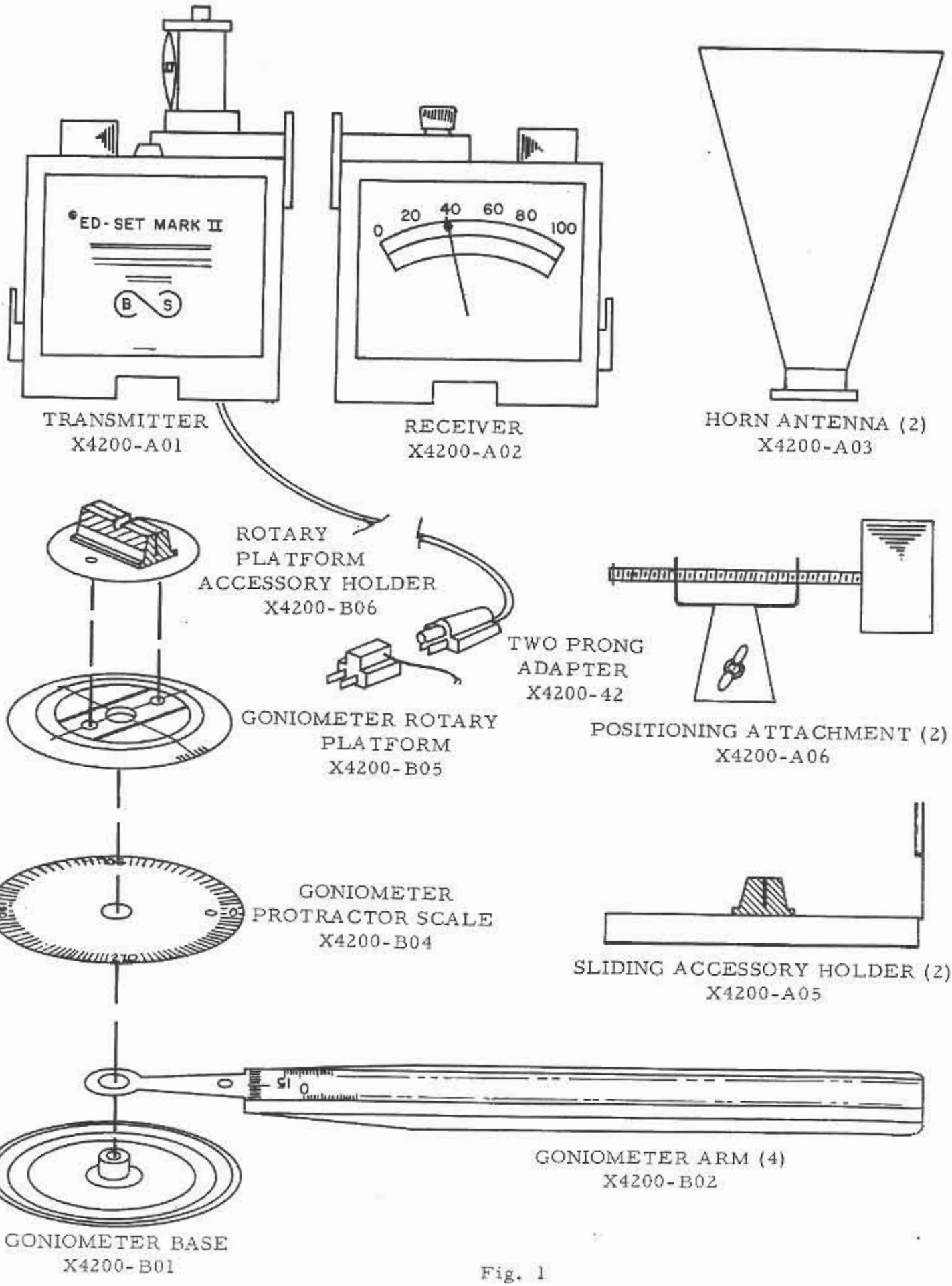
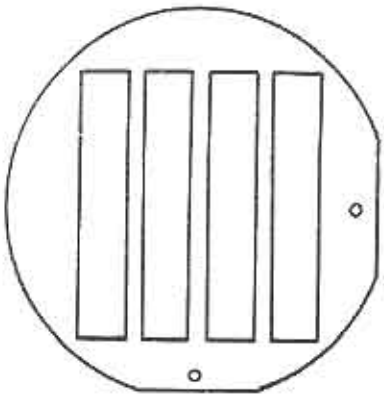
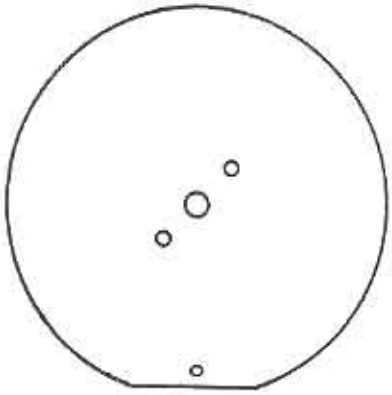

ED-SET MARK II
B
S
0
20
40
60
80
100
TRANSMITTER
X4200-A01
RECEIVER
X4200-A02
HORN ANTENNA (2)
X4200-A03
ROTARY
PLATFORM
ACCESSORY HOLDER
X4200-B06
TWO PRONG
ADAPTER
X4200-42
POSITIONING ATTACHMENT (2)
X4200-A06
GONIOMETER ROTARY
PLATFORM
X4200-B05
GONIOMETER
PROTRACTOR SCALE
X4200-B04
SLIDING ACCESSORY HOLDER (2)
X4200-A05
GONIOMETER ARM (4)
X4200-B02
GONIOMETER BASE
X4200-B01

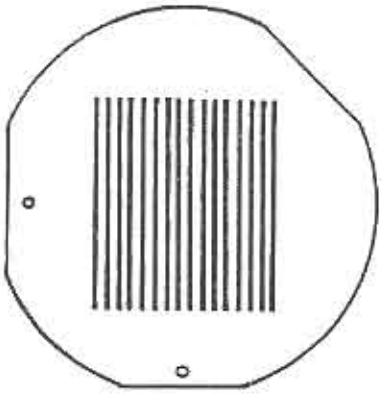
Fig. 1



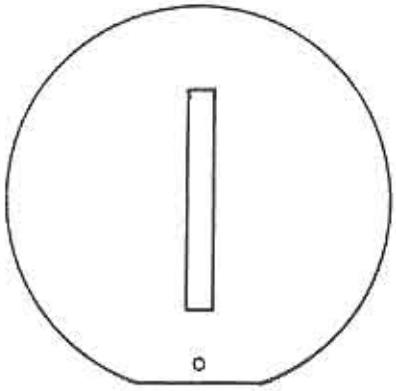
HALF REFLECTOR
X4200-15



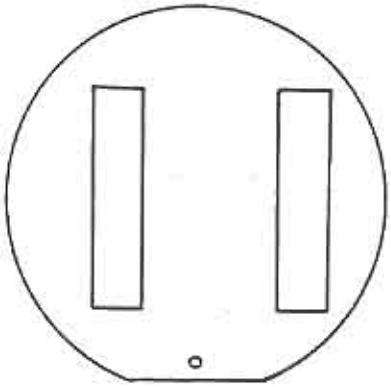
FULL REFLECTOR (2)
(FABRY-PEROT PLATE)
X4200-06



POLARIZATION GRID
X4200-07



SINGLE SLIT PLATE
X4200-19

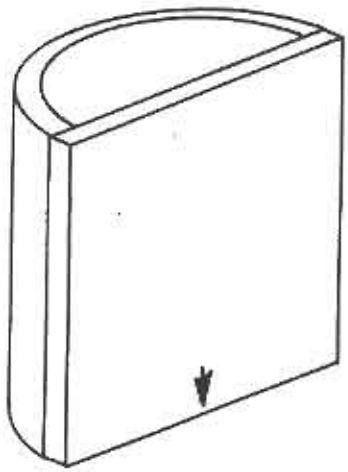


DOUBLE SLIT PLATE
X4200-20

PROBE
X4200-25

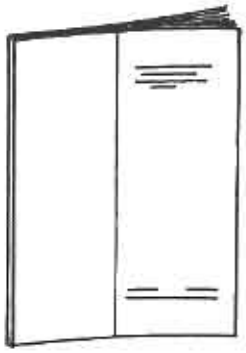
KLYSTRON
TUNING KEY
SK-1190

SCREW (8)
30546B



REFRACTION TANK
X4200-B07

PLASTIC BAG (2)
X4200-45-1



INSTRUCTION MANUAL
X4200-44

POLYETHYLENE BEADS (2)
(APPROX. 1 LB. EACH)
X4200-46
PACKED IN CYLINDRICAL PLASTIC BAG
X4200-45-1

Fig. 2

Chapter 1

MARK II ED-SET DESCRIPTION AND ASSEMBLY INSTRUCTIONS

The previous pages illustrate the various component parts which comprise the Mark II ED-SET. As you unpack the ED-SET, compare each part with the corresponding illustration and identify it by name.

A - The Goniometer

1. Place the Goniometer Base on a flat, smooth work surface.

2. Mount the four Goniometer Arms on the center bushing of the Goniometer Base in any sequence, at approximately right angles to each other.

3. Place the Goniometer Protractor Scale on the Base bushing over the Arms, and then engage the pin protruding from the underside of the Scale in the mating hole of the Arm to your left. (a)

4. Place the Goniometer Rotary Platform on the bushing, over the Protractor Scale.

5. Place the Rotary Platform Accessory Holder on the Rotary Platform engaging the pins in the mating holes.

B - The Transmitter

1. The knob on the Transmitter is a combination on-off switch and voltage control for the repeller plate of the Klystron. This is referred to as the "Repeller Tuning Knob." It is used to vary the repeller voltage to obtain maximum power output from the Klystron.

2. Rotation of the small brass square shaft on the Klystron varies its frequency. This is called the "Klystron Frequency Tuning Shaft." The Klystron Tuning Key, which fits the shaft, is furnished to make this adjustment. After each change of frequency, adjust the Repeller Tuning Knob as described in Chapter 2, Paragraph 3, Page 4. Turning (b) the key counterclockwise until a mechanical stop is reached will tune the Klystron to a frequency of 9,830 megacycles/sec ± 2% (3.06 cm.)

3. The underside of the case is fitted with a standard 1/4 x 20 tripod thread.

C - The Receiver

1. The large knob varies the gain of the Receiver and is called the "Gain Control".

Notes: (a) This fixes the Protractor Scale at 0 degrees relative to the Arm to which it is pinned.

(b) Do not unnecessarily change the frequency which has been initially set at the factory for maximum power output. Do not repeatedly retune the Klystron if avoidable.

2. The small knob is a part of the crystal detector assembly and should not be used except for crystal replacement or when specifically stated in the Manual.

3. With respect to the Microammeter, all readings, unless otherwise specified, will be taken on the upper or "main" scale which is calibrated from 0 to 100. These readings are proportional to power received (subject to the square law characteristics of the crystal). (a)

4. The small plastic screw on the lower face of the Microammeter can be used, if necessary, to zero adjust the Microammeter.

5. The underside of the case is fitted with a standard 1/4 x 20 tripod thread.

D - Recommended Setup

1. It will be found most convenient to place the Transmitter on the Arm to the left of the user in most experiments. This arrangement permits the Receiver to be placed on the right Arm thus providing maximum visibility of the Receiver Microammeter. The Receiver and Transmitter are placed facing each other.

2. Place the four Arms at 90 degrees to each other, with the Transmitter and Receiver as described above. Note that each Arm is equipped with two different centimeter scales; one scale starts at zero centimeters and indicates the distance from the axis of rotation to the aperture plane of either Horn when attached to the Transmitter or Receiver. The other scale starts at 15 centimeters and indicates the distance from the axis of rotation to any accessory mounted in the Sliding Accessory Holder. A red arrow on the lower part of the Horn side of the Transmitter and Receiver, and a black arrow on the flat surface of the Sliding Accessory Holder indicate which scale is to be used.

E - The Accessories

1. The Positioning Attachments can be installed as follows:

a. Loosen the locking screw by turning the wing nut counterclockwise.

b. Turn the large knurled knob on the Positioning Attachment until the long lead screw is approximately centered in the U-shaped frame.

c. Place the Transmitter, Receiver, or Sliding Accessory Holder on one of the Arms in the position defined in the particular experiment.

Note: (a) Full-scale deflection of the Microammeter indicates 20 microamperes. To avoid burnout or other damage, keep the Receiver Gain control set so that the deflection does not exceed 100 and preferably remains in the 85 to 95 range, unless otherwise indicated in the instructions. The VSWR scale and the Decibel scale on the Microammeter are for use with accessories which will be available at a future date.

d. Place the Positioning Attachment on the Arm so that the part to be positioned is between the Positioning Attachment and the Goniometer axis of rotation. The large knurled knob on the Positioning Attachment is furthest from the Goniometer axis of rotation.

e. Engage the small round foot on the end of the Positioning Attachment lead screw in the shoe of the Sliding Accessory Holder, Transmitter, or Receiver, as the case may be.

f. Lock the Positioning Attachment to the Radially-Rotatable Arm by turning the wing nut clockwise until it is moderately tight.

g. Turn the large knurled knob through exactly 360 degrees and you will note that the movement will be exactly 0.1 centimeter (1 millimeter), or one minor division on the Arm scale. There are 100 grooves on the knob and therefore rotating the knob one groove will move the attached part .01 millimeters. In this way, by counting fractions of a turn, positions on the Arm can be very accurately determined when necessary. Effects of backlash must be eliminated by taking out any existing play between parts before counting the turns of the large knurled knob.

2. The Full Reflector, the Half Reflector, the Single Slit Plate, the Double Slit Plate, and the Polarization Grid each have a small hole above their straight edge, which edge is to be placed downward in the Rotary Platform Accessory Holder and the Sliding Accessory Holder. This hole is to be centered in the "V" notch of the Accessory Holder and will ensure centering of the Accessory.

Chapter 2

INITIAL TURN-ON INSTRUCTIONS

1. Assemble the equipment as described in Chapter 1.

2. Arrange the ED-SET as shown in Fig. 3.

3. Plug the Transmitter into a 115 volt, 50-60 cycle A. C. outlet which is not subject to sudden variations in line voltage. Remove the Two Prong Adapter if necessary. CAUTION: The Transmitter can be severely damaged by connecting to an improper power source. Set the Gain Control of the Receiver at 3 on its scale. Turn on the Transmitter by rotating the Repeller Tuning Knob in a clockwise direction. The red pilot lamp will light, indicating that power is "ON". Wait at least two minutes to permit the Klystron to warm up and stabilize.

Very slowly adjust the Repeller Tuning Knob to obtain maximum power on the Receiver Microammeter. Do this very carefully and note the Repeller Tuning Knob setting for each peak reading on the Receiver Microammeter. After each peak has been explored, return the Repeller Tuning Knob to the setting which gave the highest reading. This tuning must be done very carefully and should be rechecked for minor adjustment before each experiment. The ED-SET is now in operating condition.

4. During all experiments, avoid placing your hand or any other object within the field while making measurements. Failure to do so will cause inaccurate Microammeter readings.

5. The Microammeter has been heavily damped for the purpose of reducing the effects of variation in input line voltage. It is therefore recommended that, when seeking a peak Microammeter reading by moving either the Transmitter, Receiver, Rotary Platform, or the Sliding Accessory Holder, all changes in the position of these components be made very slowly.

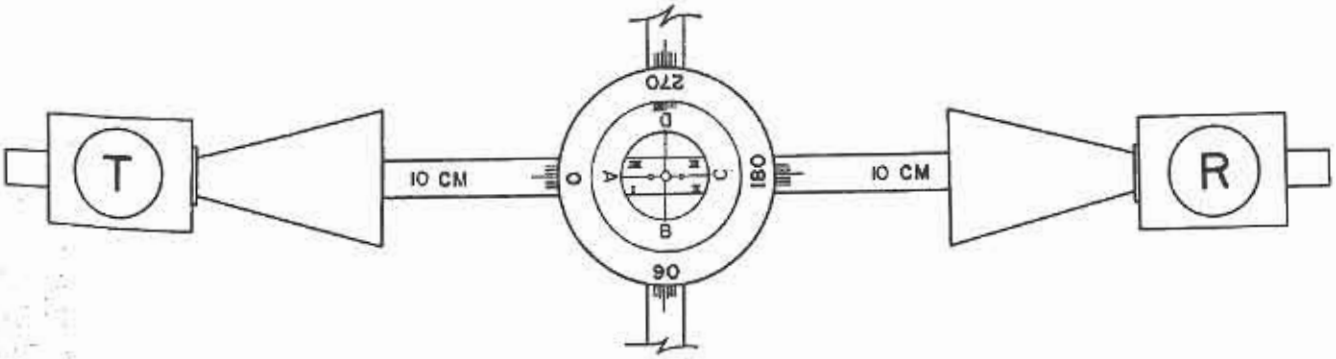
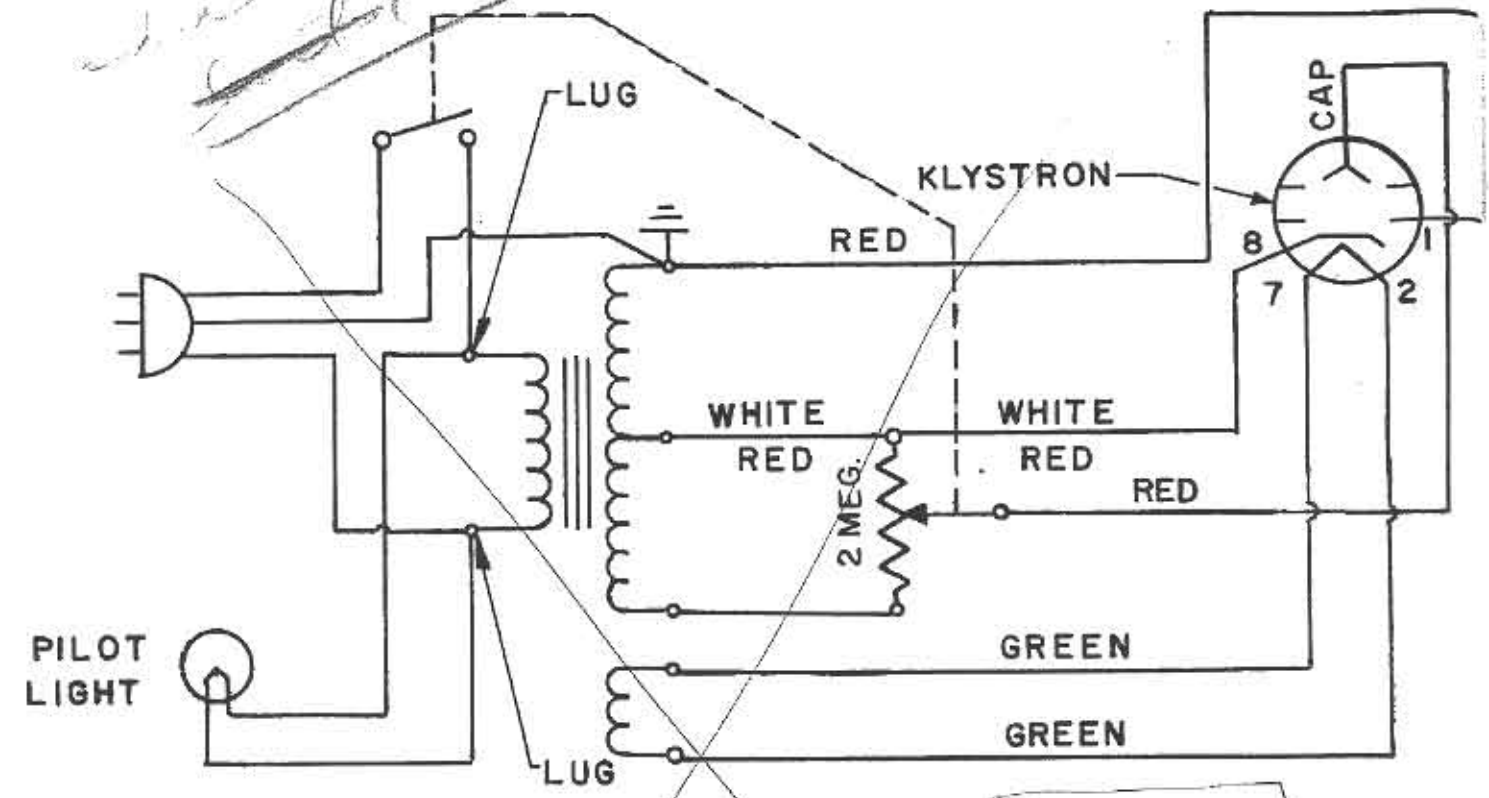
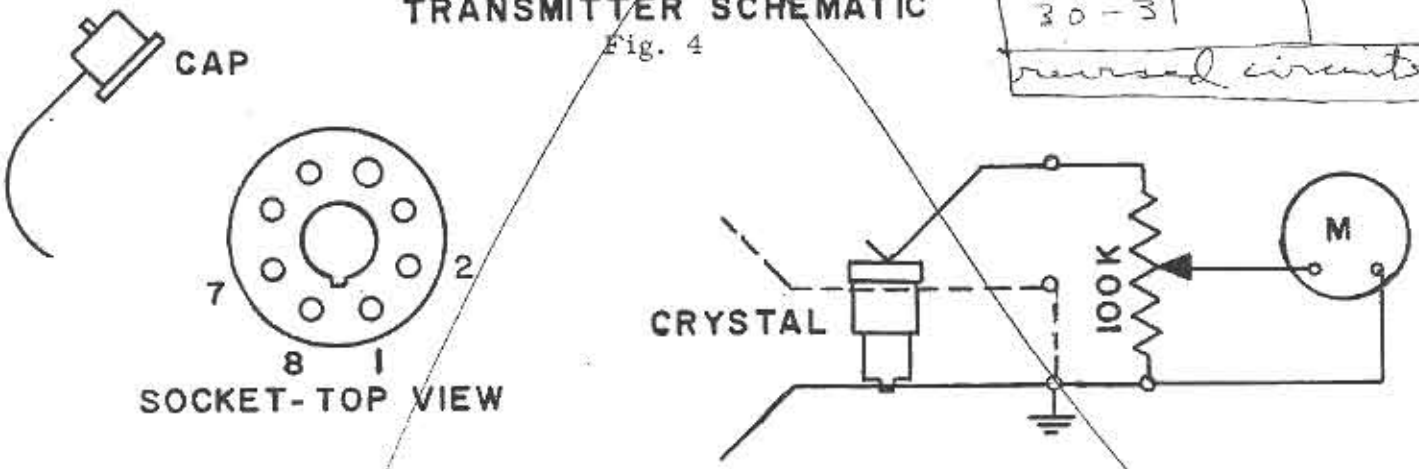


Fig. 3



TRANSMITTER SCHEMATIC

Fig. 4



RECEIVER SCHEMATIC

Fig. 5

VOLTAGES BETWEEN	VOLTAGE AC
7 & 2	6.3
1 & 8	220
1 & CAP	220-440

Chapter 3

TROUBLE SHOOTING

If no reading is obtained on the Receiver Microammeter after following the Initial Turn-On Instructions in Chapter 2, Page 4, the following procedure, in sequence, is suggested:

1. Is the ED-SET plugged into a live 115 Volt AC outlet? (A burned-out pilot light will not adversely effect operation of the Transmitter.) Is the Receiver Crystal Retainer Knob tight?

2. Set Receiver Gain Control at 6 and repeat Initial Turn-On Instructions.

3. Change the frequency of the Klystron by rotating the Klystron Tuning Key 180° either clockwise or counterclockwise. Repeat Initial Turn-On Instructions.

4. Are the Transmitter and Receiver Horns attached with 4 Screws each. This avoids the possibility of cross-rotation and resultant misalignment of the Horn and the waveguide.

5. Remove the Klystron (as described in Maintenance Instructions, Chapter 4, Page 8) and check the voltages at the Klystron Socket using a 20,000 ohm/volt, Volt-Ohm Milliammeter. Set the Repeller Tuning at 6, observe safety precautions, and check the actual voltages against those shown on the Transmitter schematic, Fig. 4, Page 5. If the voltages are not correct within ± 20%, send the Transmitter to your ED-SET distributor for repair.

6. Remove the Crystal (as described in Maintenance Instructions, Chapter 4, Page 8). Check the resistance between the pin tip and the base of the crystal using a 20,000 ohm/volt, Volt-Ohm Milliammeter. A good crystal will show in one direction a reading of several hundred ohms, and several thousand ohms in the other direction. A front to back ratio greater than 10 is typical, a ratio of less than 5 indicates crystal replacement is necessary. Otherwise re-install the Crystal.

7. Check the Receiver Microammeter by connecting a 1 1/2 volt battery in series with 100,000 ohm resistor and complete the circuit by contacting the Crystal Retainer Bracket and any unpainted surface of the Receiver case. With the Receiver Gain Control set at 6, a Microammeter reading should be obtained. If not, the Microammeter is inoperative, send the Receiver to your ED-SET distributor for repair.

8. The Klystron, by a process of elimination, has been determined to be defective and replacement is necessary.

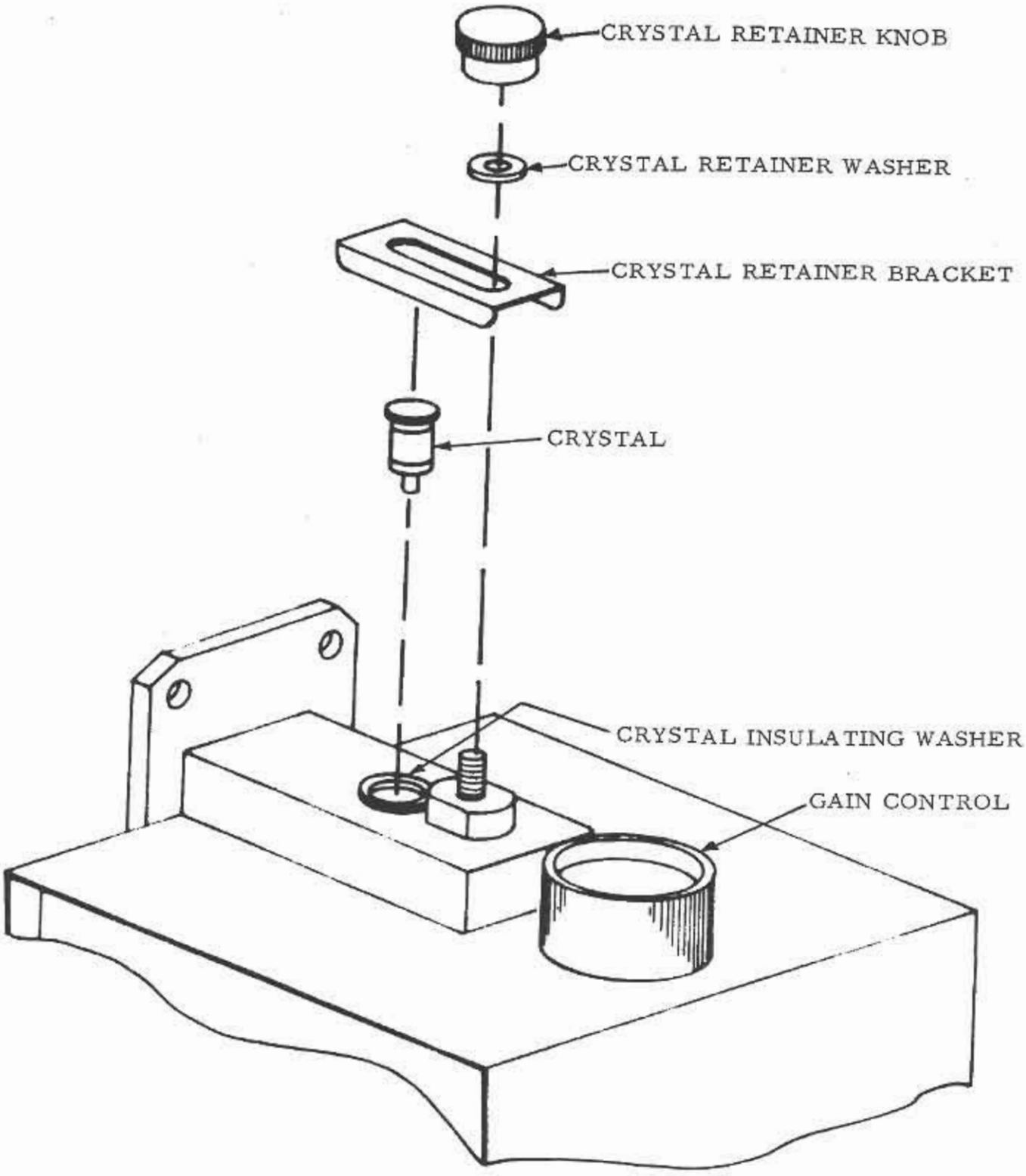

CRYSTAL RETAINER KNOB
CRYSTAL RETAINER WASHER
CRYSTAL RETAINER BRACKET
CRYSTAL
CRYSTAL INSULATING WASHER
GAIN CONTROL

Fig. 6

Chapter 4

MAINTENANCE INSTRUCTIONS

1. INSTRUCTIONS FOR REPLACING CRYSTALS

It will eventually become necessary to replace the Crystal in the ED-SET Receiver. The replacement Crystal is part number SK1191, available from your ED-SET distributor. As shown in Fig. 6, replacement is accomplished as follows:

A. Loosen the Crystal Retainer Knob on top of the Receiver wave guide.

B. Slide the Crystal Retainer Bracket back, exposing the top of the crystal.

C. Do not use any tools. Remove the Crystal with your fingertips. It is a small, bullet-shaped cylinder with brass contacts at each end and a white ceramic center which is marked IN23B. Do not simultaneously touch both ends of the new crystal with your fingers as this can cause Crystal burnout by discharging your body static electricity.

D. If during Step C, the Crystal Insulating Washer should come loose, carefully re-seat it. Place the new Crystal, pin tip down, into the opening. The pin tip of the Crystal must be seated in the small hole in the lower wall of the waveguide.

E. Slide the Crystal Retainer Bracket back in position. Tighten the Crystal Retainer Knob.

2. INSTRUCTIONS FOR REPLACING KLYSTRON

It will eventually become necessary to replace the Klystron in the ED-SET Transmitter. The replacement Klystron is part number X4138A, available from your ED-SET distributor. As shown in Fig. 7, replacement is accomplished asfollows:

A. Disconnect the ED-SET from the 110 Volt A. C. outlet. Allow the Klystron to cool until it can be comfortably handled.

B. Lift and wiggle loose the grid cap.

C. Remove the Klystron by gently rocking it while lifting. Slowly withdraw the Klystron from its socket in order not to damage the delicate plastic antenna which protrudes from its underside.

D. Carefully insert the plastic antenna of the new Klystron in the round "through" hole of the socket and align the Klystron pins with the socket holes. Firmly seat the Klystron with a downward pressure. Attach the grid cap to the top of the Klystron.

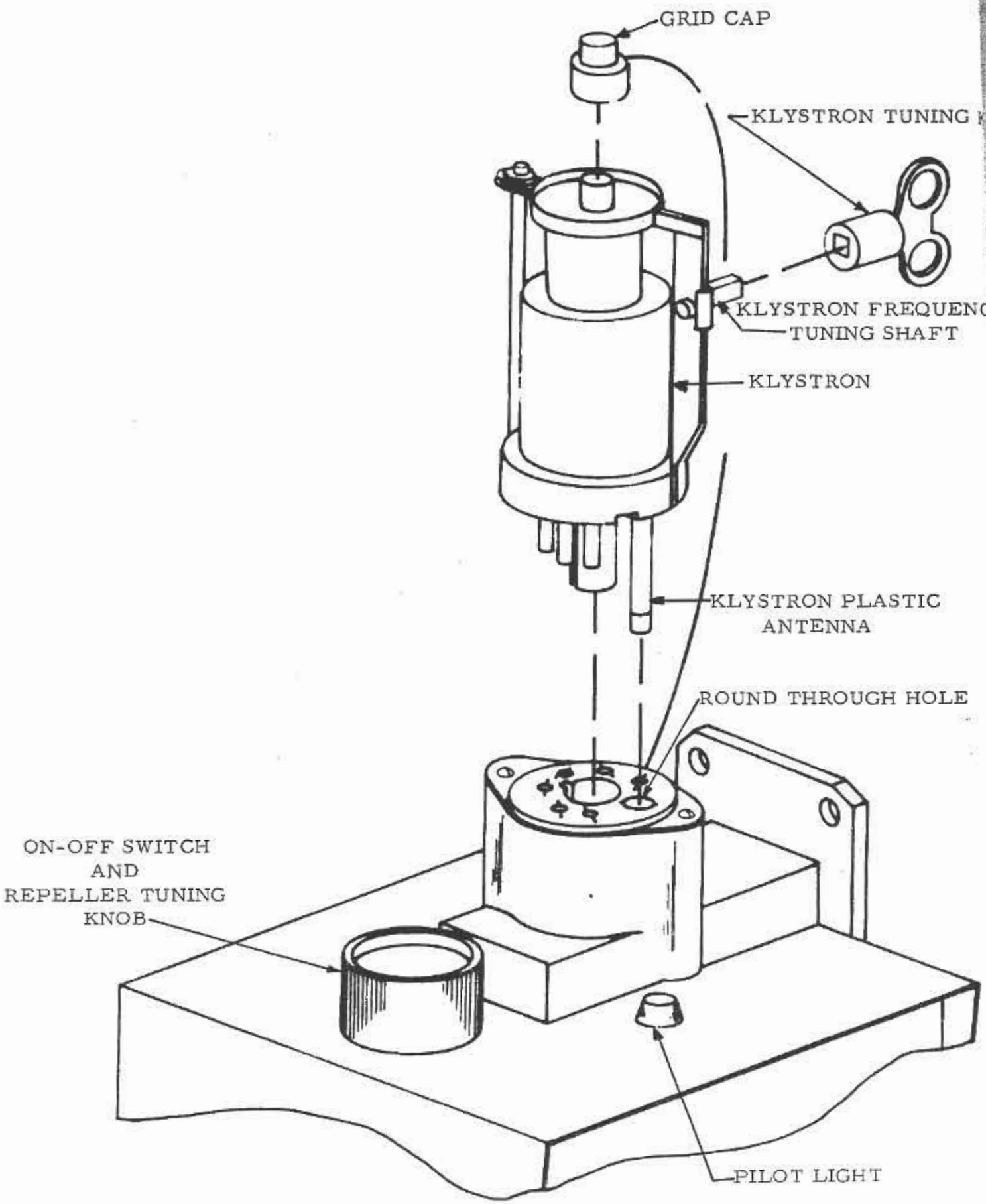

GRID CAP
KLYSTRON TUNING K
KLYSTRON FREQUENC
TUNING SHAFT
KLYSTRON
KLYSTRON PLASTIC
ANTENNA
ROUND THROUGH HOLE
ON-OFF SWITCH
AND
REPELLER TUNING
KNOB
PILOT LIGHT

Fig. 7

Chapter 5

ABSORPTION, MEASUREMENT OF

1. Place the ED-SET in operating condition as described in Chapter 2. Remove the Rotary Platform Accessory Holder.

2. Arrange the ED-SET as shown in Fig. 8.

3. Adjust the Gain Control of the Receiver to obtain a Microammeter reading of 100. Place on the Rotary Platform an absorber such as a text book, with the cover which faces the Receiver on line AC, with the plane of the absorber vertical to the direction of transmission. Record the Receiver Microammeter reading.

4. Measure the reflection from the absorber by rotating the Receiver to the 90 degree position. Record the Receiver Microammeter reading. The original power level minus the total of the attenuated and reflected power is the absorbed power.

5. Try various other absorbers such as wood, plaster board, cellulose sponge, and glass plate.

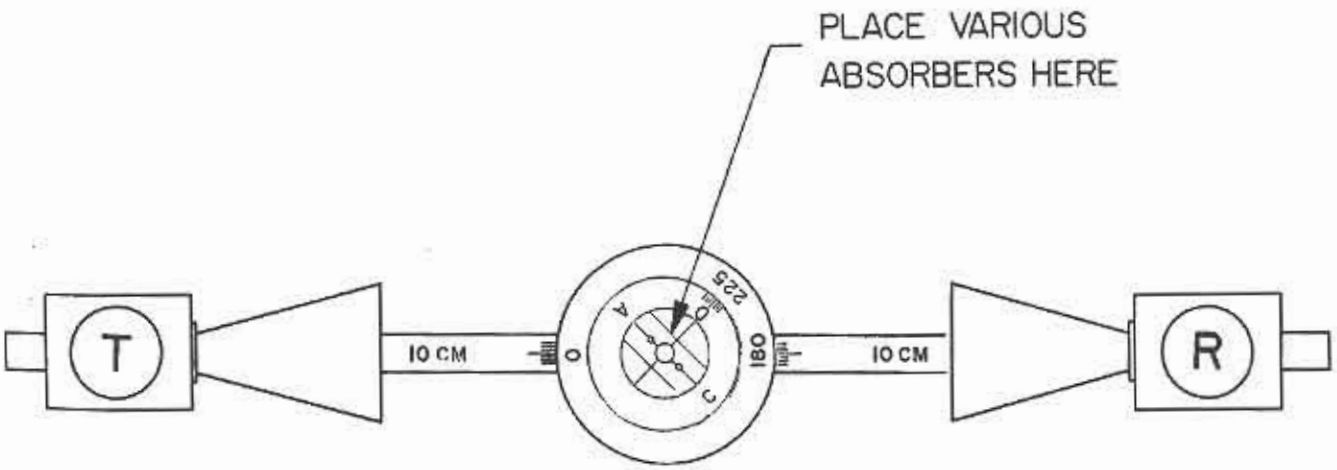


Fig. 8

Chapter 6

POLARIZATION, MEASUREMENT OF

1. Place the ED-SET in operating condition, as described in Chapter 2.

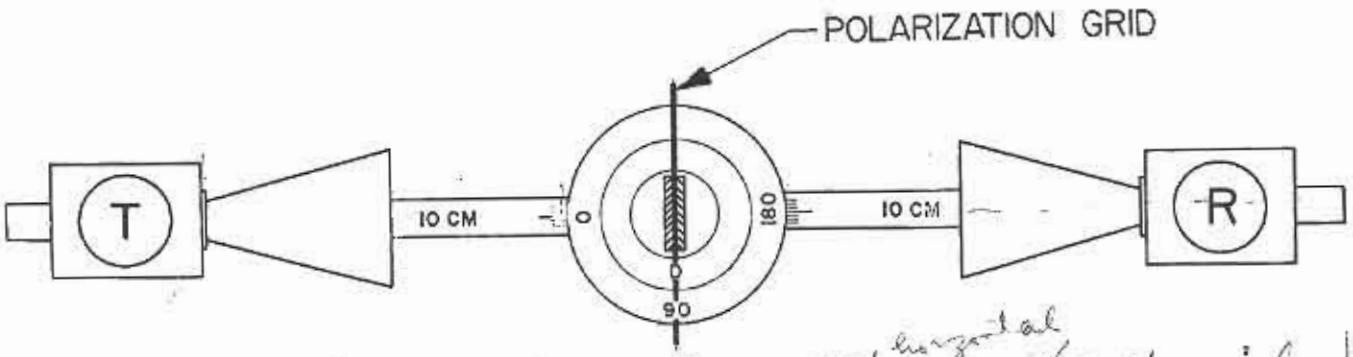
2. Arrange the ED-SET as shown in Fig. 9.

3. Place the Polarization Grid in the Rotary Platform Accessory Holder with the grids in a horizontal position and note the Receiver Microammeter reading.

4. Repeat step 3 except rotate the Polarization Grid so that the grids are 45 degrees from the horizontal by placing appropriate straight edge of the Polarization Grid in the Rotary Platform Accessory Holder. Note the Receiver Microammeter reading.

5. Repeat step 3 except with the grids in a vertical position. Note the Receiver Microammeter reading.

6. The ED-SET 3 centimeter microwaves are vertically polarized, similar to polarized light. You will note that the transmission decreases as rotation of the Polarization Grid increases from horizontal to vertical.



7. Turn the receiver 90° about its horizontal axis (so it is parallel to the) and repeat 3 & 5. explain

Fig. 9

SECOND LAW OF REFLECTION, VERIFICATION OF

1. Place the ED-SET in operating condition as described in Chapter 2.

2. Arrange the ED-SET as shown in Fig.10.

3. Slowly rotate the Rotary Platform until a peak reading is obtained on the Receiver Microammeter. Is the angle of incidence equal to the angle of reflection as stated in the Second Law of Reflection? Repeat the experiment using different angles.

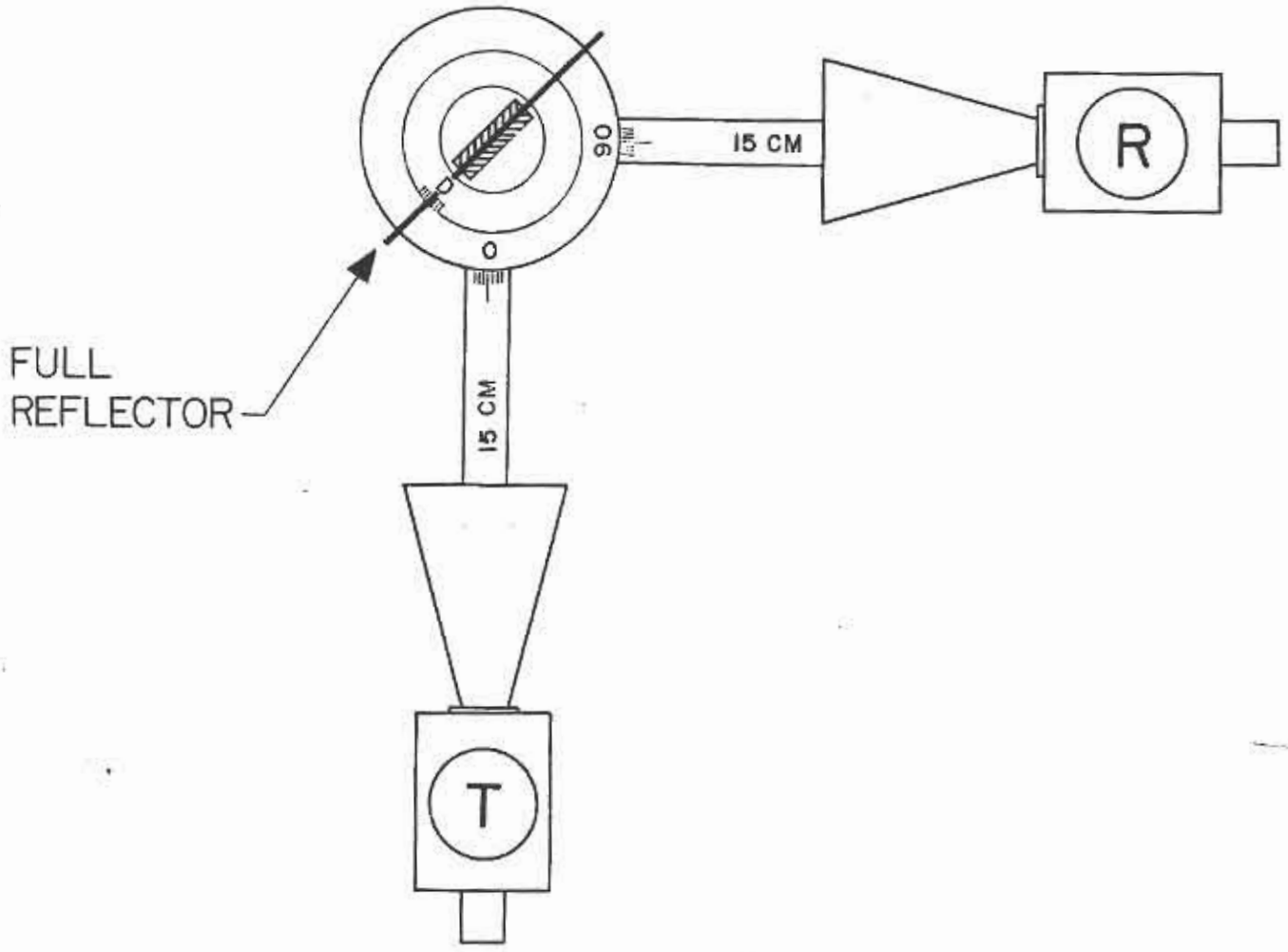


Fig. 10

STANDING WAVES, MEASUREMENT OF

1. Place the ED-SET in operating condition as described in Chapter 2.

2. Arrange the ED-SET as shown in Fig. 11.

3. This arrangement will create a standing-wave pattern between the Transmitter and the Full Reflector. A portion of the wave pattern is picked up by the Probe Plate and reflected to the Receiver.

4. As the Full Reflector is moved by the Positioning Attachment, the maxima and minima can be observed on the Receiver Microammeter. At the first maximum, adjust the Gain Control to obtain a maximum Microammeter reading. Record the reading and the position on the 180 degree Arm.

5. Using the Positioning Attachment, move the Full Reflector away from the axis and record the Receiver Microammeter reading at each position one millimeter (one full turn of the knob of the Positioning Attachment) away from the previous position. Repeat until 20 Microammeter readings and positions have been recorded.

6. Sufficient data is now available to plot a graph of the standing wave in terms of Reflector position and Receiver Microammeter readings.

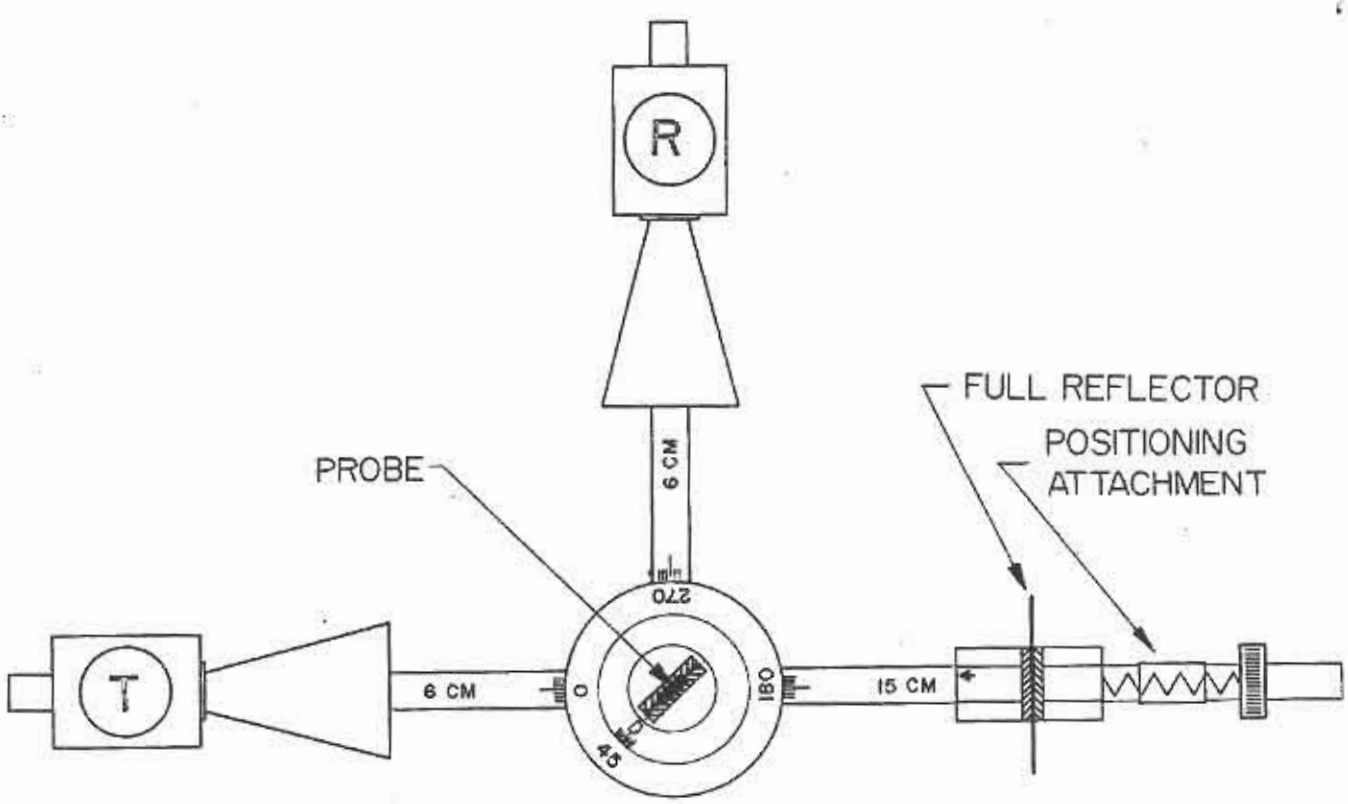


Fig. 11

Chapter 9

MICHELSON'S INTERFEROMETER, USE OF IN MEASURING WAVELENGTH

1. Place the ED-SET in operating condition as described in Chapter 2.

2. Arrange the ED-SET as shown in Fig. 12.

3. Optimize the setup for sharpest nulls by removing the Full Reflectors from the two Sliding Accessory Holders and slightly changing the positions of the Transmitter and Receiver from their 10-centimeter marks until a maximum Receiver Microammeter reading is obtained. Replace the two Full Reflectors and position the 270 degree Full Reflector for a minimum reading on the meter. Sharpen this null by adjusting the 180 degree Full Reflector. Adjusting the 270 degree Full Reflector will now give deep nulls.

4. The free-space wavelength can now be calculated by measuring the distance traveled by the 270 degree Full Reflector between nulls. This distance is equal to one-half wavelength in free-space. Where λ = free-space wavelength in centimeters, then $\frac{\lambda}{2}$ = distance between nulls in centimeters.

5. With the ED-SET arranged for a null reading as in Step 4, the Index of Refraction of low loss materials (a) in thin sheet form can be measured by placing the sheet in a vertical position between the 270 degree Full Reflector and the Half Reflector. Subject to minor error caused by multiple reflections within the sample, the Index of Refraction can be calculated using the formula:

$$n = 1 + \frac{\Delta}{d}$$ derive this formula

where
- n = index of refraction
- Δ = Full Reflector movement in centimeters required to restore the original null obtained prior to insertion of material being measured.
- d = thickness of sample in centimeters

Note: (a) Polyethylene, polystyrene, paraffin wax, teflon.

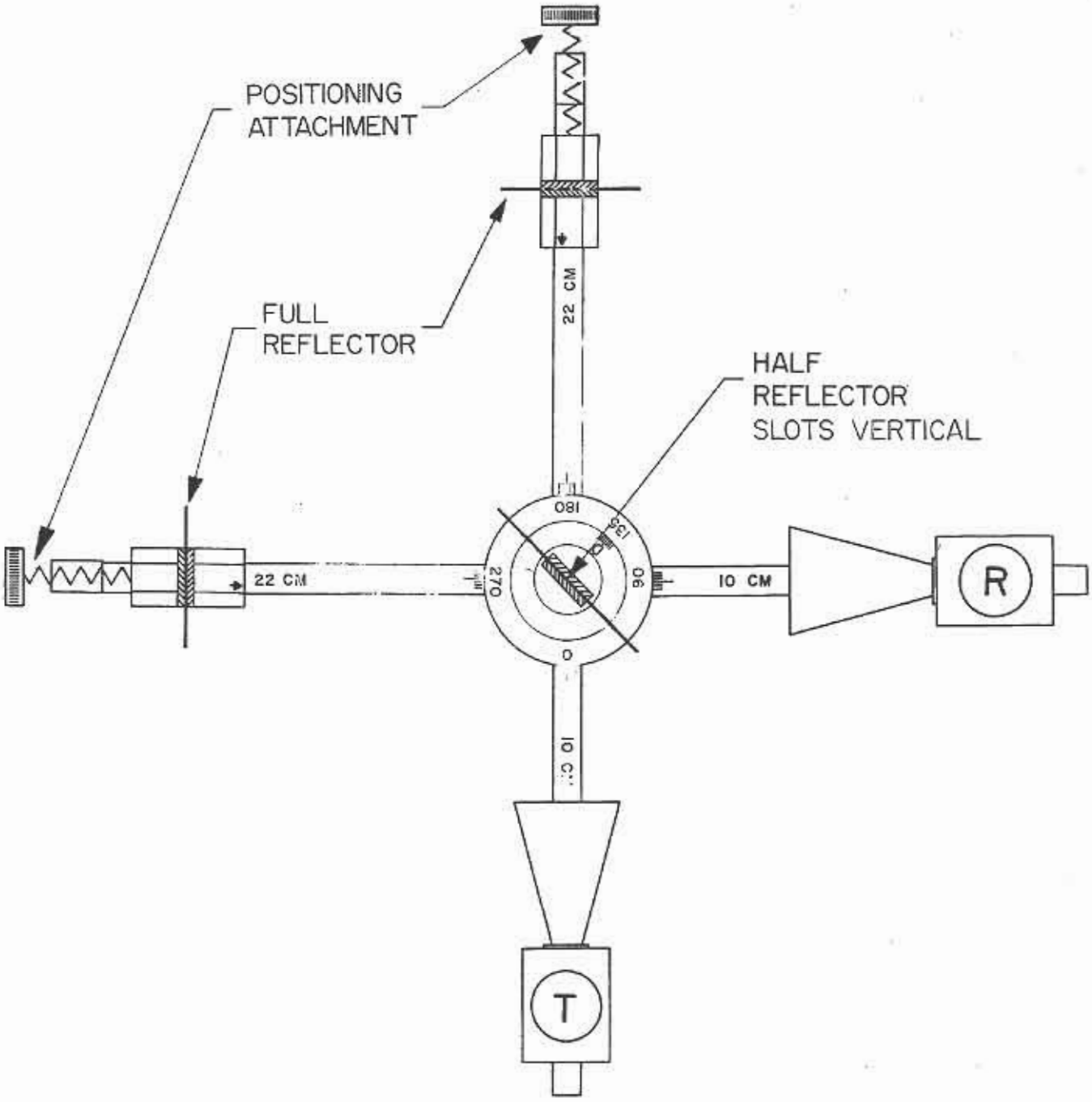

POSITIONING
ATTACHMENT
FULL
REFLECTOR
HALF
REFLECTOR
SLOTS VERTICAL
22 CM
22 CM
10 CM
10 CM
180
135
90
270
0
R
T

Fig. 12

Chapter 10

SPEED OF ELECTROMAGNETIC WAVES, MEASUREMENT OF

1. Set the Transmitter to a frequency of 9830 megacycles per second, as described in Chapter 1, paragraph B2.

2. Place the ED-SET in operating condition as described in Chapter 2.

3. Arrange the ED-SET for Michelson's Interferometer experiment as described in Figure 12, and measure the wavelength as described in Chapter 9.

4. Repeat this measurement at two additional different spacings of the Full Reflectors. Average the three readings in order to minimize errors due to inherent limitations of accuracy of the centimeter scale readings.

5. Since the frequency is known and the wavelength has been measured, the speed of electromagnetic radiation can now be calculated from the classic relation:

$$c = f\lambda$$

where c = velocity
f = frequency
λ = wavelength

Chapter 11

THIN FILM, MEASUREMENT OF

1. Place the ED-SET in operating condition as described in Chapter 2.

2. Arrange the ED-SET as shown in Fig. 13.

3. Using the Positioning Attachment, move the Full Reflector away from the axis to produce sharp nulls and peaks in the Receiver Microammeter readings. By noting the distance between the Full Reflector and the Half Reflector at null points, it will be observed that nulls occur when the distance between the Full Reflector and the Half Reflector are multiples of one-half wavelength (approximately 1.5 centimeters). Similarly, peaks occur when separation distances are multiples of one-quarter wavelength.

4. This is analogous to optical thin-film interference effects which produce dark and light bands in the reflected light of a single color. In this case the spacing between the Half Reflector and the Full Reflector is comparable to the thickness of the thin film.

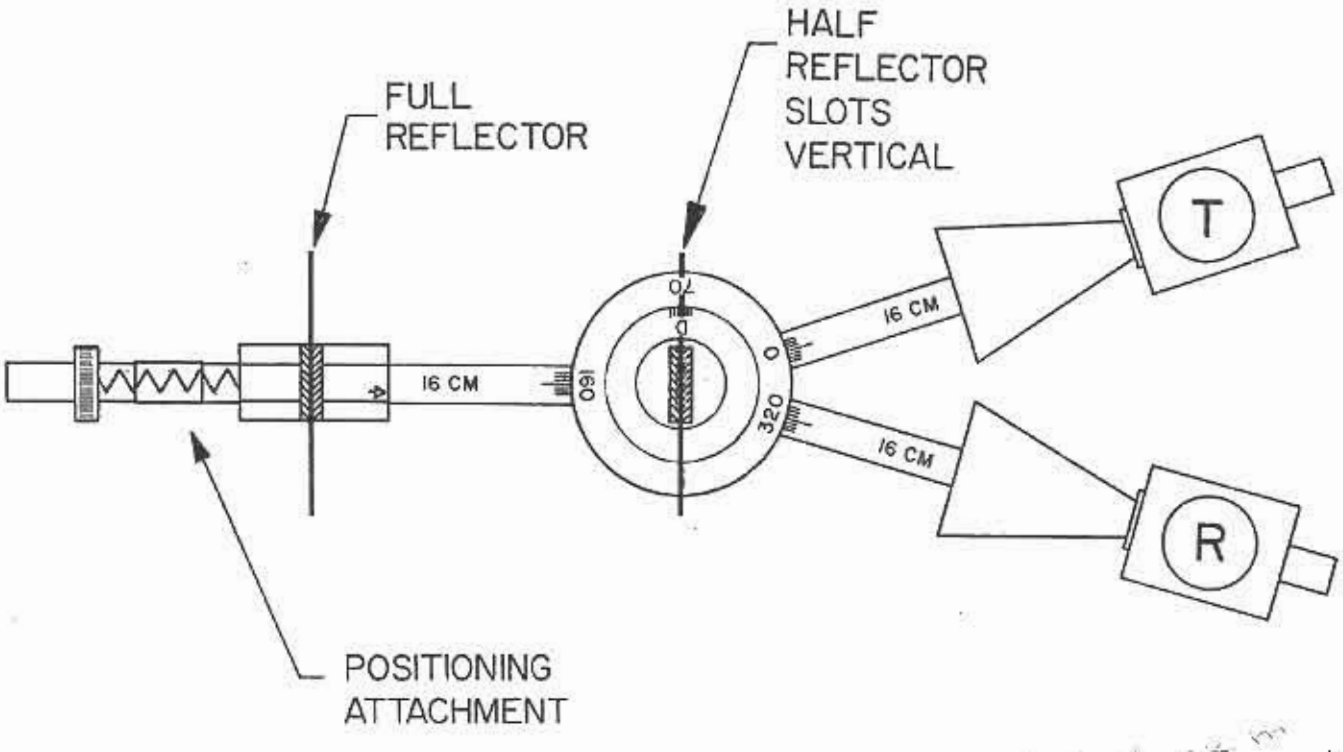


Fig. 13

Chapter 12

THIN FILM INTERFERENCE, AS APPLIED TO COATED OPTICS

1. Place the ED-SET in operating condition as described in Chapter 2.

2. Arrange the ED-SET as shown in Fig. 14.

3. Using the Positioning Attachment, withdraw the Polarization Grid from the axis until a minimum reading is obtained on the Receiver Microammeter. Note the Receiver Microammeter reading and the position of the Polarization Grid on the Arm. We have measured the amplitude of a wave which has been reflected by a medium which both transmits and reflects, and to which a means of reducing the reflectivity of the medium has been interposed between the Transmitter and the medium.

4. Remove the Half Reflector and note the Receiver Microammeter reading. We have measured the amplitude of a wave which has been reflected by a medium which both transmits and reflects.

5. Rotate the 0 degree Arm counterclockwise until the 180 degree marking is opposite the Transmitter. Remove the Positioning Attachment from the 0 degree Arm without disturbing the position of the Polarization Grid. Place the Receiver on the 0 degree Arm with its Horn lightly touching the Polarization Grid. Note the Receiver Microammeter Reading. We have measured the amplitude of a wave which has passed through a medium which both transmits and reflects.

6. Place the Half Reflector with its Slots in a Horizontal Position in the Rotary Platform Accessory Holder, the D scale of which should be on 90 degrees. Note the Receiver Microammeter Reading. We have measured the amplitude of a wave which has passed through a medium which both transmits and reflects, and to which a means of reducing the reflectivity of the medium has been interposed between the transmitter and the medium.

7. We have created in microwave frequencies an analogy to the principle employed in optics of increasing the transmission efficiency of a lens by coating it with the proper thin film to reduce its reflectivity.

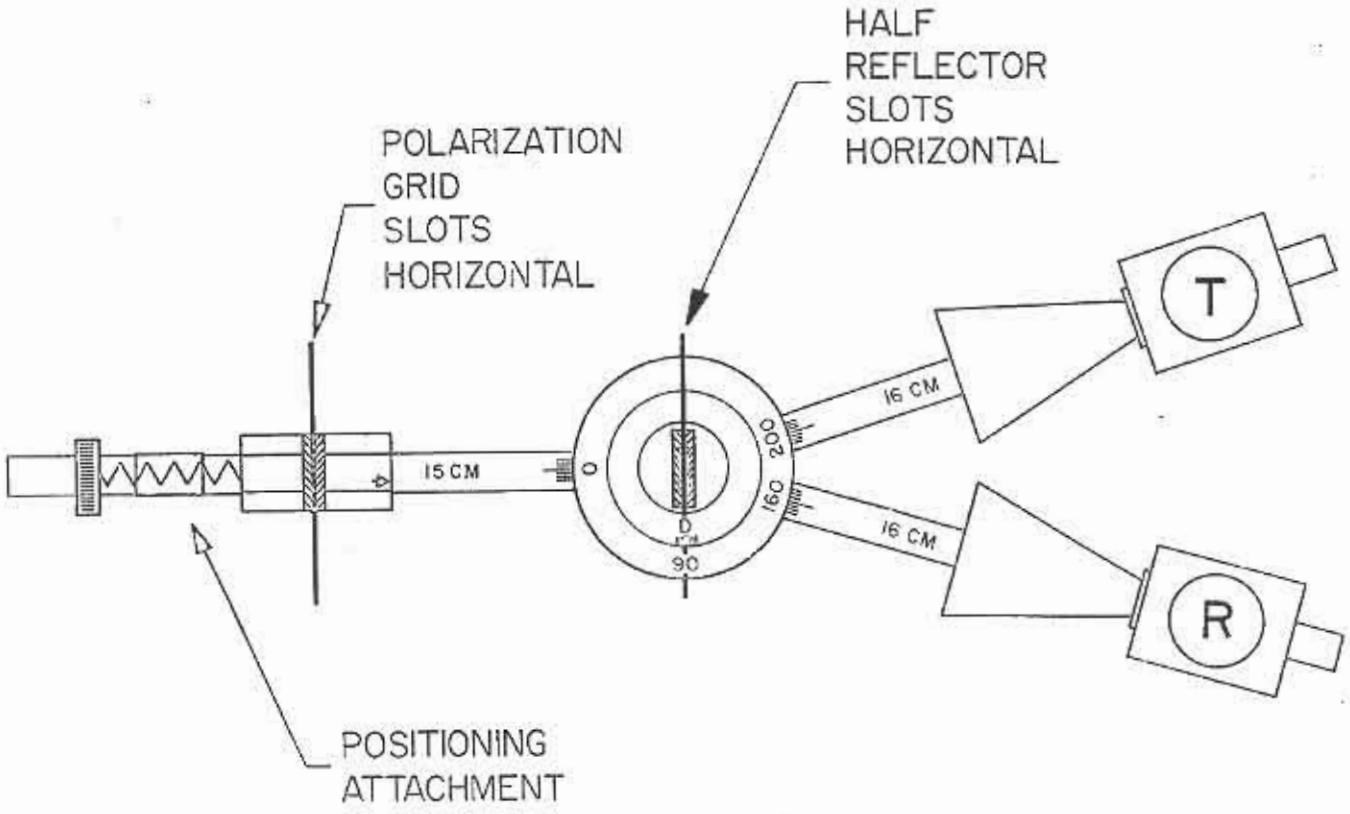

HALF
REFLECTOR
SLOTS
HORIZONTAL
POLARIZATION
GRID
SLOTS
HORIZONTAL
T
16 CM
15 CM
0
200
160
90
16 CM
R
POSITIONING
ATTACHMENT

Fig. 14

Chapter 13

SINGLE SLIT DIFFRACTION, USE OF IN VERIFYING THEORY OF SPHERICAL WAVELETS

1. Place the ED-SET in operating condition as described in Chapter 2.

2. Arrange the ED-SET as shown in Fig. 15.

3. Rotate the Receiver about the axis of rotation ± 90 degrees from the 180 degree position. Record the Receiver Microammeter reading every 5 degrees (37 readings). Plot this data on polar or rectangular coordinate paper. This will show the azimuth pattern obtained from the Single Slit Plate.

4. It will be noted that the radiation pattern of the Single Slit Plate confirms the Theory of Spherical Wavelets.

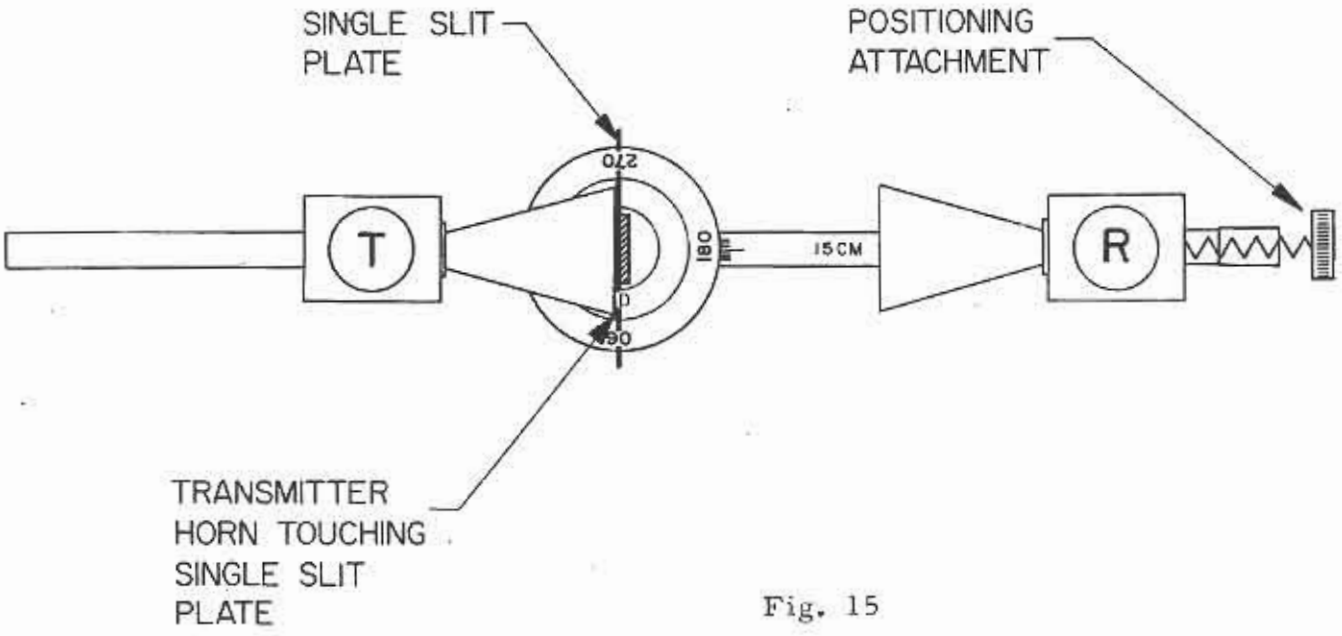


Fig. 15

Chapter 14

DOUBLE SLIT INTERFERENCE, PLOTTING PATTERNS OF

1. Place the ED-SET in operating condition as described in Chapter 2.

2. Arrange the ED-SET as shown in Fig. 16.

3. Follow the procedure described in Chapter 13. Plot the data obtained on polar or rectangular coordinate paper. Distinct maxima and minima will be observed on each side of the central position, resulting from the cancellation and reinforcement at points where the spherical waves being transmitted from each of the two slits intersect.

4. Measure in centimeters the spacing between centerlines of the slits and the aperture of each slit. Calculate the theoretical position of the maxima and minima and compare with the observed results.

5. Move the Receiver to a somewhat greater distance from the Double-Slit Plate and repeat Steps 3 and 4.

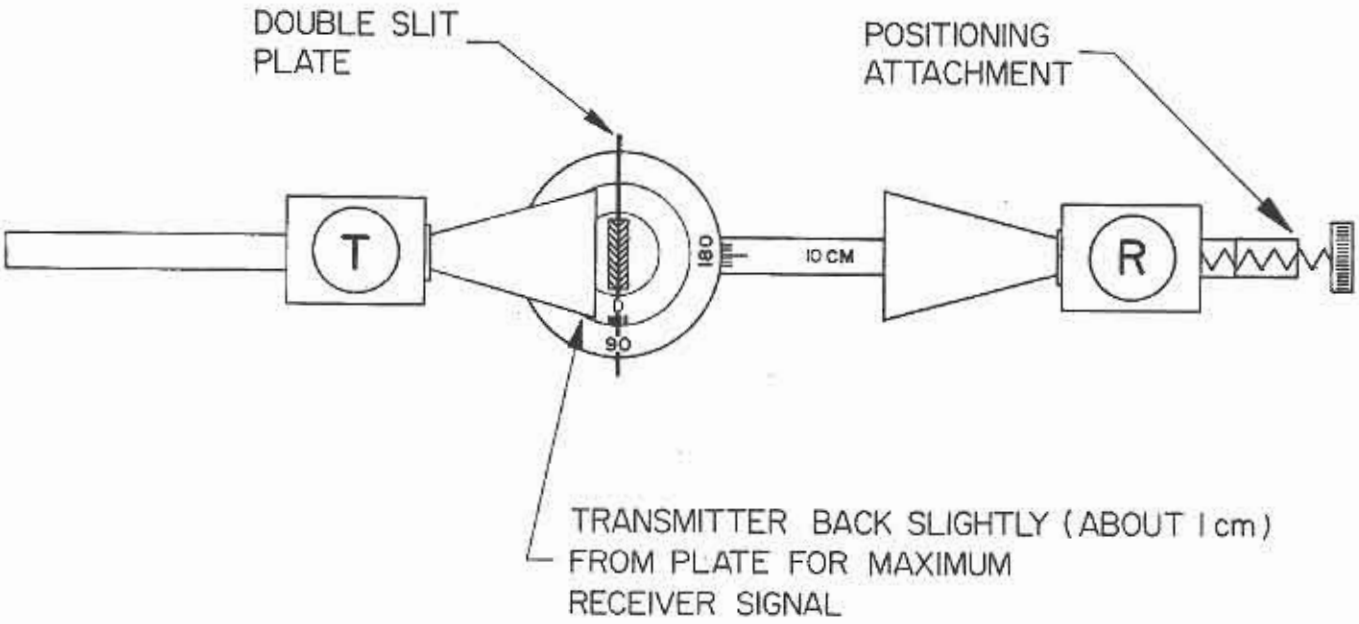


Fig. 16

Chapter 15

DIFFRACTION GRATING, USE OF IN MEASURING WAVELENGTH

1. Place the ED-SET in operating condition as described in Chapter 2.

2. Arrange the ED-SET as shown in Fig. 17.

3. Move the Receiver clockwise about the axis of rotation until first a minimum and then the maximum reading is obtained (approximately 105 degrees). This locates the center of the beam after it is bent by the diffraction grating. Calculate from this the angle of incidence and the angle of diffraction. See Fig. 18. In Chapter 13 we observed the behavior of a single slit at microwave frequencies, and in Chapter 14 the behavior of two slits. In this experiment we observe a wave diffracted by multiple slit sources.

4. A Diffraction Grating is formed by a series of very fine, closing spaced, parallel slits which, when light is incident upon it at a definite angle, produces a succession of interferences and maximums (spectra). The action of a plane transmission grating may be explained approximately as follows: A plane, monochromatic wave W, incident at angle i (see Fig. 18), reaches the slits at different times. The Horn receives the waves emerging from any two adjacent slits, A and B (among many others), after they have traveled paths differing by CA + AD; that is, by S sin i + S sin d, in which S = AB. If the Horn is so placed that this path difference is a whole number of wavelengths, $n\lambda$, the successive wave-trains will reach it in the same phase, they will be in synchronism and will produce a maximum reading. Therefore, any angle d for which this result is possible is subject to the condition:

$$S \sin i + S \sin d = n\lambda \ ,$$

or

$$\sin d = \frac{n\lambda}{S} - \sin i.$$

The spacing between slits S is 2.7 cm. for the Half Reflector Plate and the letter n denotes the order of the maximums (or images), which in this case is 1. Calculate the wavelength, λ .

5. Repeat Paragraph 4 and 5 also for other angles of incidence. (Use between 30 and 50 degrees for best results.)

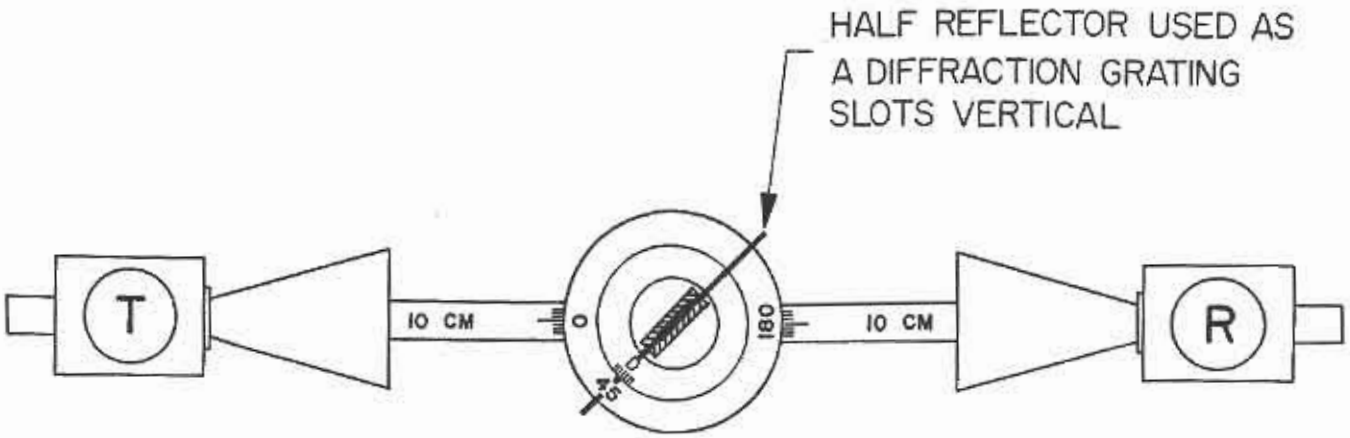

HALF REFLECTOR USED AS
A DIFFRACTION GRATING
SLOTS VERTICAL
T
10 CM
0
45
180
10 CM
R

Fig. 17

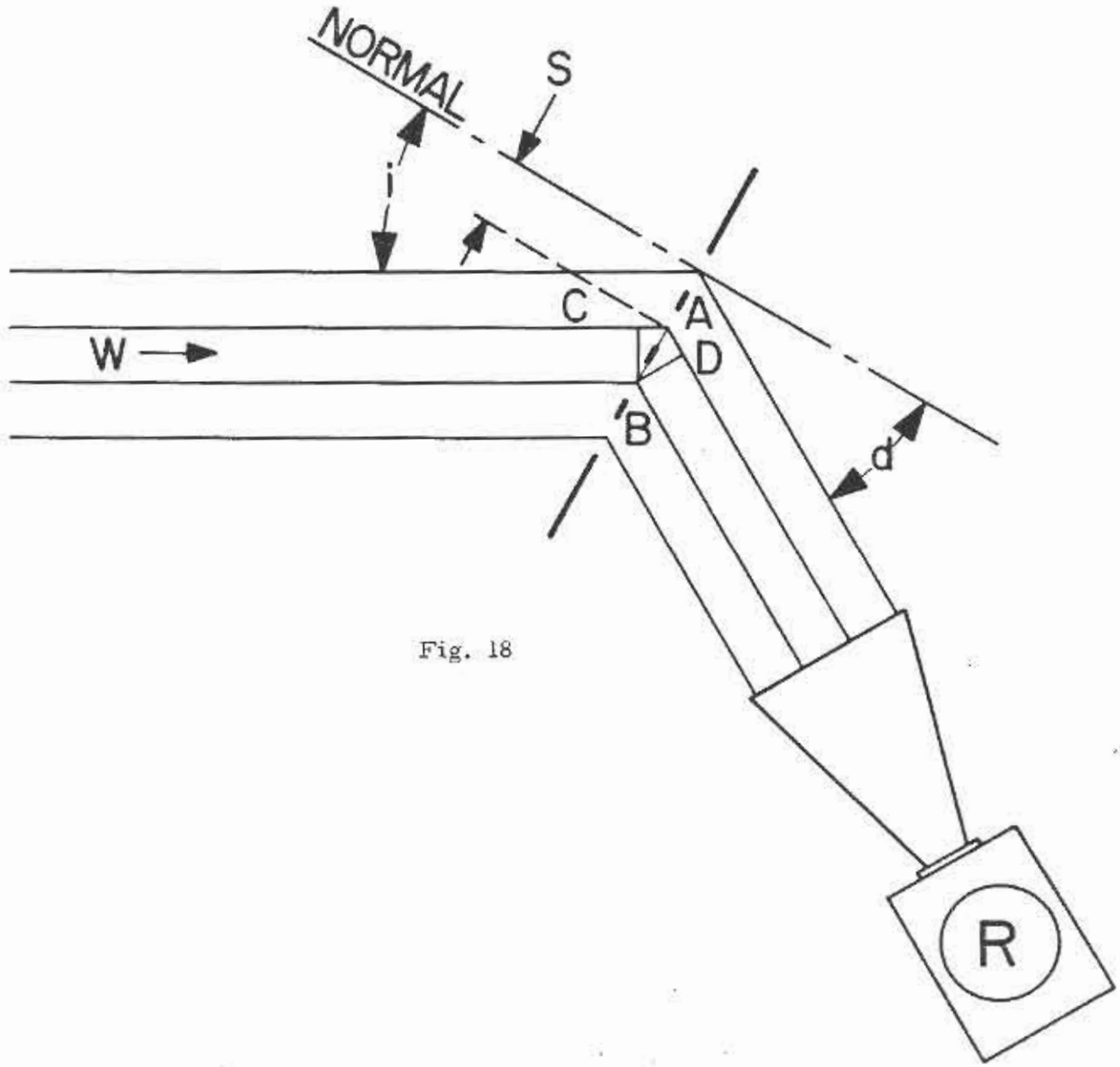

NORMAL
S
i
C
A
D
B
W
d
R

Fig. 18

TWO REMOTE SOURCES INTERFERENCE, PLOTTING A GRAPH OF

1. Place the ED-SET in operating condition as described in Chapter 2.

2. Arrange the ED-SET as shown in Fig. 19.

3. Using the Positioning Attachment, slowly move the Full Reflector away from the axis of rotation until the Receiver Microammeter indicates the first minimum.

4. Record the position of the Full Reflector and the reading on the Receiver Microammeter.

5. Using the Positioning Attachment, move the Full Reflector away from the axis of rotation until the Receiver Microammeter indicates the first maximum. Repeat step 4.

6. Continue as in steps 3 and 4 above until all maxima and minima have been obtained and recorded.

7. Plot a graph of the Receiver Microammeter readings against the Full Reflector positions. This graph is a representation of the interference pattern resulting from the coincidence of the two waves reaching the Receiver, one from the Probe, the other from the Full Reflector.

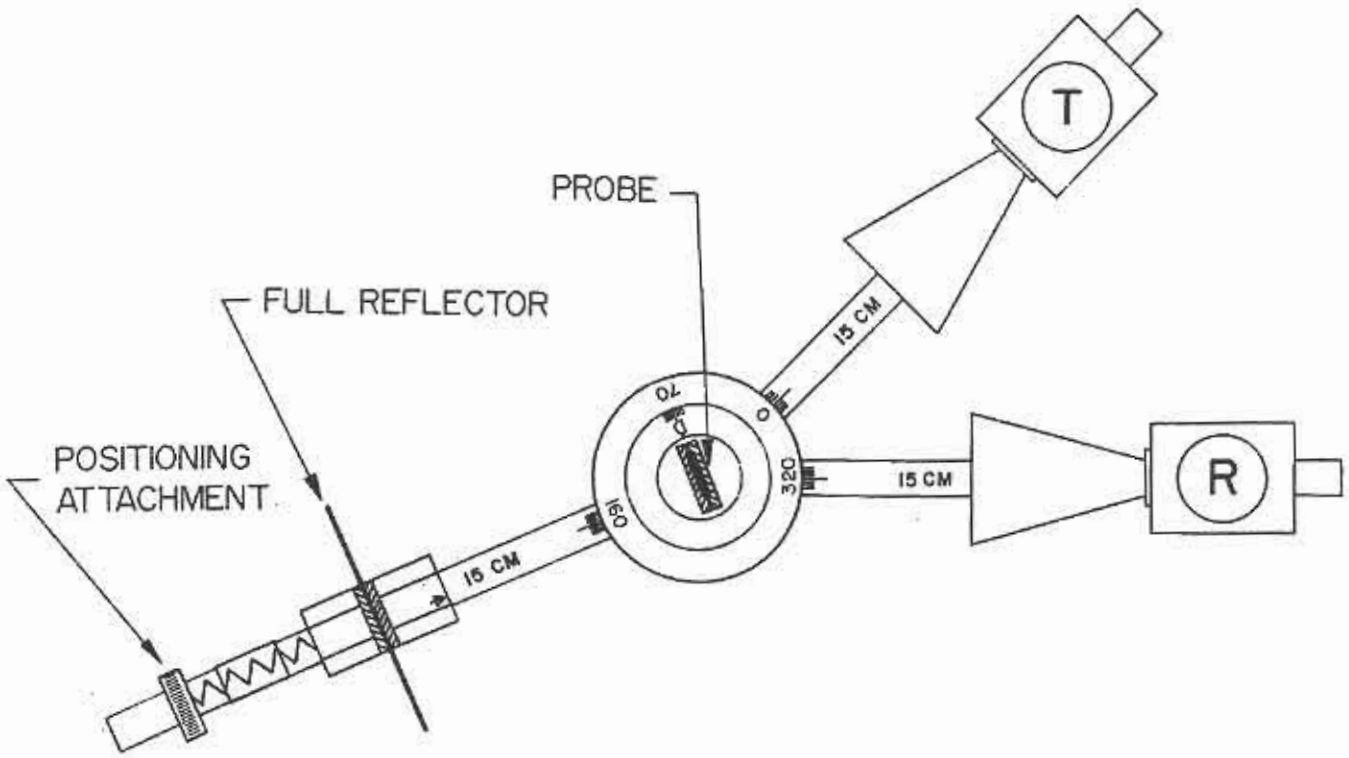


Fig. 19

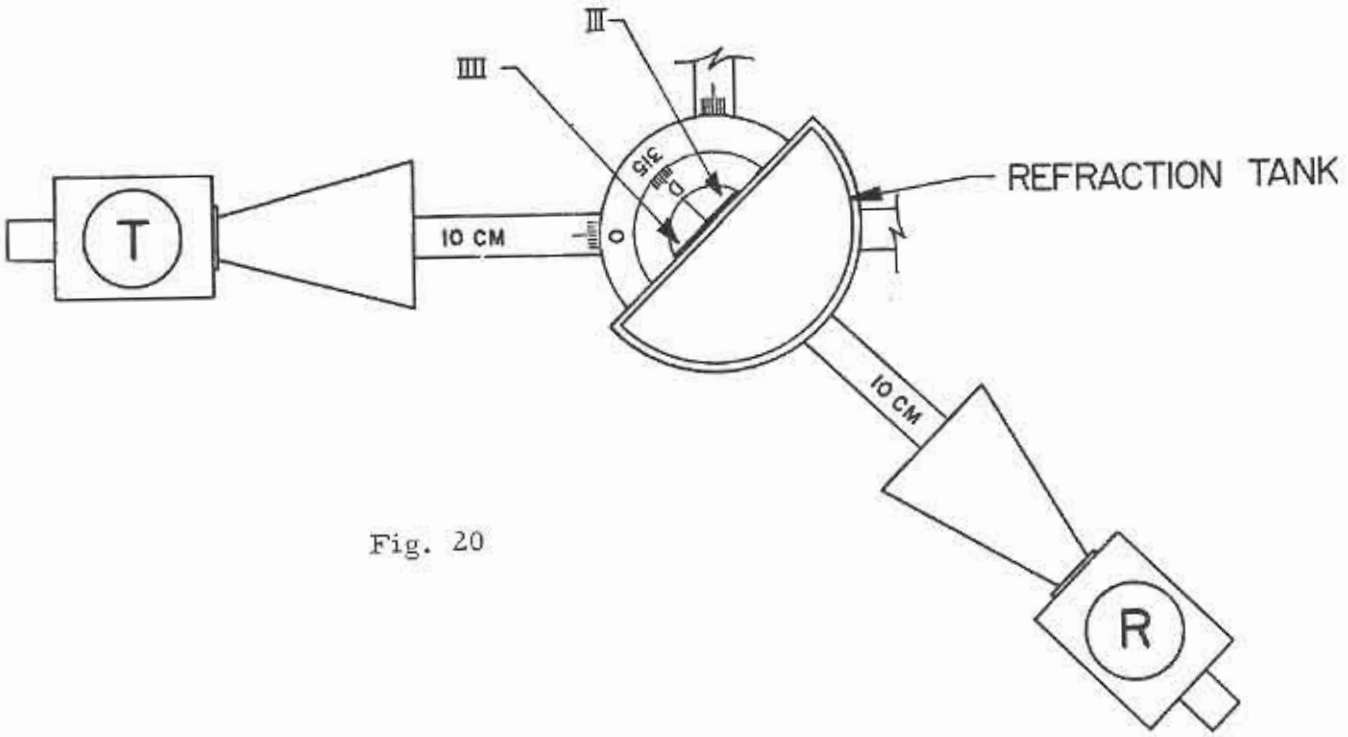


Fig. 20

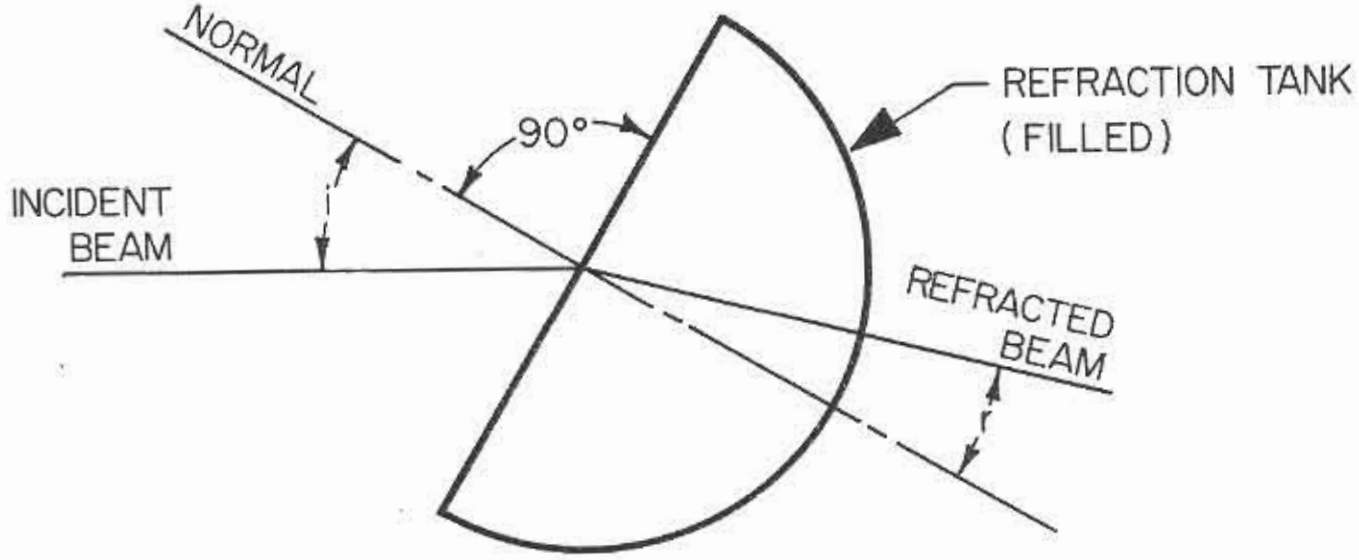


Fig. 21

i = ANGLE OF INCIDENCE
r = ANGLE OF REFRACTION

Chapter 17

INDEX OF REFRACTION, MEASUREMENT OF

1. Place the ED-SET in operating condition, as described in Chapter 2. Remove the Rotary Platform Accessory Holder.

2. Arrange the ED-SET as shown in Fig.20.

3. Remove and fill the Refraction Tank with the material to be measured, (sawdust, dry sand, sugar, polyethylene beads, household wax, etc.) using the plastic bag provided to facilitate handling.

4. Position the Refraction Tank on the Rotary Platform so that its bottom straight edge is aligned with line III-IIII and its indicating arrow is aligned with line B-D.

5. Rotate the Receiver Arm until a peak Receiver Microammeter reading is obtained.

6. Carefully remove the Refraction Tank and read the angles of incidence and refraction. See Fig.21.

7. Calculate the Index of Refraction $\frac{\sin i}{\sin r}$ for the material used.

8. Repeat the experiment using an angle of incidence of 60 degrees.

9. See Chapter 9, Paragraph 5, for use of Michelson's Interferometer for measurement of Index of Refraction of materials in sheet form.

FIBRE OPTICS, PRINCIPLE OF

1. Place the ED-SET in operating condition as described in Chapter 2. Remove the Rotary Platform Accessory Holder.

2. Arrange the ED-SET as shown in Fig. 22. Remove the Horns.

3. Note the Receiver Microammeter Reading.

4. Fill the Cylindrical Plastic Bag with Polyethylene Beads and close the end with a rubber band.

5. Holding the Cylindrical Bag from above, place it so that its ends are touching the waveguide mouth openings of the Transmitter and Receiver.

6. Note the Receiver Microammeter Reading.

7. Rotate the Transmitter Arm so it is in the 240 degree position.

8. Note the Receiver Microammeter Reading.

9. Repeat step 5.

10. Note the Receiver Microammeter Reading.

11. We have now demonstrated the Principle of Fibre Optics. Theory states that efficient transmission will be obtained when the diameter of the dielectric fibre is a minimum of one wavelength. The diameter of the filled Cylindrical Plastic Bag is approximately one and one-half wavelengths.

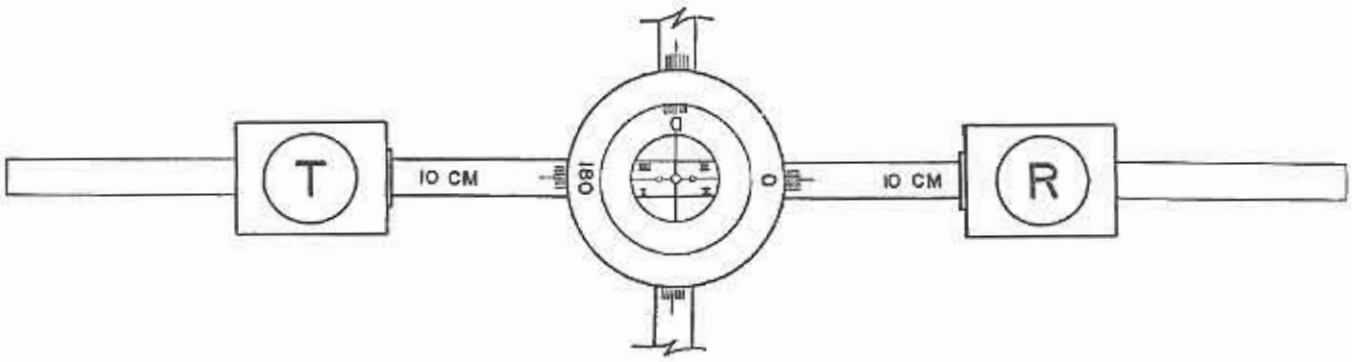


Fig. 22

FABRY-PEROT INTERFEROMETER, USE OF IN MEASURING WAVELENGTH

1. Place the ED-SET in operating condition as described in Chapter 2.

2. Carefully remove the Horns from the Transmitter and Receiver. CAUTION: Be careful not to drop, bend or damage the Horns in any way. Such damage will adversely effect the results obtained in experiments.

3. You will note that each Full Reflector has three holes in it. The center hole of each Plate will serve as a transmitting and receiving aperture. These Reflectors, which also serve as Fabry-Perot Plates, are to be attached to the Transmitter and the Receiver in place of the Horns. Using the screws, attach the Fabry-Perot Plates to the waveguide flanges, with the flat edge of each Plate up.

4. Arrange the ED-SET as shown in Fig. 23.

5. Extremely slowly and with great care, use the Positioning Attachment to move the Receiver away from the Transmitter. The Positioning Attachment must be manipulated with maximum care. When a very sharp resonance is observed, the distance between the Fabry-Perot Plates will be equal to $\frac{\lambda}{2}$. Distance between Plates is determined by sighting down the face of the Fabry-Perot Plates and reading the centimeter scale of the Arm. Additional resonances of lower amplitude will occur at distance multiples of $\frac{\lambda}{2}$.

6. With the above instructions followed carefully, it may be possible to observe several distinct maxima of substantially lower amplitude spaced very closely together. This occurs because the ED-SET is operating on alternating current, as a result of which the Klystron does not operate in a completely monochromatic manner. During the upward swing of the A. C. voltage, the repeller goes through several modes and oscillates at low power at several secondary frequencies.

7. The "Q" factor of the resulting cavity can be determined using this formula:

$$Q = \frac{\lambda}{\Delta}$$

where λ = wavelength in centimeters
Δ = distance in centimeters between half-power points

The half-power points are those points on the scale of the Arm, on each side of peak location, at which the Receiver Microammeter reads one-half of peak reading.

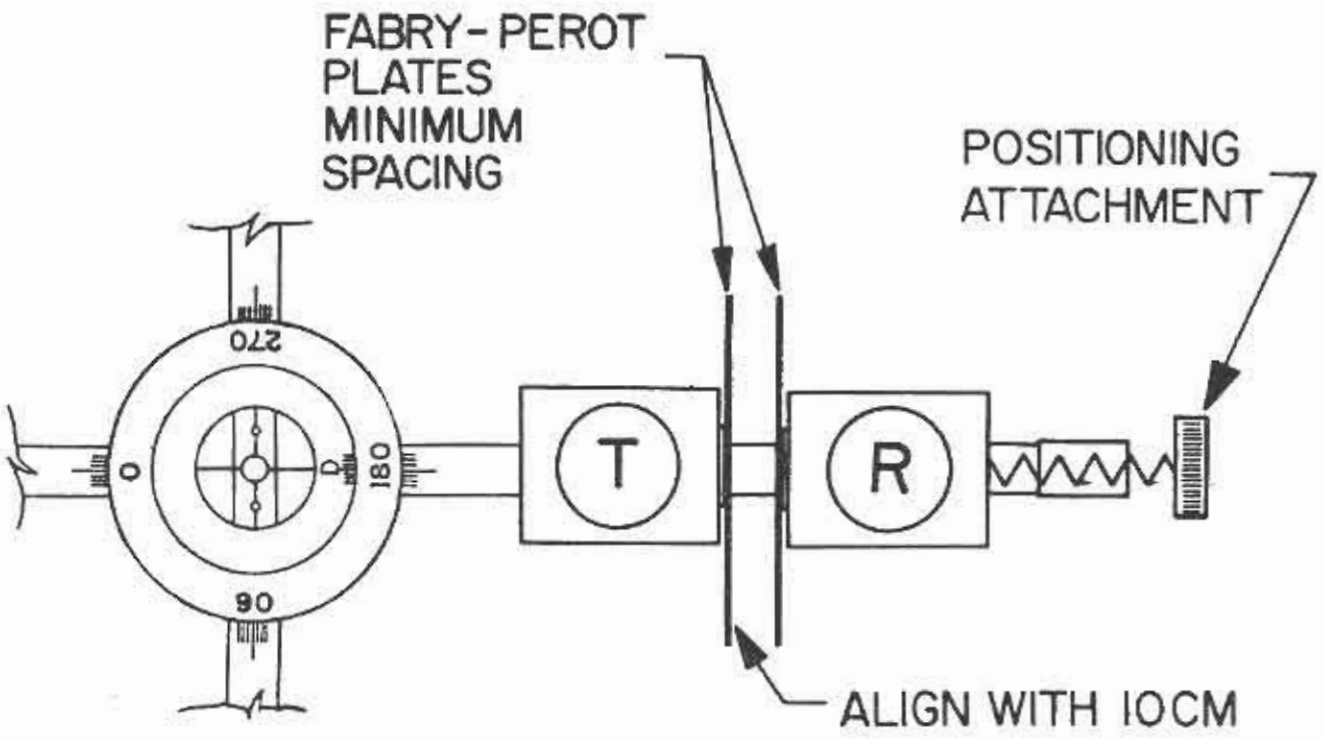

FABRY-PEROT
PLATES
MINIMUM
SPACING
POSITIONING
ATTACHMENT
270
0
180
90
T
R
ALIGN WITH IOCM

Fig. 23

Cat. No. 2643A Transmitter, Microwave
Addendum to Instruction Manual
Cat. No. 2643 Microwave Optics Ed-Set Mark 2

Cat. No. 2643A Transmitter is the microwave transmitter component of the Cat. No. 2643 Microwave Optics Ed-Set Mark 2 and the Cat. No. 2641 Microwave Bragg Diffraction Apparatus.

The unit consists of a klystron tube with related circuitry suitably mounted in a case with attached horn antenna. The transmitter operates on 115 volts, 50/60 cycle A.C.

The klystron tube now used differs from the klystron described in the manual in that there is no provision for varying the frequency. The transmitter operates on a fixed frequency in the range of 10,000-11,000 MH_z. The exact frequency is readily determined by the method given in Chapter 9 of the Instruction Manual for the Microwave Optics Ed-Set.

Several minutes may be required for the tube to warm up sufficiently for satisfactory operation. The tube becomes very hot. DO NOT TOUCH!

The knob on the transmitter is a combination on-off switch and repeller voltage control. Its function is described in the manual.

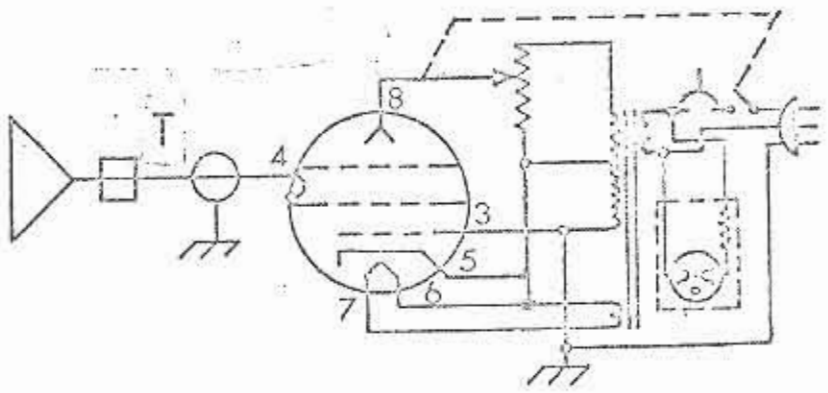
A circuit breaker in the primary of the transformer will open if an overload occurs. Wait several minutes for the circuit breaker to cool and then push in the red reset button on the rear of the transmitter case. If it quickly or repeatedly opens, the cause is probably a defective klystron and a new tube should be tried.

A revised schematic for the transmitter and receiver to replace Fig. 4 and Fig. 5 of page 5 is attached.

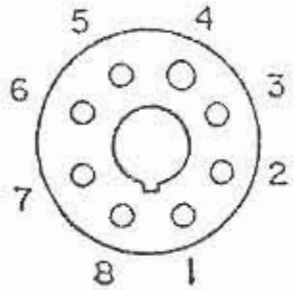
J62967HH

THE WELCH SCIENTIFIC COMPANY
7300 North Linder Avenue
Skokie, Illinois 60076

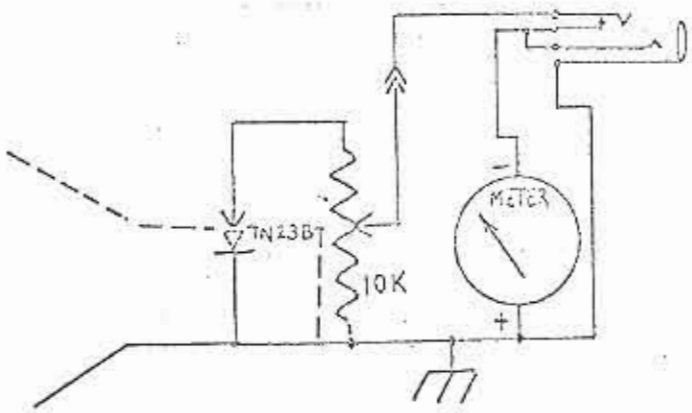
(30)



TRANSMITTER SCHEMATIC
Fig. 4



SOCKET-TOP VIEW



RECEIVER SCHEMATIC
Fig. 5

VOLTAGES BETWEEN	VOLTAGE AC
7 and 6	6.3
3 and 5	350
3 and 8	350 - 550

31

WARRANTY

Budd-Stanley Co. Inc. warrants these instruments to be free of all defects in material or workmanship for a period of two years. Our liability under this warranty is limited to servicing or adjusting any instruments returned to the factory for that purpose and to replace any defective parts. All electron tubes, fuses and batteries are specifically excluded from any liability.