DOCUMENT RESUME

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TITLE Electronic Principles X, 7-14. Military Curriculum Materials for Vocational and Technical Education.

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SPONS AGENCY Department of Education, Washington, DC.

PUB DATE 75

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IDENTIFIERS Military Curriculum Project; *Soldering

ABSTRACT

This tenth of 10 blocks of student and teacher materials for a secondary/postsecondary level course in electronic principles comprises one of a number of military-developed curriculum packages selected for adaptation to vocational instruction and curriculum development in a civilian setting. Prerequisites are the previous blocks. This block on microwave devices and soldering contains five modules covering 27 hours of instruction on waveguides and cavity resonators (6 hours), microwave amplifiers and oscillators (8), soldering tools and materials (3), soldering and desoldering procedures (7), and multiconductor and coaxial cable fabrication (3). Printed instructor materials include a plan of instruction detailing the units of instruction, duration of the lessons, criterion objectives, and support materials needed. Student materials include a student text and five guidance packages containing objectives, assignments, review exercises, and answers for each module. A digest of the modules in the block is provided for students who need only to review the material. Designed for self- or group-paced instruction, the material can be adapted for individualized instruction. Additional print and audiovisual materials are recommended but not provided. (YLB)

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

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Military Curriculum Materials
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The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except Ohio)

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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

NORTHEAST
Joseph F. Kelly, Ph.D.
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225 West State Street
Trenton, NJ 08625
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Olympia, WA 98504
206/753-0879

SOUTHEAST
James F. Shill, Ph.D.
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Mississippi State, MS 39762
601/325-2510

WESTERN
Lawrence F. H. Zane, Ph.D.
Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

ELECTRONIC PRINCIPLES X

Table of Contents

Developed by:

United States Air Force

Development and Review Dates

November 7, 1975

D.O.T. No.:

003.081

Occupational Area:

Electronics

Target Audiences:

Grades 11-adult

Print Pages:

216

Cost:

$4.50

Availability:

Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Contents:	Type of Materials: Lesson Plans:	Programmed Text:	Student Workbook:	Handouts:	Text Materials:	Audio-Visuals:	Instructional Design: Performance Objectives:	Tests:	Review Exercises:	Additional Materials Required:	Type of Instruction: Group Instruction:	Individualized:
			No. of pages									
Block X – *Microwave Devices and Soldering*												
Module 74 – **Waveguides and Cavity Resonators**	•		40		•	★	•	★	•		•	•
Module 75 – **Microwave Amplifiers and Oscillators**	•		29		•	★	•	★	•		•	•
Module 76 – **Soldering Tools and Materials**	•		24		•	★	•	★	•	★	•	•
Module 77 – **Soldering and Desoldering Procedures**	•		15		•		•	★	•	★	•	•
Module 78 – **Multiconductor and Coaxial Cable Fabrication**	•		7		•	★	•	★	•	★	•	•

★ Materials are recommended but not provided.

Course Description

This block is the tenth of a ten-block course providing training in electronic principles, the use of basic test equipment, safety practices, circuit analysis, soldering, digital techniques, microwave principles and troubleshooting basic circuits. Prerequisites to this block are Blocks I through IX covering DC circuits, AC circuits, RCL circuits, solid state principles, solid state power supplies and amplifiers, solid state wave generating and wave shaping circuits, digital techniques, the principles and application of electron tubes, and transmitting and receiving systems. Block X—*Microwave Devices and Soldering* contains five modules covering 27 hours of instruction over waveguides; cavity resonators; amplifiers; oscillators; soldering tools, materials and procedures; and fabricating multiconductor and coaxial cables. The module topics and respective hours follow:

- Module 74 — **Waveguides and Cavity Resonators** (6 hours)
- Module 75 — **Microwave Amplifiers and Oscillators** (8 hours)
- Module 76 — **Soldering Tools and Materials** (3 hours)
- Module 77 — **Soldering and Desoldering Procedures** (7 hours)
- Module 78 — **Multiconductor and Coaxial Cable Fabrication** (3 hours)

This block contains both teacher and student materials. Printed instructor materials include a plan of instruction detailing the units of instruction, duration of the lessons, criterion objectives, and support materials needed. Student materials consist of a student text used for all the modules; five guidance packages containing objectives, assignments, review exercises and answers for each module; and a digest of modules 74 through 78 for students who have background in these topics and only need to review the major points of instruction.

This material is designed for self- or group-paced instruction to be used with the preceding nine blocks. Most of the materials can be adapted for individualized instruction. Some additional military manuals and commercially produced texts are recommended as references but are not provided. Audiovisuals suggested for use with the entire course consist of 143 videotapes which are not provided.

PLAN OF INSTRUCTION

(Technical Training)

ELECTRONIC PRINCIPLES

(Modular Self-Paced)

KEESLER TECHNICAL TRAINING CENTER

6 November 1975 - Effective 6 January 1976 with Class 760106

Volume 10

7-14

4

DEPARTMENT OF THE AIR FORCE
USAF Sch of Applied Aerosp Sci (ATC)
Keesler Air Force Base, Mississippi 39534

PLAN OF INSTRUCTION 3AQR30020-1
6 November 1975

FOREWORD

1. PURPOSE: This publication is the plan of instruction (POI) when the pages shown on page A are bound into a single document. The POI prescribes the qualitative requirements for Course Number 3AQR30020-1, Electronic Principles (Modular Self-Paced) in terms of criterion objectives and teaching steps presented by modules of instruction and shows duration, correlation with the training standard, and support materials and guidance. When separated into modules of instruction, it becomes Part I of the lesson plan. This POI was developed under the provisions of ATCR 50-5, Instructional System Development, and ATCR 52-7, Plans of Instruction and Lesson Plans.

2. COURSE DESIGN/DESCRIPTION. The instructional design for this course is Modular Scheduling and Self-Pacing; however, this POI can also be used for Group Pacing. The course trains both non-prior service airmen personnel and selected re-enlistees for subsequent entry into the equipment oriented phase of basic courses supporting 303XX, 304XX, 307XX, 309XX and 328XX AFSCs. Technical Training includes electronic principles, use of basic test equipment, safety practices, circuit analysis, soldering, digital techniques, microwave principles, and troubleshooting of basic circuits. Students assigned to any one course will receive training only in those modules needed to complement the training program in the equipment phase. Related training includes traffic safety, commander's calls/briefings and end of course appointments.

3. TRAINING EQUIPMENT. The number shown in parentheses after equipment listed as Training Equipment under SUPPORT MATERIALS AND GUIDANCE is the planned number of students assigned to each equipment unit.

4. REFERENCES. This plan of instruction is based on Course Training Standard KE52-3AQR30020-1, 27 June 1975 and Course Chart 3AQR30020-1, 27 June 1975.

FOR THE COMMANDER

W. H. HORNE, Colonel, USAF
Commander
Tech Tng Gp Prov, 3395th

OPR: Tech Tng Gp Prov, 3395th
DISTRIBUTION: Listed on Page A

5

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE Electronic Principles
BLOCK NUMBER X	BLOCK TITLE Microwave Devices and Soldering

1 COURSE CONTENT	2 DURATION (Hours)
1. Waveguides and Cavity Resonators (Module 74)	6 (5/1)

a. Given a list of statements on waveguides, select the one that describes the physical appearance of waveguide sections. CTS: 9a Meas: W

(1) Definition.

(2) Basic types.

(a) Rectangular.

(b) Circular.

b. Given a list of statements on waveguides, select the ones that describe the electrical characteristics. CTS: 9a Meas: W

(1) Waveguide development.

(a) Two wire line.

(b) Two wire line with a quarter wave stub.

(c) The half wave frame.

(d) Frequency and power determining factors.

1 Wall designation.

2 Frequency determining.

3 Power determining.

(e) Waveguides versus transmission lines.

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

SIGNATURE	DATE	SIGNATURE	DATE

PLAN OF INSTRUCTION NO.	DATE	PAGE NO.
3AQR30020-1	4 December 1975	63

ATC FORM 133 ATC Keesler 6-1020 REPLACES ATC FORMS 337, MAR 73, AND 770, AUG 72, WHICH WILL BE USED.

1 Physical.

2 Electrical.

(2) Waveguide energy propagation.

(a) Electromagnetic energy.

1 Bends.

2 Twists.

3 Flexible sections.

4 Choke joints.

c. Given a list of statements, select those that describe the advantages of pressurizing waveguide systems. CTS: 9a Meas: W

(1) Waveguide pressurization.

(a) Purpose.

(b) Gases used.

d. Given the diagram of coupling devices in a waveguide system, identify the various types. Probe; Loop; Aperture; CTS: 9a Meas: W

(1) Operational characteristics.

(a) E field.

(b) H field.

e. Given illustrations of a directional coupler and a bidirectional coupler, match each illustration with the statement that describes the purpose of each. CTS: 9a Meas: W

(1) Operation.

(a) Incident wave.

(b) Reflected wave.

f. Given an illustration of a simple parallel duplexing system and a list of related statements, select the statement that describes the purpose of the duplexer. CTS: 9a Meas: W

(1) Purpose.

(2) Operation.

(a) Transmit.

(b) Receive.

g. Given statements concerning resonant cavities, select the statement that describes capacitance, inductance, and volume tuning. CTS: 9b Meas: W

(1) Advantages.

(2) Development.

(a) Frequency.

1 Size.

2 Shape.

(b) Fields.

1 E field.

2 H field.

(c) Coupling.

1 Probe.

2 Loop.

3 Window.

(d) Tuning.

1 Capacitive.

2 Inductive.

3 Volume.

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
KEP-GP-74, Waveguides and Cavity Resonators
KEP-ST-X, Microwave Devices and Soldering
KEP-110
KEP-ST/Digests (Modules 74-76)

Audio Visual Aids
TVK 30-954, Waveguides
TVK 30-955, Cavity Resonators

PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

Training Methods
Discussion (5 hrs) and/or Programmed Self Instruction
CTT Assignment (1 hr)

Instructional Guidance
Assign specific objectives to be covered during CTT time in KEP-GP-74. Students need to be shown the need for the devices discussed in this module. The purposes of the directional and bidirectional coupler are frequently missed and should therefore be given more emphasis. The Audiovisual tapes provided are fairly descriptive. Considerable research is recommended in this area to handle the frequent number of questions asked.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Electronic Principles

BLOCK NUMBER	BLOCK TITLE
X	Microwave Devices and Soldering

1 COURSE CONTENT	2 DURATION (Hours)
2. Microwave Amplifiers and Oscillators (Module 75)	8 (6/2)
a. Given a list of statements and a schematic diagram of a two-cavity klystron amplifier, select the statement that describes the operation. CTS: 9c Meas: W	(1.5)

(1) Vacuum tube limitations.

(a) Interelectrode capacitance.

(b) Lead inductance.

(c) Electron transit time.

(d) RF losses.

(2) Velocity modulation.

(a) Define.

(b) Electron movement in electrostatic field.

1 Gains energy.

2 Gives up energy.

3 Bunching action.

(c) Extracting energy from bunched electrons.

(3) Construction of two cavity klystron amplifier.

(a) List component parts.

(b) Purpose of component parts.

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

SIGNATURE	DATE	SIGNATURE	DATE

PLAN OF INSTRUCTION NO.	DATE	PAGE NO.
3AQR30020-1	4 December 1975	67

PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

(4) Klystron amplifier.

(a) Buncher grid action.

(b) Drift space action.

(c) Catcher cavity action.

(5) Klystron oscillator.

(a) Compare oscillator with amplifier.

(b) Operation.

b. Given a list of functions and a schematic diagram of a reflex klystron, match each function with its appropriate part. CTS: 9c Meas: W (1)

(1) Component parts.

(a) Location.

(b) Purpose.

(2) Operation.

(a) Velocity modulation.

(b) Repelling action.

(c) Feedback.

c. Given a list of functions and a schematic diagram of a traveling wave amplifier, match each function with its appropriate part. CTS: 9c Meas: W (1)

(1) Advantages.

(2) Component parts.

(a) Location.

(b) Purpose.

(3) Operation.

(a) Bunching.

(b) Amplification.

(c) Prevention of feedback.

PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

d. Given a list of statements and a schematic diagram, select those that describe the operation of a parametric amplifier. CTS: 9c Meas: W (1.5)

(1) Advantages.

(2) Basic operation.

(a) Pump frequency.

(b) Varying capacitance.

1 Junction diode.

2 Varactor.

(3) Nondegenerative type.

(a) Component parts.

1 Location.

2 Purpose.

(b) Operation.

1 Input frequency.

2 Signal cabity.

3 Idler cavity.

4 Output signal.

(4) Up-Converter.

(a) Component parts.

1 Location.

2 Purpose.

(b) Operation.

1 Input frequency.

2 Signal cavity.

3 Idler cavity.

4 Output frequency.

PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

c. Given a list of statements and a schematic diagram, select those that describe the operation of a megnetron. CTS: 9c Meas: W (1)

(1) Purpose.

(2) Construction.

(a) Description of component parts.

(b) Purpose of component parts.

(3) Operation

(a) Fields.

1 AC.

2 DC.

3 Magnetic.

(b) Field interaction on electron

1 Cycloidal paths.

2 Electron bunching.

3 Feedback

(c) Coupling methods.

(d) Typical application

3. Measurement and Critique (Part 1 of 2 parts) 1

a. Measurement test

b. Test critique

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
KEP-GP-75, Microwave Amplifiers and Oscillators
KEP-ST-X
KEP-110

Audio Visual Aids
TVK 30-913, Magnetrons
TVK 30-956, VHF and Microwave Oscillators

PLAN OF INSTRUCTION/LESSON PLAN PART 1 (Continuation Sheet)

COURSE CONTENT

Training Methods
Discussion (6 hrs) and/or Programmed Self Instruction
CTT Assignment (2 hrs)

Instructional Guidance
Make specific objective assignments to be completed during CTT time in KEP-GP-75. Velocity modulation is the basic concept that is used in the discussion of the majority of devices contained in this module. The process of varying the speed of electrons in order to obtain bunching needs to be explained to the student in detail. The audio visual aids listed for this module provide a comprehensive coverage of all devices except the parametric amplifier. The concept of achieving voltage gain in the parametric amplifier circuit is vague for many students. Review the operation of the varicap (varactor diode). Inform students that part one of the measurement test covers modules 74 and 75.

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Electronic Principles

BLOCK NUMBER	BLOCK TITLE
X	Microwave Devices and Soldering

1 COURSE CONTENT	2 DURATION (Hours)
4. Soldering Tools and Materials (Module 76)	3 (2/1)

a. Given a list of applications pertaining to the soldering process, match them with the following pictures of tools and list of materials: Tools. Soldering iron; Bending tools; File; Heat Sink; Wire Strippers; Diagonal Cutting Pliers. - Materials. Emery cloth; Erasers; Brushes; Cloth, Paper tissues, or Sponge.
CTS: 8a Meas: W

(1) Tools.

(a) Safety.

(b) Soldering iron.

1 Purpose of solder.

2 Types of solder.

(c) Bending tools.

1 Purpose.

2 Types.

(d) File.

1 Purpose.

2 Type to be used.

(e) Heat sink

1 Purpose.

2 Types available.

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

SIGNATURE	DATE	SIGNATURE	DATE

PLAN OF INSTRUCTION NO.	DATE	PAGE NO.
3AQR30020-1	4 December 1975	73

ATC FORM 133 APR 75 ATC Keesler 6-1029 REPLACES ATC FORMS 337, MAR 73, AND 770, AUG 72, WHICH WILL BE USED.

(f) Wire strippers.

1 Purpose.

2 Type to be used.

3 Methods of use.

(2) Materials.

(a) Purpose of emery cloth.

(b) Purpose of erasers in soldering.

(c) Purpose of brushes in soldering.

(d) Use of cloth, paper tissues, and sponges in soldering.

b. Given a printed circuit board with examples of soldered connections, indicate those with the correct amount of solder: Single turret connection; Single bifurcate connection; Pads. CTS: 8b, 8c Meas: PC

(1) Tinning of stripped wire.

(2) Mechanical connection.

(3) Soldering process.

(4) Acceptable standards.

(5) Mounting of components.

(6) Bending leads.

(7) Clinching leads.

c. Given a printed circuit board with examples of soldered connections, indicate those with the correct insulation clearance: Single turret connection; Single bifurcate connection. CTS: 8b, 8c Meas: PC

(1) Minimum clearance.

(2) Maximum clearance.

PLAN OF INSTRUCTION/LESSON PLAN PART I (Continuation Sheet)

COURSE CONTENT

d. Given a list of statements covering soldering principles, select the correct statement(s) that describe(s) results of improper heat; type of solder used in electronics; proper alloy ratios and melting points; correct mechanical and electrical characteristics of a properly soldered connection; proper type and use of soldering flux; correct type and use of solvent. CTS: 8b, 8c
Meas: W

(1) Results of improper heat.

(a) Heat sensitive components.

(b) Damaged insulation.

(c) Damaged pads.

(d) Pitted or dull colored components.

(2) Type of solder used in electronics.

(a) Define soldering.

(b) Types of solder.

1 Hard.

2 Soft.

(3) Alloy ratios and melting points.

(a) Lead/tin ratios.

(b) Various states of lead/tin alloy solder.

1 Ratio.

2 Melting point.

3 No plastic state.

(4) Characteristics of solder connections.

(a) Mechanical.

(b) Electrical.

(5) Soldering flux.

(a) Purpose.

(b) Types.

COURSE CONTENT

1 Corrosive.

2 Noncorrosive.

(6) Solvents used in soldering.

(a) Purpose.

(b) Safety.

(c) Types available.

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
KEP-GP-76, Soldering Tools and Materials
KEP-ST-X
KEP-110

Audio Visual Aids
TVK 30-461A, Handtools
TVK 30-107, Soldering Techniques

Training Equipment
Soldering Tools and Supplies (1)

Training Methods
Discussion (1.5 hrs) and/or Programmed Self Instruction
Performance (.5 hr)
CTT Assignment (1 hr)

Multiple Instructor Requirements
Supervision (2)

Instructional Guidance
Assign specific objectives to be covered during CTT time in KEP-GP-76. Students may find it difficult to understand the proper method of preparing components to be soldered and the proper soldering methods. Every student should see TVK 30-107, Soldering Techniques, before going to the laboratory.

18

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Electronic Principles

BLOCK NUMBER	BLOCK TITLE
X	Microwave Devices and Soldering

1 COURSE CONTENT	2 DURATION (Hours)
5. Soldering and Desoldering Procedures (Module 77)	7 (6/1)

a. Given the required tools, materials, and conductors, solder connections on turret terminals in accordance with TO 00-25-234. CTS: 1a, 8a, 8b Meas: PC

(1) Preparation of soldering iron

(a) Clean iron tip and barrel.

(b) Tin the tip.

(2) Preparation of stranded conductors.

(a) Cut wires.

(b) Strip insulation.

(3) Tin stranded conductors.

(a) Apply flux.

(b) Tin wire.

(4) Turret terminal solder connection.

(a) Position wire on PC Board holder.

(b) Make mechanical connection.

(c) Make solder connection.

(d) Clean connection.

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

SIGNATURE	DATE	SIGNATURE	DATE

PLAN OF INSTRUCTION NO.	DATE	PAGE NO.
3AQR30020-1	4 December 1975	77

ATC FORM APR 75 133 ATC Keesler 6-1029 REPLACES ATC FORMS 337, MAR 73, AND 770, AUG 72, WHICH WILL BE USED.

COURSE CONTENT

b. Given the required tools, materials, and conductors, solder connections to slotted terminals in accordance with TO 00-25-234. CTS: 8a, 8b Meas: PC

(1) Make mechanical connection.

(2) Make solder connection.

(3) Clean the connection.

c. Given soldering tools and materials, desolder leads from terminal connections in accordance with TO 00-25-234. CTS: 1a, 8a, 8b Meas: PC

(1) Desolder the connection.

(2) Clean the connection.

d. Given the required tools, materials, and conductors; solder connections in accordance with TO 00-25-234 on printed circuit boards: Passive components (resistor or capacitor); Active components (solid state diode or transistor). CTS: 1a, 8a, 8c Meas: PC

(1) Prepare PC board.

(a) Inspect board for cracks and other defects.

(b) Clean all pads.

(2) Install components.

(3) Solder components.

(4) Clean board.

e. Given soldering tools and materials, desolder components from printed circuit boards in accordance with TO 00-25-234. CTS: 1a, 8a, 8c Meas: PC

(1) Solder solid wire to pads.

(a) Clean pads.

(b) Bend and fit.

(c) Clinch to pad and trim.

(d) Solder.

(e) Clean.

COURSE CONTENT

(2) Solder components to pads.

(a) Clean pads.

(b) Bend leads to fit.

(c) Clinch leads and trim.

(d) Solder.

(e) Clean.

(3) Desolder components.

(a) Heat solder connection.

(b) Unclinch leads.

(c) Remove components.

(d) Clean pads.

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
KEP-GP-77, Soldering and Desoldering Procedures TO 00-25-234

Training Equipment
Performance (6 hrs)
CTT Assignment (1 hr)

Multiple Instructor Requirements
Supervision (2)

Instructional Guidance
Make an assignment in KEP-GP-77 on specific objectives to be covered during CTT time. Inform the student that five progress checks must be performed as directed in KEP-GP-77. Insure that students are informed of safety procedures before working on laboratory projects.

21

PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR	COURSE TITLE
	Electronic Principles

BLOCK NUMBER	BLOCK TITLE
X	Microwave Devices and Soldering

1 COURSE CONTENT	2 DURATION (Hours)
6. Fabricate Multi-Conductor and Coaxial Cables (Module 78)	3 (3/0)
a. Given the required tools, material, and multimeter, fabricate a multi-conductor cable in accordance with TO 1-1A-14 to include multipin plug; terminal lugs; tie down strap. CTS: 8d Meas: PC	
(1) Prepare the conductors.	
(a) Cut wire.	
(b) Strip wires.	
(c) Tin wires.	
(2) Solder wires into plug.	
(3) Assemble plug.	
(4) Install tie down strap.	
b. Given the required tools, materials and a multimeter, fabricate a coaxial cable in accordance with TO 1-1A-14. CTS: 8d Meas: PC	
(1) Prepare the cable.	
(2) Install the center pin.	
(3) Assemble the connector.	
(4) Check for continuity and shorts.	
7. Related Training (identified in course chart)	3

SUPERVISOR APPROVAL OF LESSON PLAN (PART II)

SIGNATURE	DATE	SIGNATURE	DATE

PLAN OF INSTRUCTION NO.	DATE	PAGE NO.
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Technical Training

ELECTRONIC PRINCIPLES (MODULAR SELF-PACED)

VOLUME X

MICROWAVE AND SOLDERING

1 October 1974

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Designed For ATC Course Use

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Basic and Applied Electronics Department
Keesler Air Force Base, Mississippi

ATC ST 3AQR3X020-X
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1 October 1974

ELECTRONIC PRINCIPLES

BLOCK X

MICROWAVE AND SOLDERING

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CONTENTS

Supersedes student text, KEP-ST-IX, 1 January 1974, to be used until supply is exhausted.

25

Chapter 1

WAVEGUIDES

1-1. The Basic Waveguide.

1-2. A waveguide is a hollow tube that conducts and guides electromagnetic waves. The movement of electromagnetic energy through a waveguide is called wave propagation. Although a waveguide is a transmission line, propagation does not mean the energy flows through it in the ordinary sense.

1-3. Waveguides appear much like sections of hollow pipe as shown in figure 1-1. They may be circular or rectangular in shape. This subject will mainly concern the rectangular waveguide, because it is the type most widely used.

1-4. The frequency range in which a waveguide will operate, as well as its power-handling ability, depends on the waveguide size. For example, of the two rectangular waveguides shown in figure 1-2, A will operate at the higher microwave frequency, but B can handle the greater amount of power becuase of its size.

1-5. A rectangular waveguide can be developed from a single two-wire transmission line. Figure 1-3 shows a two-wire transmission line supported by porcelain insulators. From the viewpoint of the line, the impedance of insulator A to ground is shown by Z1. The impedance of insulator B to ground is shown in Z2. If the impedance values of these insulators were not high, the lines would be shorted to ground.

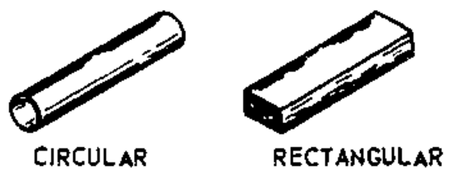

Figure 1-1. Waveguide Shapes

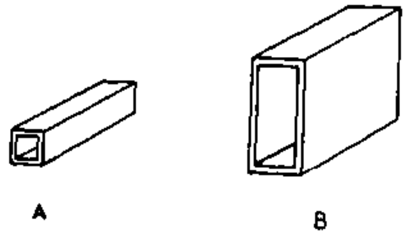

Figure 1-2. Waveguide Sizes

1-6. Z1 and Z2 are not perfect resistances. The insulators themselves, cause a certain amount of capacitive reactance to be present between each transmission line and ground. The dielectric for the capacitor is the insulator; the plates are the transmission line and the ground plate.

1-7. Because the wires have an impedance to ground (and ground, itself, is a low impedance), the wires have an impedance between them. The wires then, look upon the terminals of insulators A and B as high impedance Z3, which is the combined effect of the other impedances.

1-8. Recall that a quarter-wave line shorted at one end acts as an open at the other end. The high impedance of the open end can be an insulator. Because the transmission line in figure 1-3 regards its insulators as two terminals between which a high impedance exists, it can be supported on a quarter-wave

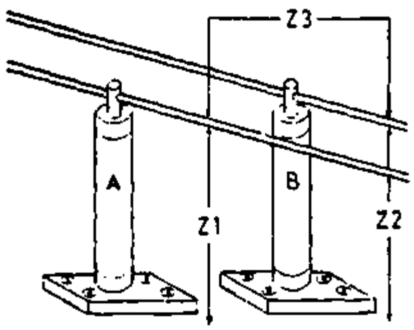

Figure 1-3. A Two-Wire Transmission Line with Ordinary Insulators

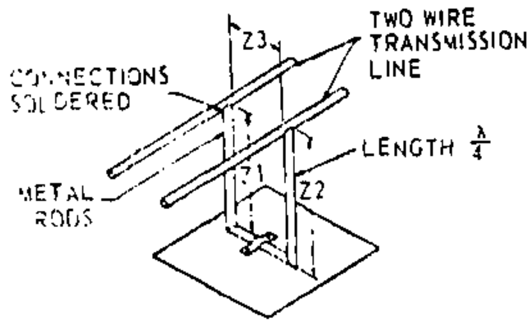

Figure 1-4. A Two-Wire Transmission Line with Quarter-Wave Stub

stub as shown in figure 1-4. Now Z1- Z2, and Z3 are higher in impedance value because a quarter-wave has lower losses. This quarter-wave line is sometimes called a METALLIC INSULATOR.

1-9. Obviously, porcelain insulators with two-wire transmission lines can be used with a wide range of frequencies. The quarter-wave line, however, can be used only for a very narrow frequency band. Also, it can be used only with extremely high frequencies; it would be much too large for the lower frequencies. If a different frequency were used, the stub length would no longer be a quarter wave in length and, therefore, could no longer act as an insulator.

1-10. Figure 1-5 shows another step in developing the waveguide. The two-wire line is now supported at top and bottom by quarter-wave insulators. The transmission lines are at the center of the half-wave line, shorted at both ends. This is called a half-wave frame.

1-11. If we keep adding quarter-wave supports until they touch at all points (figure 1-6A), we would have a rectangular metal

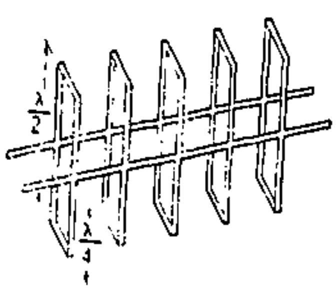

Figure 1-5. A Half-Wave Frame

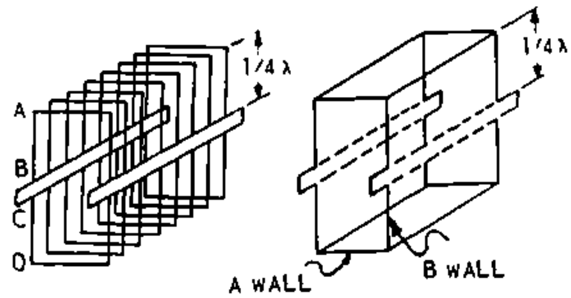

Figure 1-6. Waveguide Near Minimum Frequency

tube. The original transmission line has now become a part of the tube's side walls. The top and bottom quarter-wave lines are the top half and the bottom half of the tube as shown in figure 1-6B. This solid structure is now a waveguide, made of two bus bars and many quarter-wave insulators. For simplicity, the tube is made of sheet metal rather than many metal rods soldered together.

1-12. The walls of the waveguide are identified by letters as shown in figure 1-6. The short wall is the A Wall, and the long wall is the B Wall.

1-13. Any waveguide then, has upper and lower quarter-wave sections of metal insulators with bus bars as center sections. Figure 1-7A shows that distances AB and CD equal one-quarter wavelengths and distance BC is the width of the bus bar.

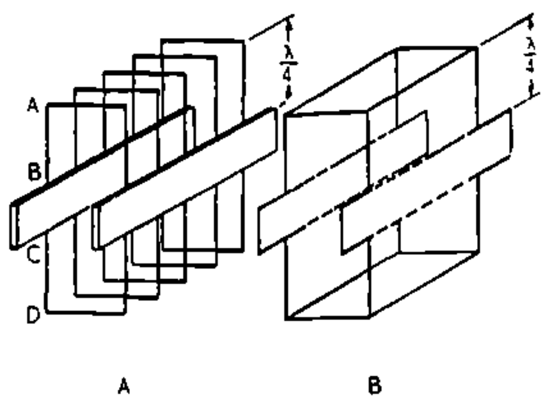

Figure 1-7. Waveguide Above Minimum Frequency

1-14. Assume the waveguide dimensions are fixed. At some higher frequency, the width of the bus bar BC (figure 1-7B) would be, in effect, increased in width. The quarter-wave insulators, AB and CD, would decrease in length until they equaled the quarter-wavelength at the new frequency. Theoretically, a waveguide could pass an infinite number of higher frequencies. As the frequency becomes higher, the quarter-wavelength would approach zero and the bus bar would become broader to finally make up the entire side wall of the waveguide. An important fact: If the wavelength increases (frequency decreases) so much that the two quarter-wave insulators cannot be created within the distance AB shown in figure 1-8, the insulators automatically becomes less than a quarter wavelength. As frequency decreases, the insulators become much lower inductive reactances instead of high resistances. The current is shorted out. This means that any waveguide of fixed dimensions has a low-frequency limit or "cutoff frequency" below which it cannot carry the energy without serious losses. The B Wall (broad) width of the waveguide at the cutoff frequency is equal to one-half wavelength because, at this frequency, the two quarter-wave sections touch and the bus bars--in effect--fade to zero.

1-15. Because the cutoff frequency will occur when the effective length of the B Wall is one-half wavelength, most waveguides are made with a B Wall size of .7 λ at the operating frequency. This gives a margin between the operating frequency and the cutoff frequency. Making the B Wall .7 λ instead of .5 λ lowers the frequency limit. The B Wall of a rectangular waveguide is the FREQUENCY-DETERMINING WALL (see figure 1-9).

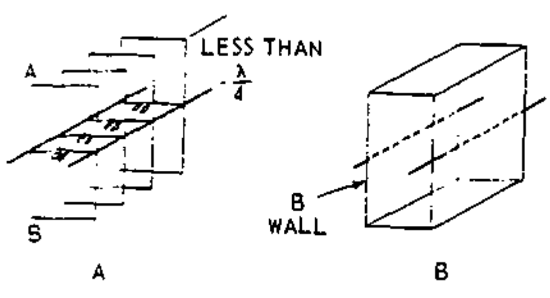

Figure 1-8. Waveguide Below Minimum Frequency

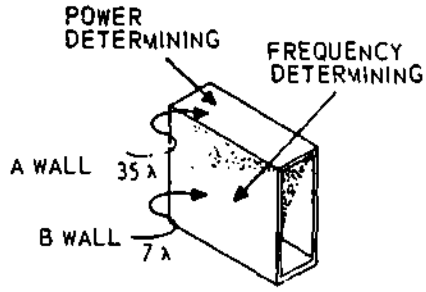

Figure 1-9. Waveguide Dimensions and Wall Identification

1-16. The other waveguide dimension, the A Wall, is the distance between the conductors located in the center of the B Wall. This dimension (similar to that of a two-wire line), is governed by the voltage breakdown potential of the dielectric, which may be pressurized air or a dry gas. The larger the A Wall, the larger the conductor spacing, the greater will be the voltage and the power-handling ability of the waveguide. Thus, the waveguide's A Wall is the POWER-DETERMINING WALL. Common A Walls range from .2 to .5 wavelengths in size; with .35 used as an average. Figure 1-9 shows waveguide dimensions and identifies the walls.

1-17. Waveguides are not made of pure copper because of the metal's bending weakness. Most waveguides are made of brass, which is a copper-tin alloy. To reduce electromagnetic losses, the inside walls may be plated with silver, gold, or copper, depending on the frequency of the energy carried.

1-18. Waveguides Versus Transmission Lines.

1-19. Waveguides have a lower power loss and a greater power-handling capability than other types of transmission lines. The reason for the greater power capability is illustrated

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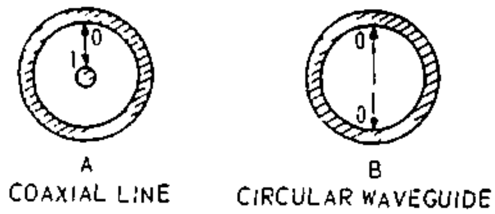

Figure 1-10. Contrast: Coaxial Line and Waveguide

by figure 1-10. In figure 1-10A, you see a coaxial line with an inner and outer conductor. The distance from 0 to 1 determines the amount of power the line can handle. Increase the voltage between these two conductors and arcing and breakdown will occur. This will damage the line and cause a serious power loss. In figure 1-10B, the circular waveguide has no center conductor and the voltage difference needed for arcing or breakdown would have to exist over twice the distance (0 to 0^1). A waveguide then, will have more power-handling ability than a coaxial cable of the same diameter.

1-20. In RF lines, the power losses include copper loss, dielectric loss, and radiation loss. Copper loss becomes great when the higher frequencies create skin effect in the conductor. Skin effect reduces the usable conducting area of the line which increases copper loss. Dielectric loss occurs in the insulators that support the lines. Radiation loss results when energy escapes from RF lines. These losses are small in waveguides. The large, inner conducting surface of the waveguide reduces copper loss. Dielectric loss is also small--there is no inner conductor in a waveguide and no supports or insulation to resist the electromagnetic energy. Radiation losses are low because the energy is confined on all sides. In an open two-wire line, the RF energy is lost as it expands far into space.

1-21. In contrast with RF transmission lines, the waveguide is not as flexible; however, waveguides are manufactured only in standard lengths--odd lengths are not available. If a transmitter were to be installed 30.25 feet from the antenna, careful planning would be needed. Another factor that limits waveguide use is the operating microwave frequency itself. The frequency-determining wall must be cut to .7 wavelengths of the operating frequency. It would not be practical then for a waveguide to handle a frequency of 10 MHz which has a wavelength of 30 meters. The B Wall of the waveguide would have to be 21 meters (.7 x 30).

1-22. Energy Propagation in the Waveguide.

1-23. The travel of electromagnetic energy through the hollow waveguide is called wave propagation. Propagation concerns the movement of electromagnetic fields.

1-24. In two-wire and coaxial transmission lines, electrical energy is transferred as current. When an antenna radiates, its energy moves through space as an electromagnetic field. A waveguide confines the electromagnetic field. It can guide this energy between microwave transmitters, receivers, and antennas.

1-25. Figure 1-11 shows the transfer of energy by electromagnetic waves. Electromagnetic energy is directed into space at an angle. It strikes the ionosphere and part of it is reflected back to earth. Not all of the electromagnetic energy will be reflected. At certain frequencies and under certain conditions, the energy would pass through the ionosphere. Energy that is not perpendicular to the ionosphere (traveling straight up) will be reflected back to earth. It will make many reflections between the earth and the ionosphere layer. A close look at figure 1-11 shows that the earth and the ionosphere form two confining walls. They can guide the energy from a transmitting antenna to a receiving antenna.

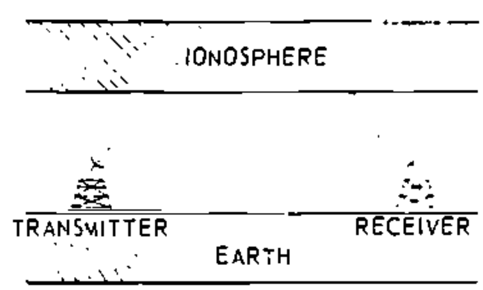

Figure 1-11. Radio Energy Confined by the Earth and the Ionosphere

1-26. A two-wire transmission line can guide energy from one point to another also, but not as well as a waveguide. Figure 1-12A shows a two-wire line. The lower illustration, figure 1-12B, shows dotted lines to represent the electric field BETWEEN the conductors. The solid circular lines represent the magnetic fields AROUND the conductors. The resultant magnetic field between the conductors is stronger than either of the magnetic fields separately. The electric field is also concentrated between the conductors and expands outward as shown.

1-27. Electromagnetic energy exists only when both the magnetic and the electric fields are present. Figure 1-12B shows that electromagnetic energy exists between the two conductors in the X and Y planes. It exists in the space between the two dotted vertical lines (AB and CD). Becuase the strength of the electromagnetic energy is largely held inside this area, we can say that a two-wire line can be used to guide electromagnetic energy. All of the energy is not confined, some is lost as radiation. This loss becomes critical above 200 MHz and makes the two-wire transmission line impractical for the higher frequencies.

1-28. Energy is radiated into a waveguide just as the Hertz and Marconi antennas radiate electromagnetic energy into free space. The only difference between antenna and waveguide propagation is that the waveguide contains and directs the RF energy. The waves within the waveguide will continue to be propagated only when the system's boundary conditions are satisfied. There are two boundary conditions:

1. To exist at the surface of a conductor, an electric field must be perpendicular to the conductor. This is shown by figure 1-13A. The electric field begins and ends on a conductor, in this case, the B Wall of a waveguide. The opposite of this boundary condition is also true. Assuming we have a perfect conductor, an electric field cannot exist parallel to the conductor. This is shown in figure 1-13B.

2. A varying magnetic field of closed loops exists parallel with the conductors and perpendicular to the electric field. This magnetic, or H-field, is illustrated in figure 1-14.

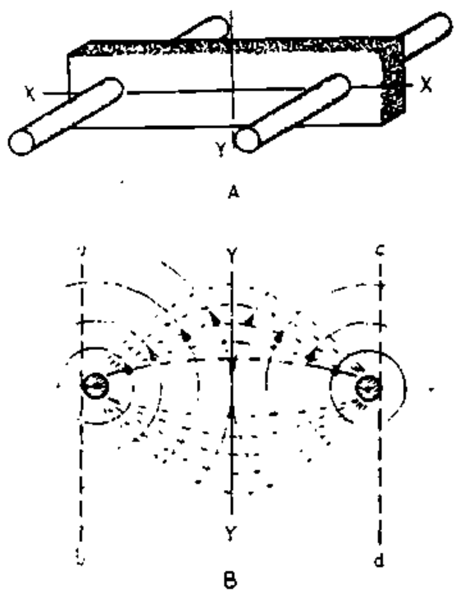

Figure 1-12. Two-Wire Transmission Line

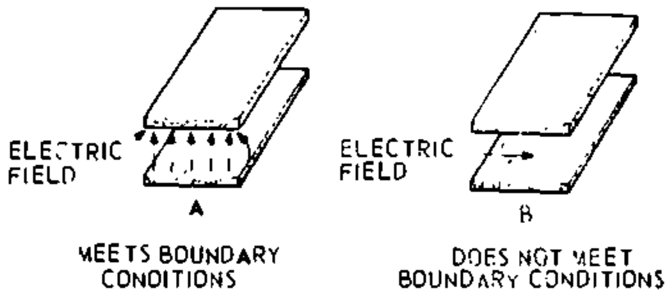

Figure 1-13. Electric (E) Field Boundary Condition

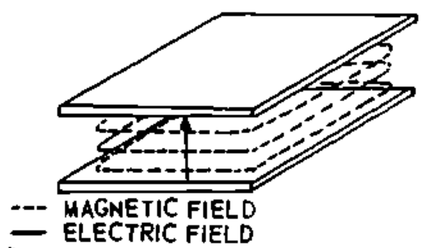

Figure 1-14. Magnetic (H) Field Boundary Condition

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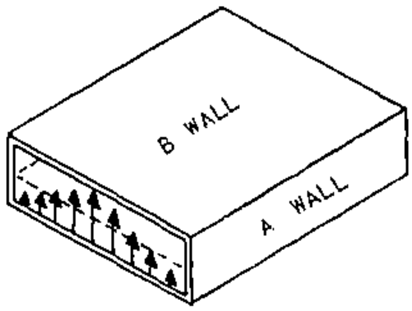

Figure 1-15. E and H Fields in a Waveguide Section

1-29. Any system that satisfies one of the boundary conditions will also satisfy the other. It is only necessary to check for one condition to decide whether a wave can exist at the surface of a conductor. Figure 1-15 shows a section of rectangular waveguide with both E and H fields present.

1-30. To understand how a waveguide uses the two boundary conditions, consider the principle of electromagnetic propagation in free space. Electromagnetic energy propagated into space is made of electric and magnetic fields at right angles to one another--and at right angles to the direction of propagation. This is shown in figure 1-16

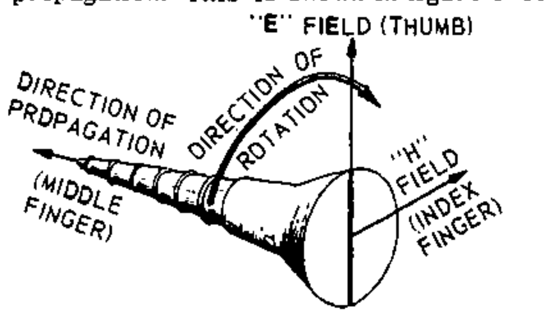

Figure 1-16. Determining the Resultant Wavefront

which illustrates the right-hand rule. The combined electric and magnetic fields act to form a resultant wavefront.

1-31. To produce a resultant wavefront that moves down a waveguide, the energy injected into the waveguide must travel in a criss-crossing (zig-zag) pattern from one A Wall to the opposite A Wall. A radiating device, such as a quarter-wave vertical antenna, can introduce the energy into the waveguide. Figure 1-17 shows such a waveguide producing expanding positive and negative quarter wavefronts similar to expanding circles. The parts of the wavefront that travel in the directions of arrows A and B are reflected from the walls. The wall is a short circuit and causes the wavefronts to be reflected in reverse phase. These two wavefronts, and all the others that follow, crisscross down the center of the waveguide to produce a resultant field pattern.

1-32. The magnetic field in a rectangular waveguide exists as a series of closed loops, parallel to the surfaces of the conductors. Figure 1-18 shows the magnetic field pattern of a half-sine electric field distribution. The magnitude of the magnetic field varies sinusoidally down the center of the guide in time phase with the electric field.

1-33. There is also a sinusoidal-electric field down the center of the waveguide. In figure 1-19, consider that wavefronts A and B are positive wavefronts at point 1. When the fronts reflect from the A Walls, they become negative fronts, traveling back across the guide at the same angle they strike the wall. When the negative fronts cross at the center of the guide (point 2), each E-field is at its maximum negative strength. The two

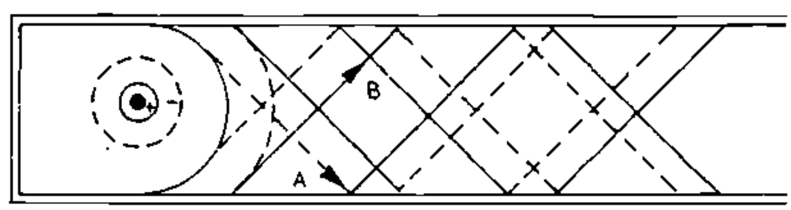

Figure 1-17. Radiated Energy in a Waveguide

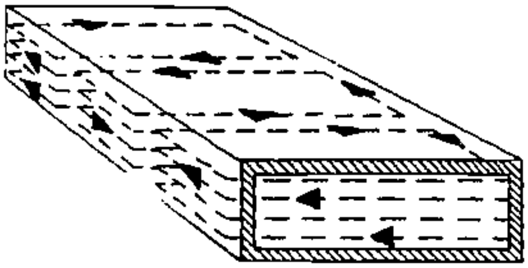

Figure 1-18. Magnetic Field Pattern Within a Guide

fields add, and this results in an extremely strong E-field between the B Walls. This is a continuous action. That is, there is always one more wave to replace the one that preceded it. The lower part of the figure shows the sine wave of the electric field that results at the center of the waveguide. Notice that the crest of the wave corresponds to the point where the positive waves cross, and the trough matches the point where the negative waves cross.

1-34. It is now apparent that a sinusoidal field pattern exists. It exists across the width of the waveguide and along its length. A three-dimensional view of the pattern is shown in figure 1-20.

1-35. The combined electric- and magnetic-field pattern moves down the guide in time phase and space quadrature.

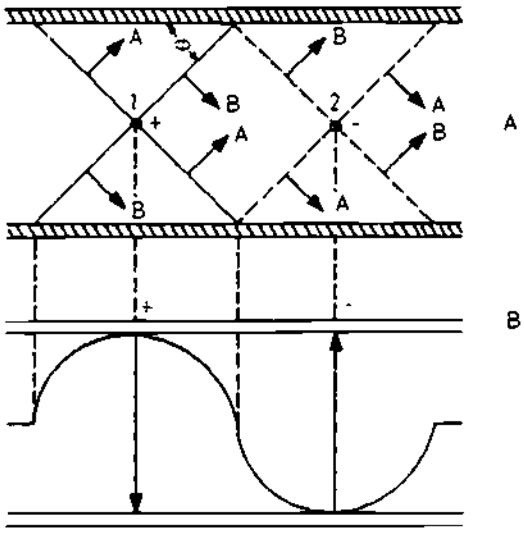

Figure 1-19. Crisscrossing Wavefronts and the Resultant E-Field at the Center of the B Wall

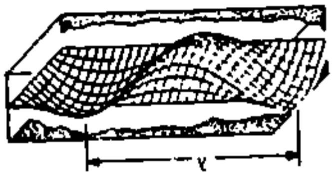

Figure 1-20. Resultant Wave of Crisscrossing Wavefronts

1. Time Phase - Peak H lines and peak E lines occur at the same instants of time, although not necessarily at the same point along the length of the guide.

2. Space Quadrature - Phase difference of 90°: the E and H lines exist at right angles to each other.

1-36. Waveguide Pressurization.

1-37. Some waveguide systems are pressurized with dry air or gas. This occurs in the higher frequency, higher power systems where high voltages demand it. The higher pressure within the waveguide increases the power-breakdown level. This means a pressurized waveguide can handle a greater amount of power before an internal arc-over or voltage breakdown would occur. A pressurized waveguide in which the dry air or gas is filtered before being circulated, keeps the inside of the system cleaner than a non-pressurized system. All foreign material is removed by the filtering. This will reduce standing waves and distortions in the transmitted wavefront.

1-38. Injecting and Extracting Waveguide Energy.

1-39. There are three ways to put energy into, or remove it from, a waveguide. They are by use of a probe, a loop, or an aperture. The operation is called energy coupling.

1-40. Probe.

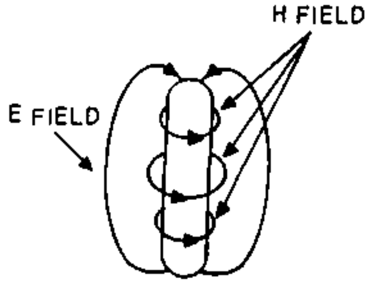

Figure 1-21. Radiation Fields around a Quarter-Wave Antenna

1-41. The probe is simply a quarter-wave antenna. Figure 1-21 shows its radiation pattern. The H-field is around the probe and the E-field is along its length. When the probe is correctly placed inside the waveguide, the desired propagation will occur. It should be mounted at the point of maximum E-field in the waveguide. This is in the center of the B Wall and one-quarter wavelength from the shorted end of the guide. Figure 1-22 shows a probe that is properly installed. The E-field of the probe becomes perpendicular to the length of the line.

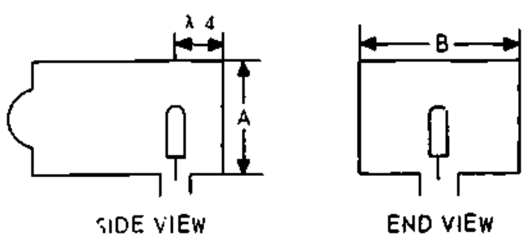

Figure 1-22. Probe Mounting in a Waveguide

1-42. There are several probe designs. Their size and shape will determine their frequency, bandwidth, and power-handling capability. The larger the probe's diameter, the lower its L/C ratio. This reduces its Q and increases its bandwidth.

1-43. One probe, shaped like a doorknob, can handle much power and a greater frequency band than a conventional probe. Its greater power-handling ability is due to its larger surface area. This allows more power to be dissipated from the probe and also permits more power to be applied to the probe itself. Figure 1-23 shows a comparison of the high-power (broadband) probe with a conventional low-power probe.

1-44. Loop.

1-45. A second way to inject or remove waveguide energy is with a magnetic loop. When it is properly positioned inside the guide, the field from the loop expands and fills the guide. This is at the place where the H (magnetic) field is of greatest strength. The circumference of the loop is a half-wavelength. Figure 1-24A shows a loop properly positioned in a waveguide. Figure 1-24B shows the expanding H-field in the guide and figure 1-24C shows other mounting

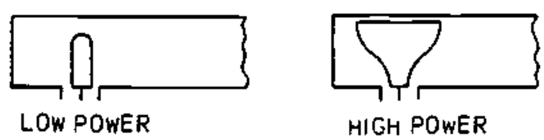

Figure 1-23. Broadband Probes

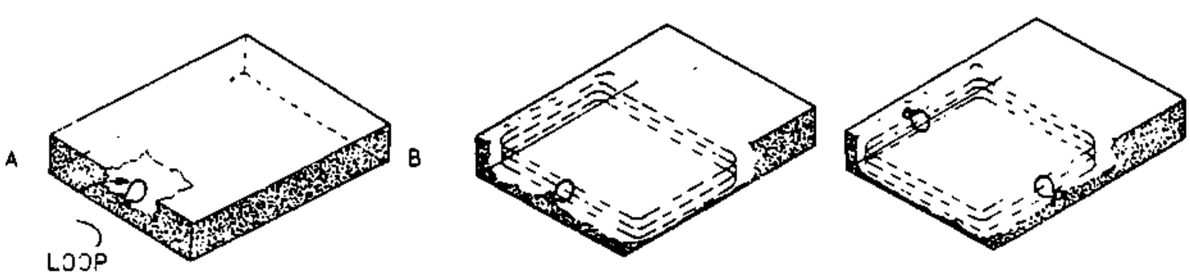

Figure 1-24. Loop Installations in Waveguide Walls

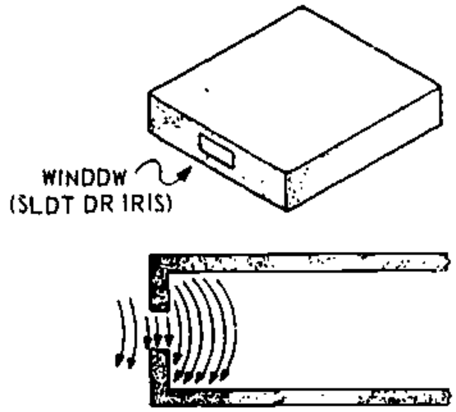

Figure 1-25. Aperture or Iris Coupling

positions for the loop. If the loop diameter is increased, its power-handling capability also increases. If the diameter of the wire used to make the loop is increased, the bandwidth will also increase.

1-46. Aperture.

1-47. The third coupling method is with the use of an aperture or window. This is also called iris coupling. The electromagnetic energy is put into, or taken from, the waveguide by passing it through a properly positioned opening. Any device that generates an E-field and which is placed near the aperture, will have its E-field expand and couple its energy into the waveguide. The amount of energy coupled can be increased or decreased by varying the size and location of the aperture. Figure 1-25 shows aperture coupling.

1-48. Waveguide Routing.

1-49. Any abrupt change in the shape, size, and dielectric material of a waveguide will cause reflections and standing waves. If this happens, the wavefront movement will be incomplete or absent. Sudden changes in the waveguide system also change the internal impedance which results in a power loss.

1-50. If the waveguide's size, shape, or direction must be changed, the twists, curves, and bends are designed to be gradual. Because the installation problems of a waveguide system are much like those in house plumbing, this type of work is called "waveguide plumbing."

1-51. Bends.

1-52. Electromagnetic energy will move easily through a waveguide as long as the guide's size, shape, and dielectric are constant. But if the spacing between the walls or the wall size changes, there will be an impedance change. Reflections and standing waves will result as well as a power loss. To reduce reflections, the bends must be gradual as shown by figure 1-26. A gradual E-bend is shown by figure 1-26A, in which the E-fields are distorted. To keep the reflections at a minimum here, the radius of the bend must be more than two wavelengths as shown. Figure 1-26C shows a gradual H-bend, so-called because the H-fields in the waveguide are distorted. Again, to minimize reflections, the bend radius must be more than two wavelengths.

1-53. Twists.

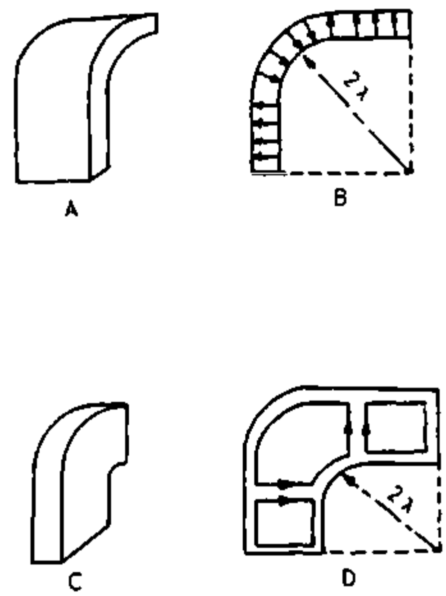

Figure 1-26. Gradual E- and H-Bends

Figure 1-27. Waveguide Twist

1-54. Sometimes it is necessary to change the energy polarization in the waveguide. This too must be done smoothly and gradually to prevent reflections. Figure 1-27 shows a waveguide with a 90° twist. All such twists and polarization changes must occur through a distance of more than two wavelengths.

1-55. Flexible Waveguide.

1-56. To allow for more flexibility in a waveguide system, a section of flexible waveguide can be used. It is made so it can be twisted or curved in any direction. The outer surface is rubber covered to make it airtight. The inner, metal-flexing part is a specially wound brass ribbon with a chromium-plated inner surface. Figure 1-28 shows a cutaway of this type of waveguide. Because its inside surface is not perfectly smooth, power attenuation is greater in the flexible waveguide than in the solid waveguide.

1-57. Choke and Rotating Joints.

1-58. Waveguide systems are made of many sections that can be removed, inspected, and replaced if necessary. A common device used to connect sections is the "choke joint."

1-59. A choke joint allows good RF continuity between waveguide sections with or without the metal surfaces being in contact.

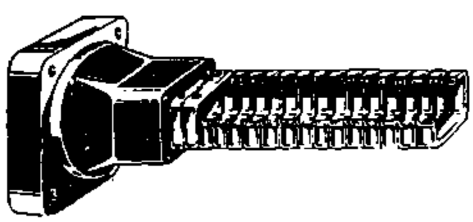

Figure 1-28. Flexible Waveguide

In figure 1-29, you see a choke joint that provides a good electrical and mechanical connection. The pressure gasket between the two metal surfaces makes the waveguide airtight. The lower part of figure 1-29 shows an end view of the upper section, looking into the hollow waveguide. Notice the slot is exactly one-quarter wavelength deep. Because the slot is shorted at point 1, there is a high impedance at point 2. Because point 2 is a high impedance, one-quarter wavelength from this point (at point 3), there is a low impedance, a short, which makes a good electrical connection between the two sections.

1-60. Some waveguide systems end with a rotating antenna. Because the waveguide plumbing is rigidly mounted and the antenna must turn, a rotating joint is used between the waveguide and the antenna. A circular waveguide is used in the rotating joint because a rectangular waveguide would distort the field pattern when it is rotated 360°. Figure 1-30 shows a rotating joint with a circular guide and a choke joint for the electrical connection. Rectangular waveguides are attached to the fixed and rotating parts of the joint. To prevent high impedance and distortions, the rectangular sections are attached so the distance 0 is three-quarters

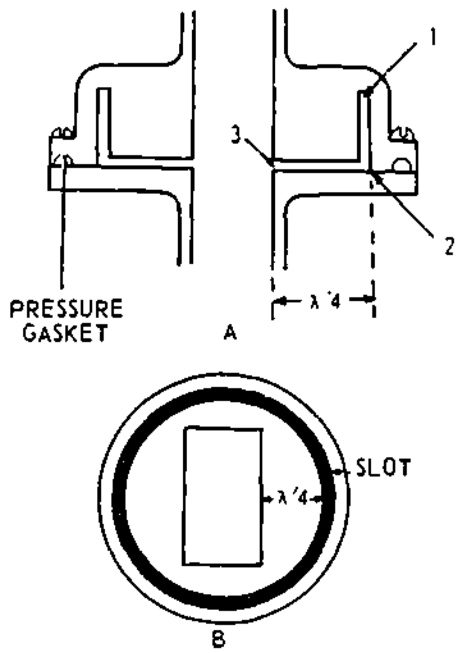

Figure 1-29. Choke Joint

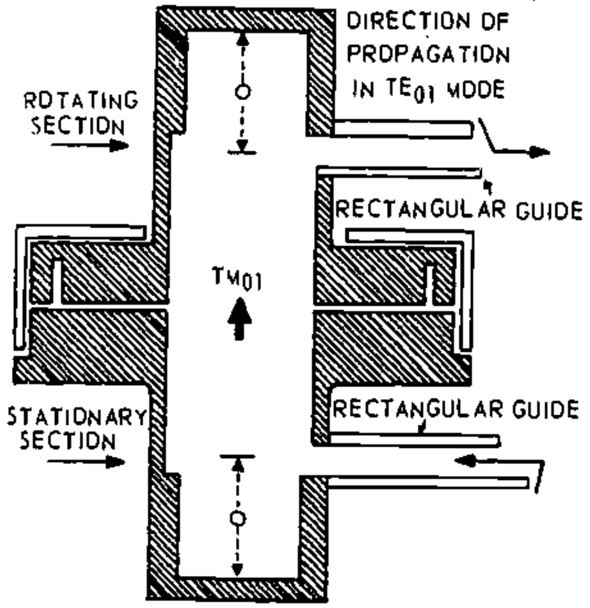

Figure 1-30. Rotating Joint

of a wavelength. Energy travels through the circular part of the waveguide and is routed to the rotating antenna. The rotating joint, like the choke joint, permits a good electrical connection with no physical connection.

1-61. Dummy Loads.

1-62. It is sometimes necessary to terminate (end) a waveguide. A resistive load, called a "dummy load," is attached to the end of the open waveguide to absorb all of the electromagnetic energy. It prevents standing waves and mismatch (field discontinuity). With a dummy load, maintenance can be done on the system without its energy radiating into space. Figure 1-31 shows a dummy load. The electromagnetic energy is dissipated as heat. The heat, in turn, is radiated into the air by the cooling fins.

1-63. Couplers.

1-64. A coupler is a device used to take a sample of the energy within the waveguide. There are two types of couplers--directional and bidirectional. The directional coupler is selective as to direction. That is, it can measure a wave traveling in one direction in the waveguide. The bidirectional coupler can sample waves traveling in either direction.

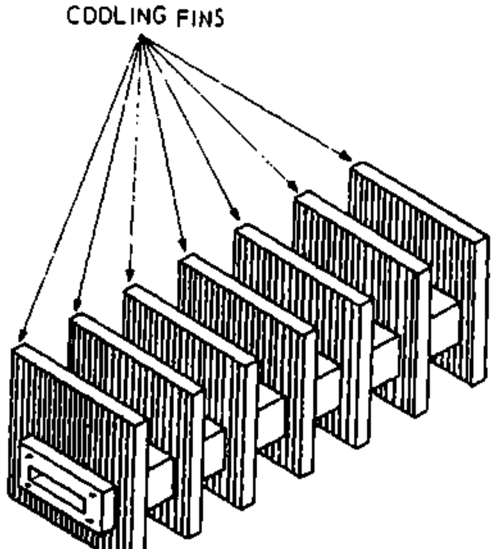

Figure 1-31. A Dummy Load

1-65. Directional Coupling.

1-66. A directional coupler samples a known portion of the overall transmitted or reflected energy. With a proper instrument attached to the coupler, the power and frequency in the waveguide can be measured.

1-67. The directional coupler shown in figure 1-32 is made from an enclosed waveguide section of the same dimensions as the waveguide system itself. There are two holes in the A wall between the two sections. They are $\lambda/4$ apart. An absorbing material is mounted at one end of the directional coupler. A pickup probe is mounted at the opposite end. The absorbing material absorbs energy not directed at the probe as well as part of the overall energy in the coupler. The probe

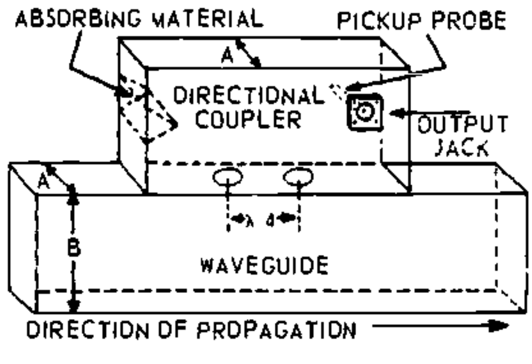

Figure 1-32. Directional Coupler

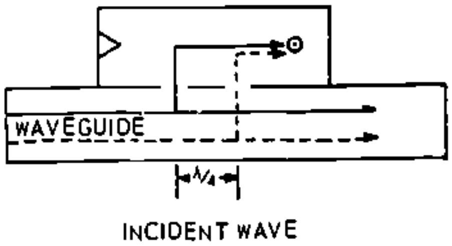

Figure 1-33. Incident Wave Travel

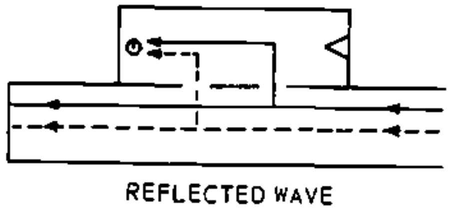

Figure 1-35. Reflected Wave Measurement

picks up the transmitted wave sample. The attenuation of the coupler has been measured and is stamped on its outer surface.

1-68. In figure 1-33, two portions of the incident wave (the wave that travels from the transmitter to the antenna) are shown. They travel down the waveguide and enter the coupler through the two holes. Both portions of the wave travel the same distance and arrive at the probe in phase. These two portions add to make up a sample of the transmitted energy.

1-69. Figure 1-34 shows two portions of the reflected wave (the return wave that travels from the antenna to the receiver). These two portions do not travel the same distance. The dotted line portion travels $\lambda/2$ farther and arrives at the probe 180° out of phase with the solid line portion. The two portions cancel at the probe and no reading can be taken. The reflected energy, however, will add at the absorbing material and be absorbed by it. The directional coupler shown by figure 1-34 then will not measure a reflected wave.

1-70. To measure the reflected wave, a coupler arranged as shown by figure 1-35 is used. Notice that the absorbing material and probe are in opposite positions from those in the preceding illustrations. The two portions of the reflected wave will now arrive in phase at the probe, add, and be measured. The incident (transmitted) energy cancels at the probe and adds at the material which absorbs it.

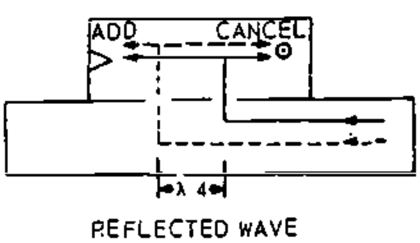

Figure 1-34. Reflected Wave Travel

1-71. Bidirectional Coupling.

1-72. It is a simple step to make a coupling device that will measure both incident and reflected energy. Another directional coupler, with probe and absorbing material reversed, is added to the opposite side of the waveguide. This is shown by figure 1-36.

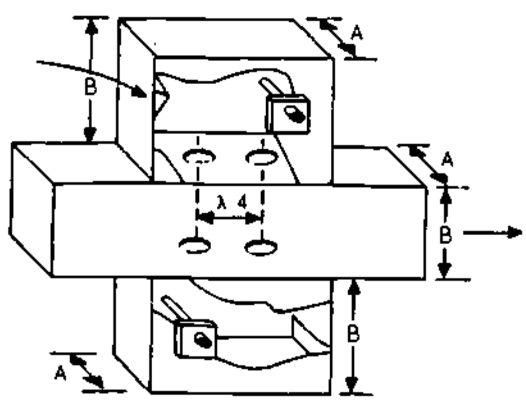

Figure 1-36. Bidirectional Coupler

1-73. A signal generator can be attached to the directional coupler. The signal generator's output can be used to simulate received energy and is useful in checking the receiver and components of the waveguide system.

1-74. Duplexing.

1-75. Two separate antennas and two transmission lines are sometimes used to transmit and receive RF signals, one for each function. When the same transmission line and antenna is used to transmit and receive, the equipment and its installation is made much simpler.

1-76. Transmission and reception can occur with one antenna by modifying the transmission line. It is important, however, to keep the transmitter signal out of the receiver when both operate on the same frequency. The high transmitter power could damage the sensitive receiver and make it inoperative.

1-77. Parallel Duplexing System.

1-78. In radar, where the receiver and transmitter use the same frequency, a duplexer system permits single antenna operation. The duplexer system has TR (transmit-receive) and ATR (antitransmit-receive) circuits. The purpose of the TR circuit is to prevent transmitter power from reaching the receiver. The purpose of the ATR circuit is to disconnect the transmitter from the circuit while the antenna is receiving.

1-79. Figure 1-37A shows a two-wire transmission line with TR and ATR duplexer components. The transmission line can be a coaxial line or a waveguide; both operate on the same principle. The receiver transmission line is perpendicular to the transmitter transmission line. A spark gap is placed in the receiver line one-quarter wavelength from the junction. This is the TR spark gap. One-quarter wavelength from the receiver line junction, toward the transmitter, another one-quarter wavelength line is placed perpendicular to the transmitter line. This line is also terminated in a spark gap called the ATR spark gap.

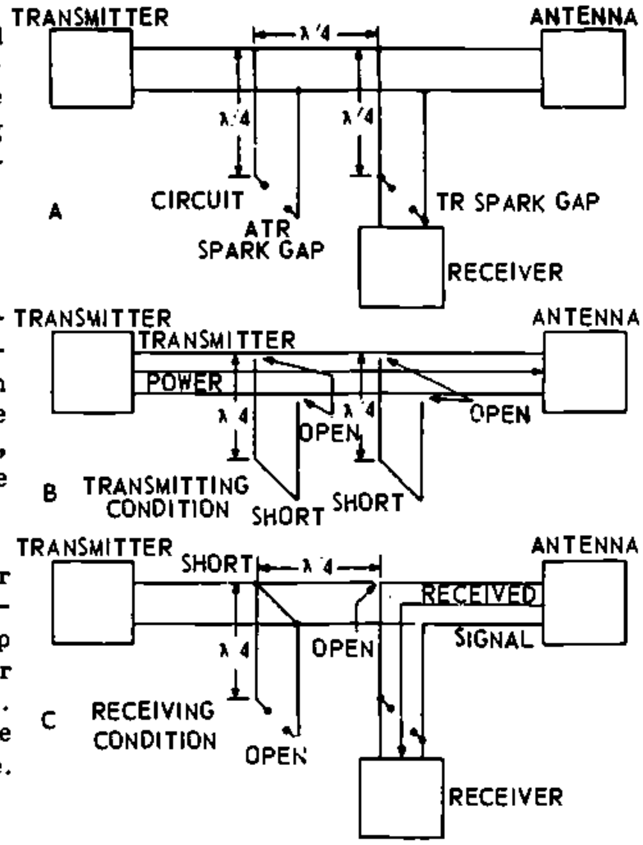

Figure 1-37. Simplified Duplexer System

1-80. During transmission, both spark gaps fire (figure 1-37B) and cause the TR and ATR circuits to act as shorted quarter-wave transmission lines. An open circuit, maximum impedance, is reflected at both junctions to the main transmission line. The transmitter power is conducted to the antenna without loss, and no power enters the receiver line.

1-81. When receiving, the low amplitude of the received power is not enough to fire either gap. Under this condition, the ATR circuit becomes a quarter-wave transmission line terminated in an open. A short is reflected back across the main transmission line, shown by figure 1-37C. This short circuit appears as an open circuit across the receiver line junction with the transmission line. The received signal, looking toward the transmitter, sees an open circuit and enters the receiver circuit.

1-82. Figure 1-38 shows the actual waveguide duplexer with the same circuit as shown in the preceding simplified system. The TR and ATR tubes are placed an odd number of quarter-wavelengths apart and one-quarter wavelength from the waveguide.

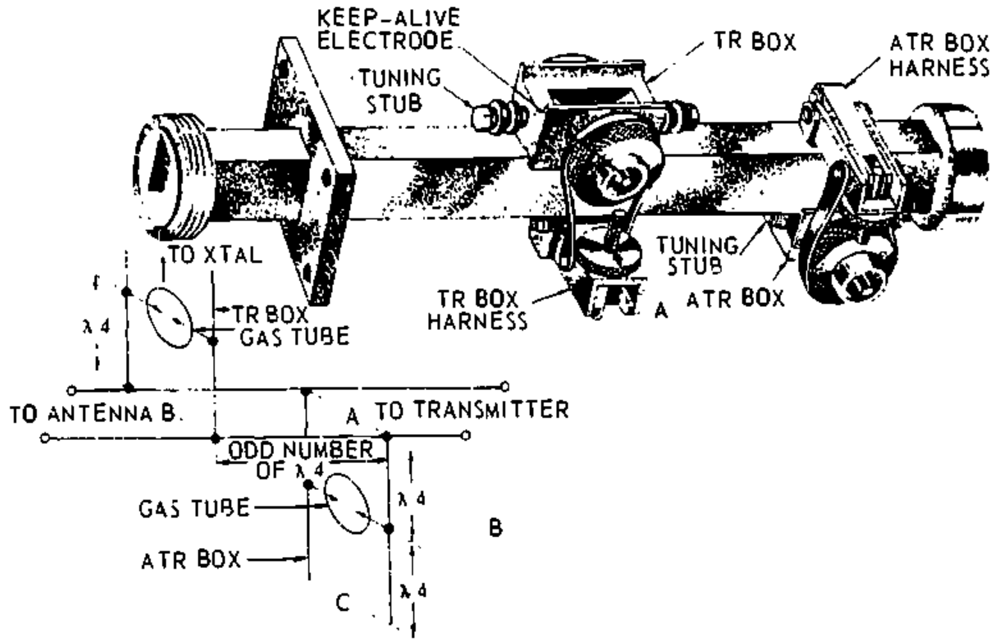

Figure 1-38. Waveguide Duplexer

46

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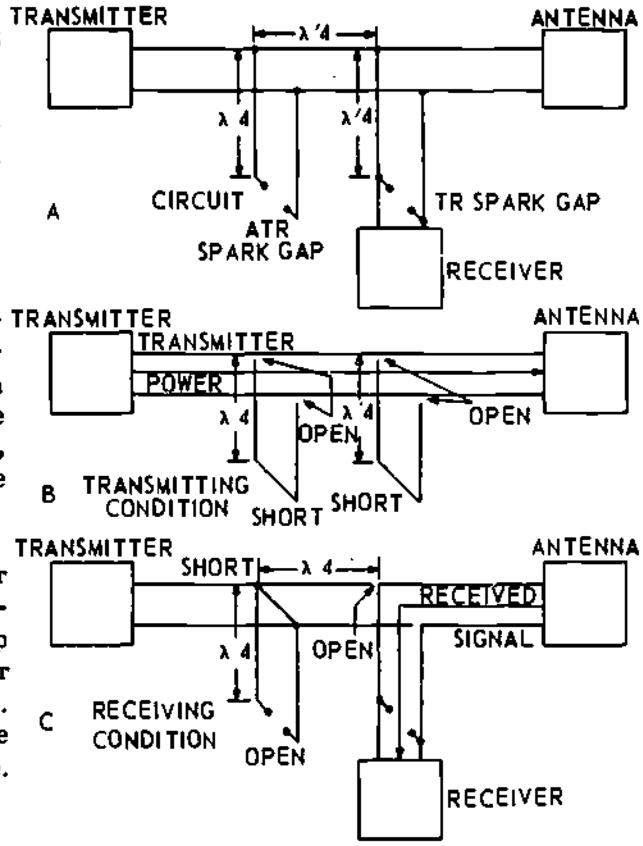

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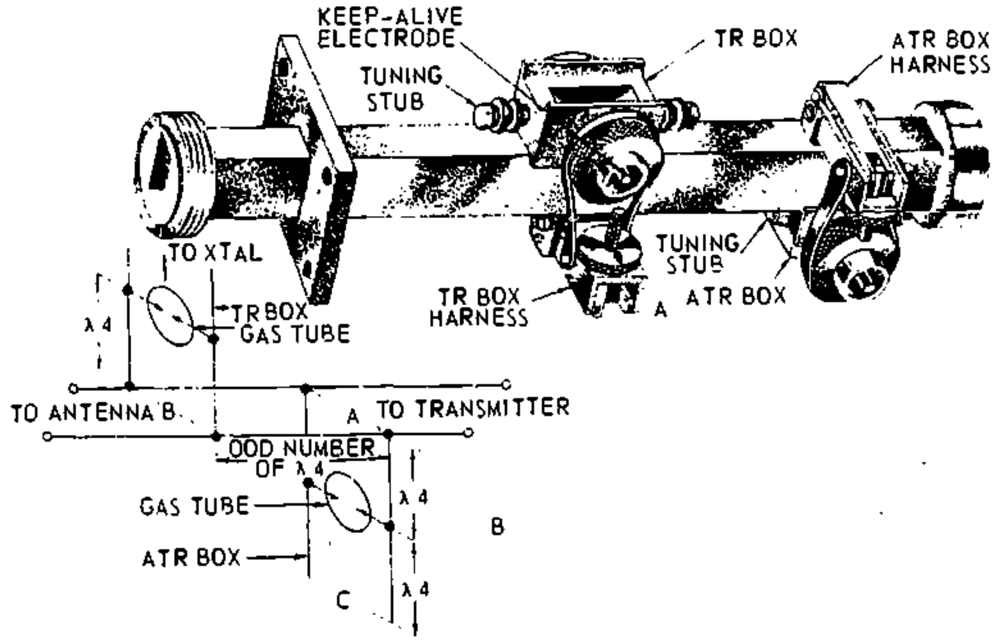

Figure 1-38. Waveguide Duplexer

Chapter 2

CAVITY RESONATORS

2-1. A resonant circuit in ordinary electronic equipment consists of a coil and a capacitor. They can be connected in series or parallel. To increase the resonant frequency, it is necessary to reduce the capacitance or inductance or both. The point will be reached, however, where the capacitance and or the inductance cannot be further reduced. This limits the highest frequency at which a conventional resonant circuit can operate. The upper frequency limit for a conventional resonant circuit is between 2000 and 3000 MHz. At microwave frequencies, the LC circuits may consist of a half-turn coil with the coil's stray capacity making up the needed capacitance. At these frequencies, the half-turn coil is about an inch long and a quarter inch across. This small component cannot handle high voltage and high current because of the short breakdown path. The resonant frequency is also affected by other circuit components. It is difficult to tune a one-half turn coil and more difficult to tune stray capacitance.

2-2. If a quarter-wavelength transmission line can act as a resonant circuit, so will a quarter-wavelength section of waveguide. Both have resonant characteristics. Because a quarter-wave section of a waveguide is hollow, it could be considered a resonant cavity. The resonant cavity made for microwave frequencies is an equivalent LC circuit. Sometimes it is called a cavity resonator.

2-3. A resonant cavity is any space that is completely confined by conducting walls and has resonant properties. It is a hollow conductor that can hold oscillating electromagnetic fields.

2-4. Advantages.

2-5. At microwave frequencies, the cavity resonator has many uses and advantages. It can be made to handle large amounts of power. It has a very high Q (gain). A cavity with a Q of more than 30,000 is not unusual. Accurate tuning and a very narrow bandpass require a high Q. The resonant cavity is a simple device and rugged. It is used in frequency meters and as LC tank circuits in microwave oscillators and amplifiers.

2-6. Developing a Cavity Resonator.

2-7. Any cylinder-shaped cavity can be thought of as being formed from many quarter-wave sections. In figure 2-1A, the quarter-wave section is equal to a resonant circuit with a very small L and C. In figure 2-1B, three quarter-wave sections are joined in parallel. Note that although the current-carrying ability of several parallel sections is greater than that of any one section, the resonant frequency does not change. This is because adding inductance in parallel lowers the total inductance, but adding capacitance in parallel increases the total capacitance in the same proportion. The resonant frequency then will remain about the same as it was for one section. The increased number of current

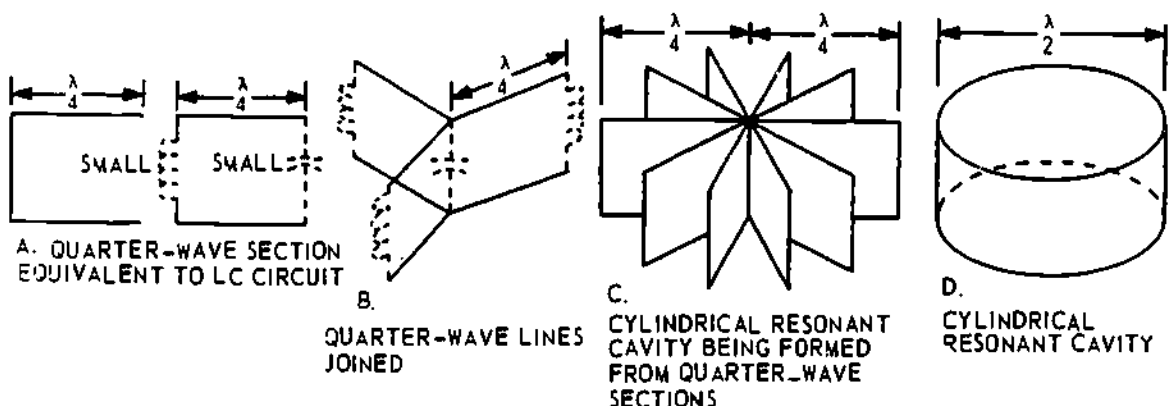

Figure 2-1. Forming a Cylindrical Resonant Cavity

42

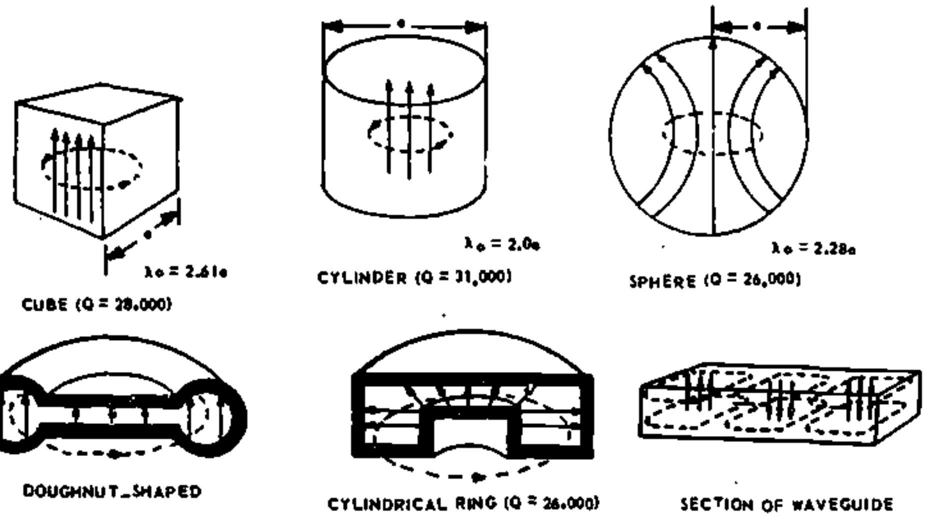

Figure 2-2. Cavity Design

paths decreases the total resistance and increases the Q of the resonant circuit. Figure 2-1C shows how a cylindrical cavity is formed by many quarter-wave sections.

2-8. Figure 2-1D shows the completed resonant cavity which has a diameter of one-half wavelength and which is thought of as a circular waveguide with the top and bottom shorted.

2-9. Primary Frequency.

2-10. Two variables determine the primary frequency of any resonant cavity. The first is the cavity's PHYSICAL SIZE. The smaller the cavity, the higher its resonant frequency. The second controlling factor is SHAPE. Figure 2-2 shows several cavity designs that are used today. Remember that any enclosed metal surface, regardless of its shape, can operate as a cavity resonator.

2-11. Fields in the Cavity Resonator.

2-12. The boundary conditions for waveguides are the same for cavity resonators. The fields generated are confined inside the cavity just as they are in a waveguide. No E- or H-lines exist outside the closed cavity, and electron flow is confined to a thin layer of metal on the cavity's inside surface.

2-13. The E- and H-field distributions in square and cylindrical cavities are shown in figure 2-3. The H-field is strongest at the vertical walls of the cylindrical cavity and along the side walls of the square cavity. The field intensity decreases toward the center of the cavity and becomes zero at the center. The E-field in both cavities is maximum at the center and decreases to zero at the edges. The walls are short circuits to the voltage.

2-14. Energy Coupling.

2-15. The same three devices that are used to insert and remove energy in the waveguide are used for the same purpose in the cavity resonator. They are the probe, the loop, and the iris.

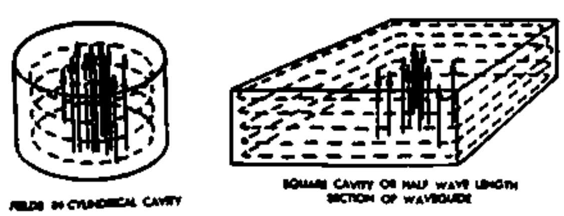

Figure 2-3. E- and H-Fields in Cavities

2-16. With a probe, the varying electrical charge along its length sets up E-fields parallel to it. (This is due to the current movement within the probe.) They, in turn, start the oscillations.

2-17. The loop is placed where the magnetic field exists. The current in the loop starts an H-field in the cavity. This causes oscillations.

2-18. In the iris (window) coupling, the energy simply passes through the iris to external circuitry. This would usually be a waveguide.

2-19. Figure 2-4 is a combined drawing of all three coupling methods. Any one of them can remove energy from or inject energy into a resonant cavity. Only one method is used at one time.

2-20. Tuning the Cavity Resonator.

2-21. The resonant cavity, used as a tank circuit at microwave frequencies, may often require tuning. Tuning is done by changing either the capacitance, the inductance, or the size (volume) of the cavity. These changes will adjust the resonant frequency.

2-22. The first method, shown by figure 2-5A, is capacitive tuning. This is done with an adjustable slug (screw) placed in the area of maximum E lines.

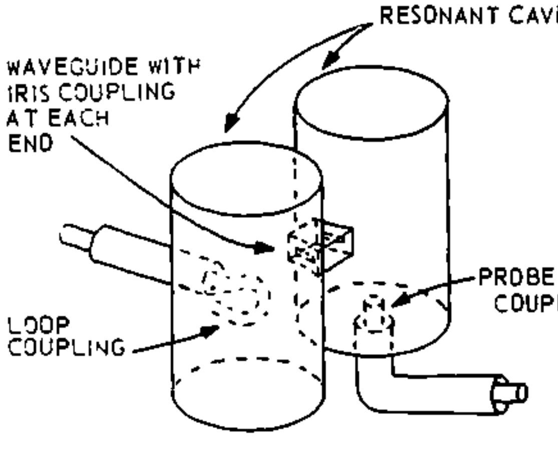

Figure 2-4. Coupling Method in Cavity Resonators

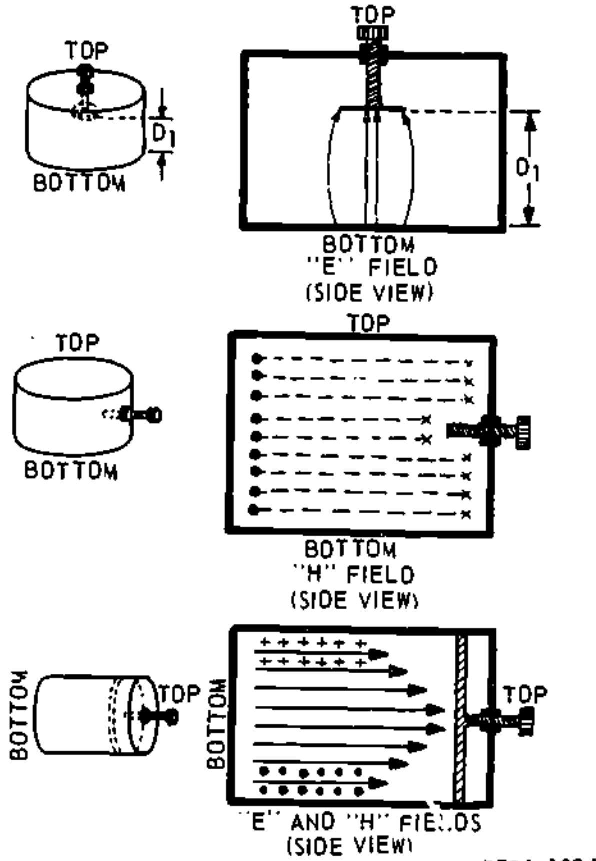

Figure 2-5. Methods of Varying the Resonant Frequency of a Cavity

2-23. D_1 represents the distance between two capacitor plates. To decrease the resonant frequency of the cavity, the slug is screwed in. As the distance between the two plates becomes smaller, the capacitance increases and the resonant frequency decreases.

2-24. Figure 2-5B shows inductive tuning. A slug is placed in the area of maximum H-lines. This is a nonmagnetic conductor of brass or copper. The changing flux induces eddy currents in the slug. The eddy currents have their own magnetic fields which opposes the original field. The total magnetic field and inductance are reduced when the slug is screwed into the cavity. The resonant frequency will increase. Moving the slug out will decrease the resonant frequency.

2-25. Figure 2-5C shows how volume tuning is performed. By moving the adjustable plunger, both inductive and capacitive changes occur, and there is a resultant change in resonant frequency. When the plunger is screwed in, the cavity volume decreases and the resonant frequency goes higher. A decrease in resonant frequency occurs when the plunger is screwed out.

2-26. Resonant Cavity Wavemeters.

2-27. A wavemeter measures the frequency of the signal in the cavity resonator. Wavemeters can be either a Transmission or Absorption type instrument. The transmission type has two terminals as shown in figure 2-6A and produces a maximum meter reading at resonance.

2-28. An absorption type has one terminal as shown in figure 2-6B and produces a minimum meter reading at resonance. In both types, a sensitive power-measuring device such as a crystal probe and a microammeter is used to indicate the resonance point.

2-29. The wavemeter shown in figure 2-7 can be used as both an absorption and transmission type. It resembles a quarter-wave coaxial line with one end open and the other end shorted. Point A in the figure is the open end: Point B is shorted by the vertical shorting bar. Turning the micrometer thimble T to move extension A farther into the cavity, in effect lengthens the quarter wave and lowers the frequency. The reverse action will increase the frequency.

2-30. When this wavemeter is used for the transmission method of frequency measurements, the unknown signal is coupled into the cavity through coupling loop C. Maximum oscillations will occur inside the cavity when the movement of extension A tunes the cavity to the unknown signal frequency.

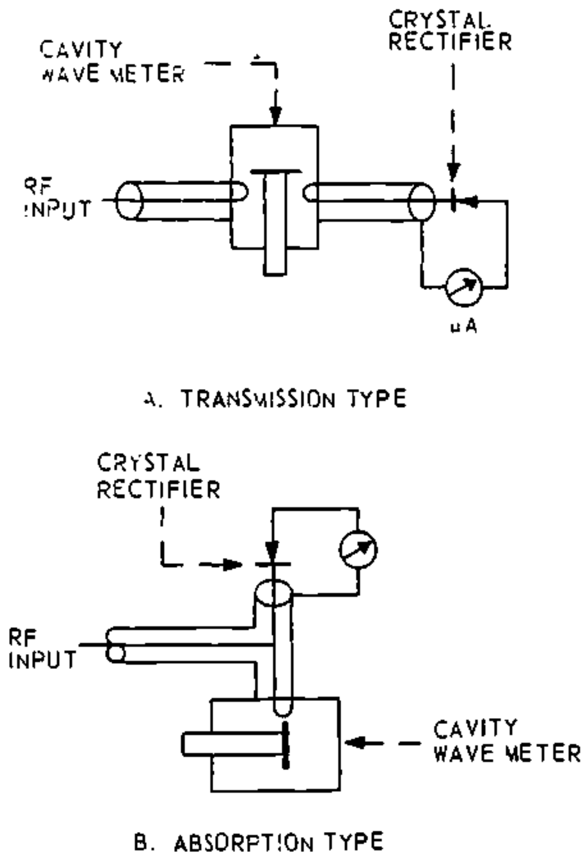

Figure 2-6. Types of Wavemeters

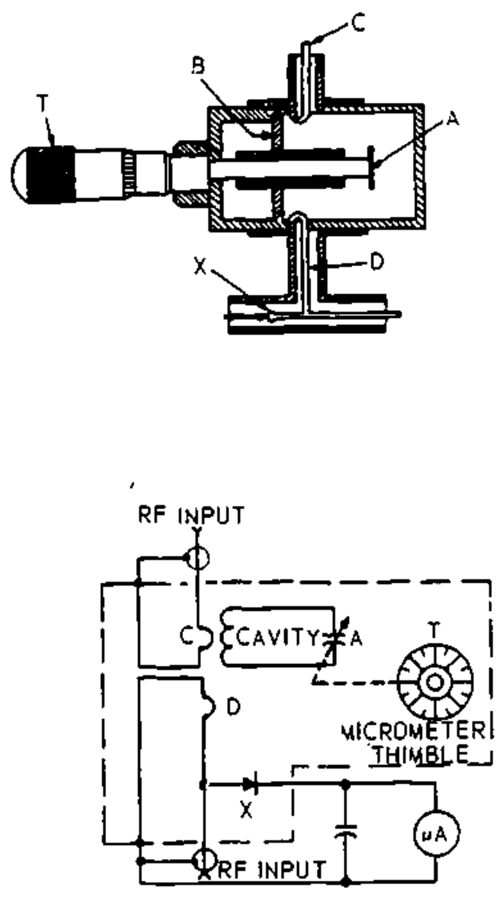

Figure 2-7. A Typical Wavemeter

2-31. Energy is coupled out through coupling loop D, and crystal X rectifies the signal. Notice in the equivalent circuit that the rectified current flows through the microammeter; and when the maximum circuit current is indicated, the wavemeter will be tuned to the same frequency as the signal being measured.

2-32. When the absorption method of measurement is used, the unknown frequency is applied to loop D. When the cavity is not tuned to the signal frequency, it absorbs only a small amount of energy and the meter would read maximum. As the cavity is tuned to the frequency of the signal being measured, there will be a dip in the meter reading. This happens when the power is absorbed by the resonant cavity through coupling loop D.

46

KLYSTRONS AND TRAVELING WAVE TUBES

3-1. Conventional tubes and circuits are not used to generate and amplify UHF and microwave frequencies because of their poor efficiency. Their inefficient operation at the higher frequencies is caused by:

1. Interelectrode capacitance.
2. Lead inductance.
3. Electron transit time.
4. RF losses in external circuitry.

3-2. Limitations of Interelectrode Capacitance.

3-3. The interelectrode capacitance and lead inductance of conventional tubes are shown by figure 3-1.

3-4. At ordinary radio frequencies, the reactance of the interelectrode capacitance in a tube is not serious. At higher frequencies, however, the reactance of the capacitance becomes small enough to influence the circuit's operation. For example, a 1 pF capacitor has a reactance of 1590 ohms at 100 MHz. With this as the plate-to-grid capacitance and the RF voltage of 500 volts between these electrodes, there will be an interelectrode capacitive current of 315 milliamperes. This amount of current will disturb the circuit's operation. But at 1 MHz, the reactance of this capacitance is about 159 k ohms and the current is only 3.15 milliamperes. This amount will not greatly alter circuit performance.

3-5. Remember that the higher the frequency (or the greater the interelectrode capacitance), the higher will be the capacitive current flow. These higher currents cause a power loss in the resistance of the circuit.

3-6. A basic tuned-plate, tuned-grid oscillator is shown in figure 3-2. Because the interelectrode capacitances are in effect in parallel with the tuned circuits, they affect the frequency at which the tuned circuits resonate. The plate-to-cathode capacitance is in parallel with the series combination of the plate-to-grid capacitance and the grid-to-cathode capacitance. All these capacitances form a part of the total capacitance of the tuned circuits.

3-7. The interelectrode capacitance LIMITS the frequency by setting the MINIMUM CAPACITANCE. Interelectrode capacitance also varies with the voltages and loading of the oscillator. This causes frequency instability when the interelectrode capacitance forms a large part of the tank capacitance.

3-8. Limitations of Lead Inductance.

3-9. Another frequency-limiting factor in the tube is inductance of the leads to each tube element. They may make up the major

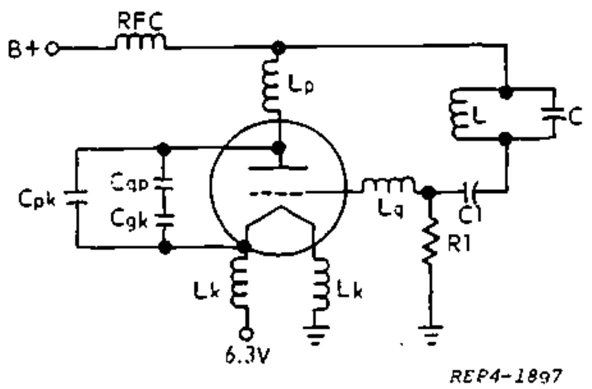

Figure 3-1. Interelectrode Capacitance and Inductance (Conventional Tubes)

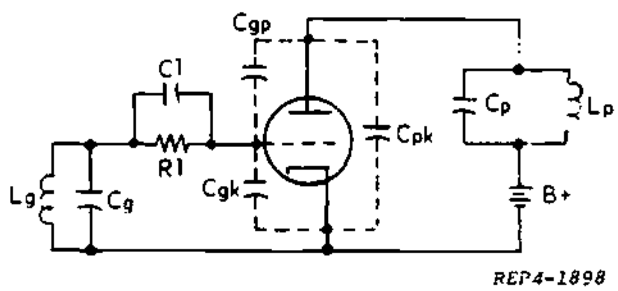

Figure 3-2. Effect of Interelectrode Capacitance on Frequency in the TPTG Oscillator

part of the inductance in a tuned circuit and limit the frequency. They do this by setting a minimum limit on the inductance. Cathode lead inductance will cause a loss in gain and reduce efficiency with negative feedback (cathode degeneration).

3-10. Limitations of Transit Time.

3-11. Transit time is the time required for electrons to travel from the cathode to the plate. There is no problem in low-frequency operation; the actual transit time is slight when compared to the time of one cycle. A transit time of 1/1000 of a microsecond is only 1/1000 of a cycle at a frequency of 1 megahertz; but, when transit time is longer than 1/10 of a cycle, the tubes efficiency drops greatly. When the transit time approaches a quarter of a cycle, most tubes will not oscillate. The relatively long transit time causes a phase shift between plate current and grid voltage and a decrease in effective resistance betweengrid and cathode.

3-12. Limitations due to External Circuits.

3-13. In a tube's external circuit, the main power losses at higher frequencies are caused by skin effect and radiation. Skin effect increases the resistance of a conductor at the ultra-high frequencies. This reduces Q and increases the I^2R losses. Radiation losses occur along conductors when electromagnetic fields that surround them are not completely cancelled. At low frequencies, when the spacing between two parallel conductors is only a small fraction or a half wavelength, there is almost complete field cancellation. At higher frequencies, the same spacing represents a much larger fraction of a wavelength. This means less cancellation, more power loss.

3-14. Microwave Tube Principles.

3-15. Conventional tubes will not operate properly at ultra-high frequencies. This is because of interelectrode capacitance, lead inductance, electron transit time, and RF losses. The conventional tube had to be redesigned to operate in the higher part of the frequency spectrum. UHF tubes were the result. The lighthouse tube in figure 3-3 is one example.

3-16. There are compelling reasons for operating at microwave frequencies (1000 to 100,000 MHz). The UHF tubes are as ineffective in this range as are the conventional tubes in the UHF spectrum. Tubes that use these higher portions of the frequency spectrum are called microwave tubes. In microwave tubes, lead inductance, interelectrode capacitance, and RF losses are reduced with low-loss resonant cavities designed into the tube.

3-17. The effects of transit time in the conventional tube demanded that its grids be smaller, with closer spacing, as the frequency increased. In the UHF tube, these physical limitations were soon reached. This suggests that higher frequencies would be impossible because of transit time, but this is not the case.

3-18. The solution to the transit-time limitation was to use it in solving the problem. All microwave tubes then, use electron transit time in converting DC power to RF power. This interchange of power uses the principle of velocity modulation.

3-19. The operation of a microwave tube begins with electron and electric field interaction. Because an electron has mass, it

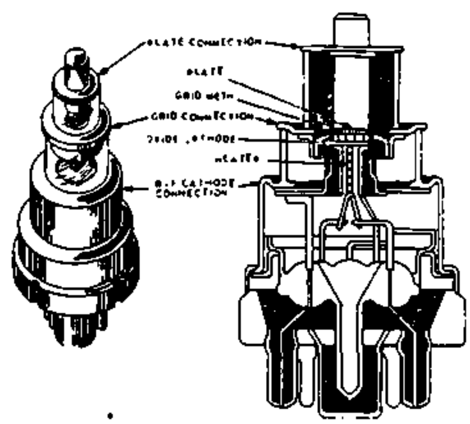

Figure 3-3. Lighthouse Tube

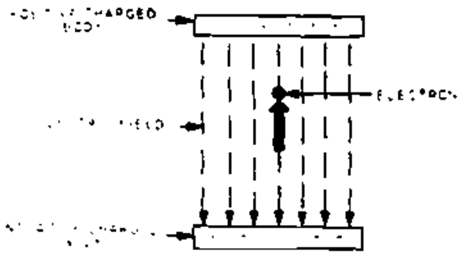

Figure 3-4. A Moving Electron Gaining Velocity and Energy

contains kinetic energy when in motion. The higher the electron velocity, the greater its energy level. This basic concept, electron energy level versus electron velocity, is the principle of energy transfer and amplification in microwave tubes.

3-20. Figure 3-4 shows an electron moving in an electrostatic field. The electron can be accelerated by this field. The direction of electron travel (heavy arrow) is against the electrostatic lines (lines of force from positive to negative charge). The electron is affected by the positive charge on top and the negative charge on the bottom. Because it is negatively charged, it will be attracted toward the positive charge and increase its velocity. As the velocity increases, so will its energy level.

3-21. Where does the electron's additional energy come from? It takes it from the electrostatic field itself. An electron traveling against the electrostatic lines absorbs energy from the electrostatic field and accelerates.

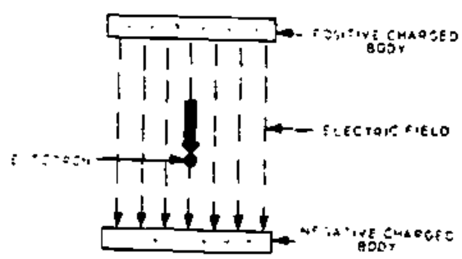

Figure 3-5. A Moving Electron Losing Velocity and Energy

3-22. Figure 3-5 shows the opposite condition where an electron travels with the field.

3-23. The negative charged body has a repelling effect on the negatively charged electrons. This lowers the electron's velocity as it gives up its energy to the electrostatic field.

3-24. Velocity Modulation.

3-25. Microwave tubes are velocity modulated. Their operation depends on changing the speed of electrons that pass through it. This change in electron speed produce bunches of electrons, each bunch separated by a space with few electrons. Velocity modulation then, means that the velocity of a beam of electrons is alternately accelerated and decelerated. The rate of this variation is within a period that compares with the transit time in the space concerned. Usually, the rate is controlled by a voltage applied between the two grids through which the beam must pass.

3-26. Figure 3-6 shows a stream of electrons developed with an electron gun (heater and cathode). All travel at the same speed. As the electrons leave the cathode, they are attracted toward the positive accelerator grid. As the electrons pass through the grid they form a beam.

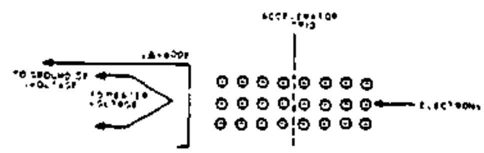

Figure 3-6. Electrons Emitted by Electron Gun

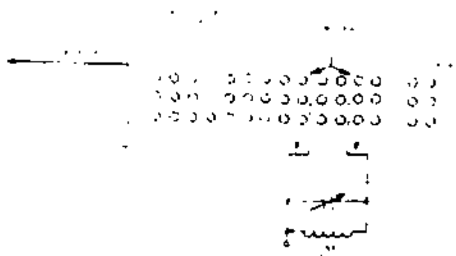

Figure 3-7. Electron Gun and Buncher Grids (Gridded Drift Tube with Resonant Cavity)

3-27. The electron beam then passes through two closely spaced grids, called buncher grids. Each grid is connected to one side of a tuned circuit as shown in figure 3-7.

3-28. The resonant circuit represents a doughnut-shaped cavity resonator. The buncher grids are the perforated center of the cavity. This design is called a "gridded-drift tube" with a resonant cavity. The buncher and accelerator grids are at the same DC potential. The alternating voltage across the tank circuit causes the velocity of the electrons to change as they travel between the buncher grids. The rate of change depends on the magnitude and direction of the electrostatic field inside the cavity as the electrons pass through the buncher grids.

3-29. To better understand how the buncher makes groups of electrons, consider the motion of individual electrons. Any electron that passes between buncher grids at the instant the alternating cavity voltage passes through zero is not affected: it leaves the buncher at the same velocity with which it entered. This is shown in figure 3-8 at points A, E, and I. The steepness of the lines in the figure indicate the electron velocity.

3-30. When grid #1 is negative in respect to grid #2, the electron will decelerate. This is shown at points B, C, and D in figure 3-8. The electron is slowed because its negative charge opposes the negative-charged grid #1. During the time A to E, grid #1 is negative with respect to grid #2. The buncher's electrostatic field exists from grid #2 to grid #1. The electron then, moves in the same direction as the electrostatic field. As it works against the field and gives up energy, its velocity decreases. Thus, any group of electrons that pass through the buncher at B, C, and D leave it at reduced velocity.

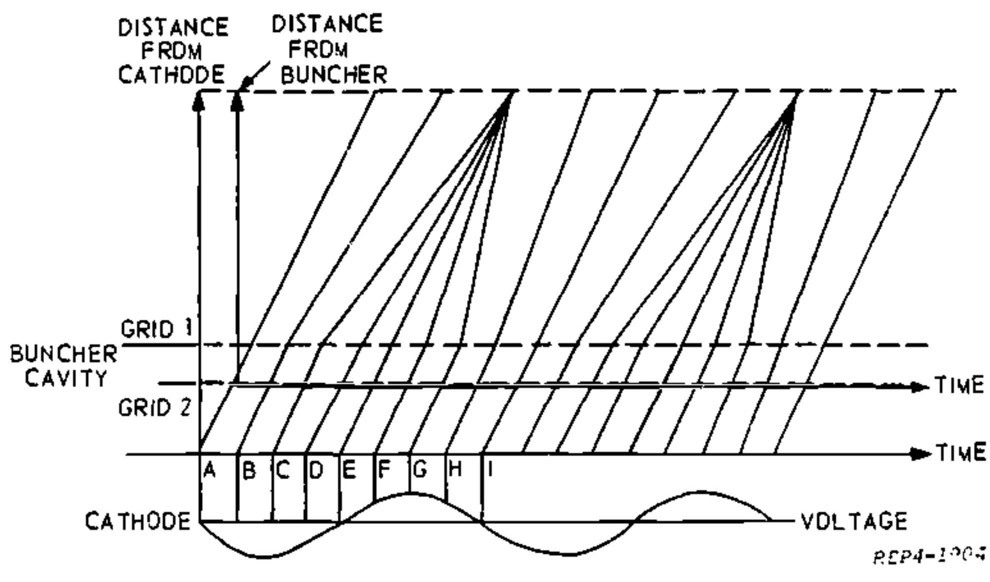

Figure 3-8. Electron Bunching

3-31. Electrons that pass through the buncher after its voltage has reversed are accelerated. Electrons at F, G, and H are accelerated, because during the period E to I, the buncher's electrostatic field is reversed. It exists in the direction opposite to electron movement. Any electrons that pass through the buncher during the period (grid #2 negative in respect to grid #1) will take energy from the electrostatic field and accelerate.

3-32. Velocity modulation of the electron beam is only one step in converting DC power to RF power. Thus far, no useful power has been produced. The energy given to the accelerated electrons is balanced out by the energy taken from the decelerating electrons. A new distribution of the beam will form, however, if the velocity-modulated electrons are allowed to drift in a field-free area. Basically, three electron groups left the buncher grid. They can be shown by figure 3-9. Electron "a" crosses the gap when the gap voltage is negative and slows down to velocity VO-X. Electron "b" crosses the gap when the gap voltage is zero and its velocity remains constant at VO. As the gap voltage goes positive, electron "c" enters the gap and is accelerated to velocity VO+X.

3-33. These three electrons drift in a field-free area beyond the buncher grids. Due to the new velocity relationships between them, electron "a" falls back toward "b" as electron "c" overtakes "b". This causes an electron bunching around electron "b" at time t2. The bunch velocity is the same as that of electron "b" or VO.

3-34. As the electrons continue to drift, they tend to "debunch" as shown in t3. They re-form with the other electrons either in front of or behind them. Eventually, at some later time, they will smooth out and return to their original beam shape. But before this happens and before the bunching and debunching electrons reaches a collecting element the RF energy must be extracted.

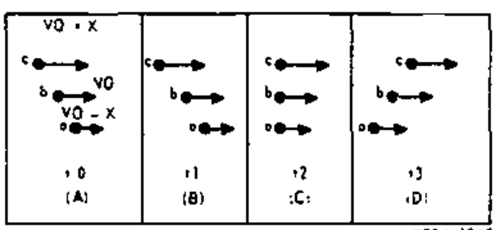

Figure 3-9. Electron Bunching Process

3-35. When velocity modulation causes electron bunches to form, a periodic variation in the density of the electron beam takes place.

3-36. Velocity modulation then, results in CURRENT DENSITY modulation. This periodic variation in beam density happens at the same rate as the RF gap voltage variation at the buncher grids. In terms of frequency, the electron beam density changes at the same frequency as the changes in the buncher field cavity. Velocity modulation transforms the DC beam into a current-modulated beam. Now, we are ready to extract useful RF energy from the beam.

3-37. The bunch (current-modulated) electron beam in figure 3-10A is shown in its various stages of buildup and decay. To take useful RF energy from the beam, a second resonant cavity is used.

3-38. When the velocity of the electrons is controlled, bunching occurs at a definite distance from the electron source. A second resonant cavity is placed at a point of maximum bunching (figure 3-10B). The electron bunch induces an RF voltage in the grid gap and causes the second cavity to oscillate. Precise placement of the cavity establishes a polarity across the gap that decelerates the electron bunches and

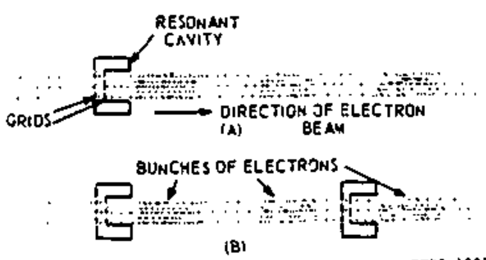

Figure 3-10. Extracting Energy from Electron Bunches

accelerates the small number of electrons between the bunches. With many more electrons in the bunches than between them, there is a transfer of energy to the output cavity.

3-39. The Two-Cavity Klystron.

3-40. A klystron is a velocity-modulated tube used in microwave equipment. It performs the same work in the microwave region that ordinary vacuum tubes do at conventional radio frequencies. They are used as oscillators or amplifiers. Large klystrons are generally used as amplifiers, while smaller klystrons are used as oscillators. The klystron uses the very thing that defeats the ordinary vacuum tube at ultra-high frequencies--the transit time of the electrons. This characteristic is common to all microwave tubes.

3-41. Figure 3-11 shows the construction of a two-cavity power klystron used as an amplifier.

3-42. An indirectly heated cathode emits electrons that are forced electrostatically into a sharp beam by the control grid which is at a low-positive potential. The control grid controls only the number of electrons in the beam. The beam is accelerated by a very high DC potential at the buncher grids.

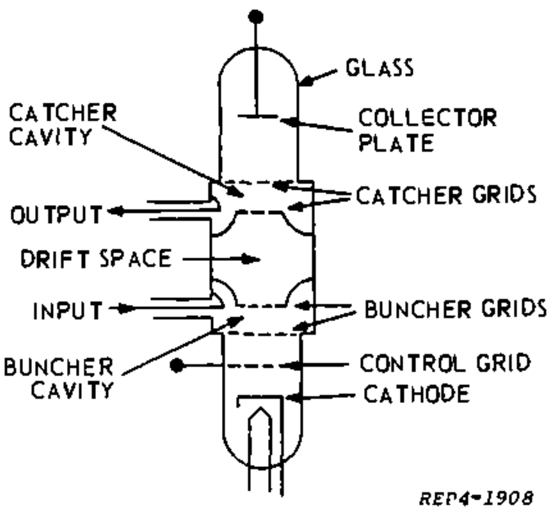

Figure 3-11. A Two-Cavity Klystron (Amplifier)

These grids are close together and connected to a cavity resonator. Superimposed on this DC potential is an AC voltage (caused by cavity oscillations) that changes the velocity of the various electrons in the beam.

3-43. Those electrons that reach the buncher grid at a time when the electrostatic field across the gap is in the same direction as the electron movement are decelerated. Electrons that reach the buncher grid at a time when the electrostatic field is zero are not affected. Those electrons that arrive when their direction of travel is opposite to the electrostatic field are accelerated. As the electrons enter the drift space (free-field area), they form into bunches. At points along the beam where the bunches are fully formed, catcher-cavity grids are placed.

3-44. The electrostatic field across the catcher-cavity grids decelerates the electron bunches. There is a maximum transfer of the electron-bunched energy to the output cavity. The purpose of the catcher grids is to absorb energy from the electron beam that has been modulated by the bunching action.

3-45. The electrons continue through the catcher grid and hit the collector plate. They are returned to the cathode through an external circuit.

3-46. Most power klystrons have more than two cavities, allowing for bandwidths of about 1 percent of the operating frequency and efficiencies of 40 to 50 percent. The power klystron is used for high-power communication links; radar, television broadcasting, particular accelerators, and industrial processing.

3-47. The klystron in figure 3-11 is an amplifier, because it takes in low-level energy at the buncher cavity and delivers a higher level output at the catcher cavity. Any two cavity klystron amplifiers can be converted into an oscillator as shown in figure 3-12, with these two changes.

1. Remove the input coupling.

2. Insert a feedback loop between the cavities.

52

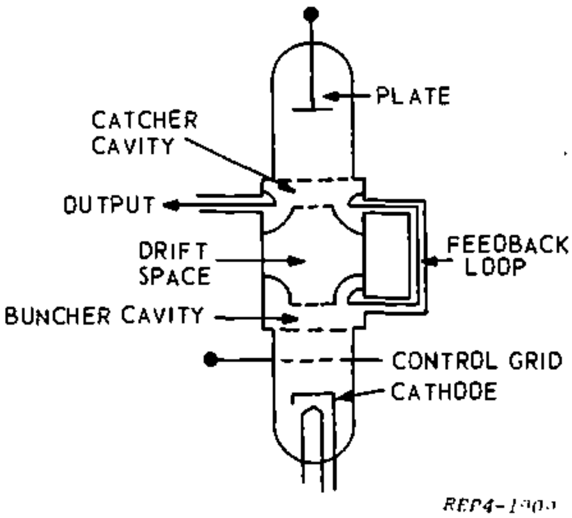

Figure 3-12. A Two Cavity Klystron (Oscillator)

3-48. The frequency of the klystron oscillator is largely determined by the physical structure of its cavities. The feedback loop provides the proper delay and phase relationship to sustain oscillations. With the exception of the feedback path, its operation is the same as the two-cavity klystron amplifier. Because of their size and weight, klystron oscillators are used mainly in ground installations. They can be used in beacons. identification equipment, and as local oscillators in pulsed radar receivers. They are reliable and easy to tune.

3-49. The Three-Cavity Klystron.

3-50. The larger klystrons, with more than two resonant cavities, develop much higher gain and operate with greater efficiency. A three-cavity klystron is shown in figure 3-13.

3-51. In this type, the heater and cathode assemblies, with leads brought out at the tube base, are insulated from the entrance to the drift tube by a glass insulating sleeve. The input cavity is close to the drift tube entrance. The middle cavity is located farther along the drift tube. The collector is beyond the output cavity. The entire drift tube assembly, the three cavities, and the collector of this

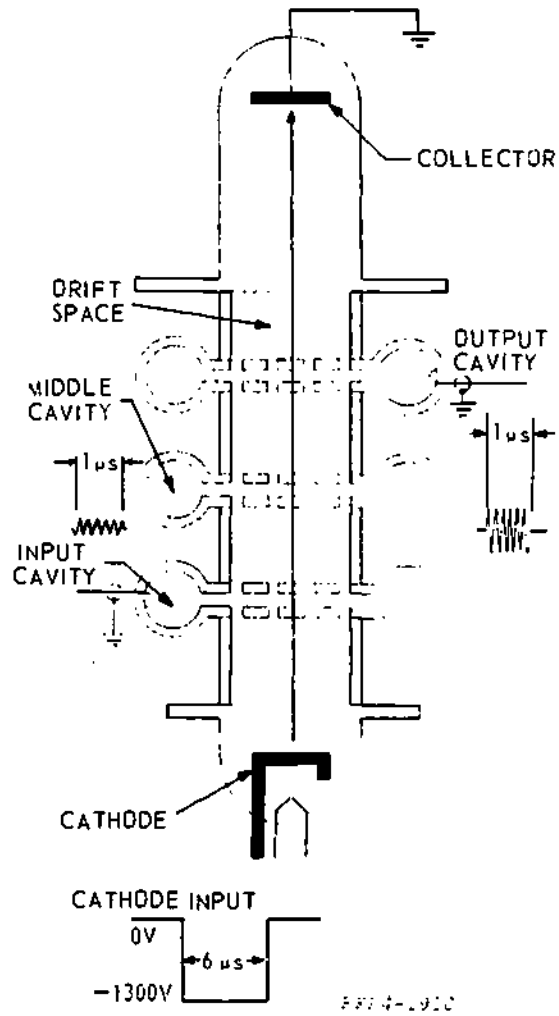

Figure 3-13

klystron are at ground potential. This eliminates hazards and complications when tuning the cavities and in liquid cooling of the tube body and the collector. With the drift tube assembly at ground potential, the cathode is pulsed with a negative voltage to accelerate electrons from the cathode toward the drift tube entrance.

3-52. The output of any klystron (regardless of cavities) is developed by velocity modulation of the electron beam. Velocity modulation, in turn, produces electron bunching. The bunching is one result of the time required for electrons to travel from the input cavity to the output cavity. The electrons that are accelerated by the beam voltage (DC for the duration of the cathode pulse) are acted upon by RF fields developed across the input and middle klystron cavities.

3-53. Some electrons are accelerated, some are decelerated, and others are unaffected. Their changes in velocity depend on the amplitude and polarity of the cavity RF voltage when the electrons pass the cavity gaps. As the electrons travel from one cavity to the next, the accelerated electrons tend to overtake the decelerated electrons. This causes density modulation. As a result, bunches of electrons arrive at the output cavity at the proper instant of each RF cycle to deliver energy to the output cavity. Transit time is a necessity, rather than a hinderance, to the klystron operation.

3-54. Only a small degree of density modulation (bunching) occurs within the electron beam in the interval of travel from the input cavity to the middle cavity. The amount is very small compared to the degree of bunching required at the output cavity. The amount of density modulation is sufficient, however, to excite the middle cavity. Because of the high Q of the cavity, a large oscillatory voltage is maintained across the gap. This voltage is responsible for most of the velocity modulation (and subsequent density modulation) produced within the klystron.

3-55. There is a negligible net transfer of energy from the beam to the middle cavity or from the cavity to the beam. The amount of energy coupled to the cavity from the beam is only the small amount necessary to overcome the cavity loss to maintain the oscillatory RF voltage across the grid gap. The degree of density modulation of the electron stream in the middle cavity, as a result of velocity modulation at the input cavity, is slight compared to that required at the output cavity. It can be considered DC for practical purposes. Therefore, the net energy delivered to or taken from the electron beam at the middle cavity is quite small as compared with the input cavity.

3-56. The large voltage across the middle cavity gap produces a much larger degree of velocity modulation than that of the input cavity. After the electrons cross the middle cavity gap, they drift into the field-free region between the middle cavity and the output cavity. The bunching process continues here but at a more rapid rate than it did between the input cavity and the middle cavity. This is because of the greater degree of velocity modulation of the beam by the middle cavity. The electron bunches cross the output gap when the gap voltage is maximum negative. Under this condition, maximum energy transfer from the electrons occurs to the output cavity. The energy given up by the electron is the kinetic energy of high velocity imparted to the electrons by the beam voltage (cathode pulse). Giving up energy causes the electron velocity to decrease sharply.

3-57. The three-cavity klystron is the equivalent of a pair of two-cavity klystrons in cascade and is referred to as a cascaded amplifier klystron.

3-58. In summary, the steps by which RF energy is taken from a drifting beam of electrons are:

1. The DC beam is velocity--modulated by a small gap field.

2. Velocity modulation causes electron bunching or density modulation.

3. Proper placement of an output cavity decelerates the electron bunches and extracts RF energy.

3-59. The Reflex Klystron.

3-60. The reflex klystron is another microwave tube whose operation is based on velocity modulation. It is used when low-power microwave signals are needed. The main differences are that the reflex klystron:

1. Has only one resonant cavity to bunch and collect the electrons.

2. Is used only as an oscillator.

3-61. Figure 3-14 shows a simplified diagram of the reflex klystron. Note that its single resonant cavity is similar to the buncher cavities in the two-cavity klystron.

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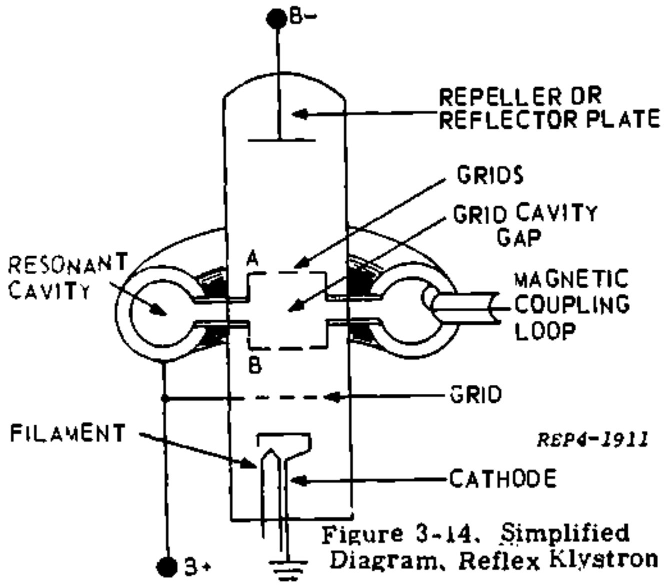

Figure 3-14. Simplified Diagram, Reflex Klystron

3-62. The electron beam is modulated by passing it through an oscillating resonant cavity. Then, the feedback needed to sustain oscillations is produced by reversing the direction of the electron beam. This makes the velocity-modulated electrons form into bunches. They reenter the resonant cavity and give up their energy to the cavity in the proper phase.

3-63. To turn the electron beam around, a negative electrode repels the electron stream. This negative-charged element is the reflector plate (or repeller). The oscillator became known as a "reflex" klystron because of the reflex action of the electrons.

3-64. The parts of a typical reflex klystron are a heater, cathode, control grid, resonant cavity, repeller, magnetic coupling loop, and a tuning apparatus (not shown in figure 3-15). Figure 3-15 shows the graphic symbol for the reflex klystron.

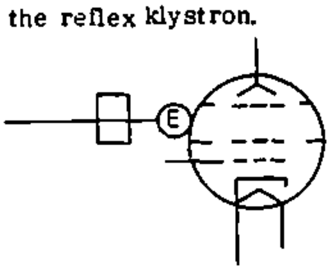

Figure 3-15. Graphic Symbol for the Reflex Klystron

3-65. Three power sources are needed to operate a reflex klystron.

1. Heater power.

2. Beam voltage to accelerate the electrons through the grid gap of the resonant cavity.

3. The negative reflector voltage to reverse the electron bunches and send them back to the grid gap.

3-66. The shape of the cathode (figure 3-16) forms an electronic lens and directs the electron beam toward the repeller plate. The shape of the electron beam is determined by the spacing of the internal parts of the tube.

3-67. The resonant cavity voltage (B+) is felt throughout the entire body of the tube as well as within the cavity.

3-68. As the electrons pass through the gap (between the grids) of the resonant cavity, they are influenced by an instantaneous voltage that appears across the gap. The instantaneous voltage is the result of the natural resonant frequency of the cavity. Grids are placed in the cavity gap for better control of the electron beam as it passes through. The operating frequency determines the size of the reflex klystron.

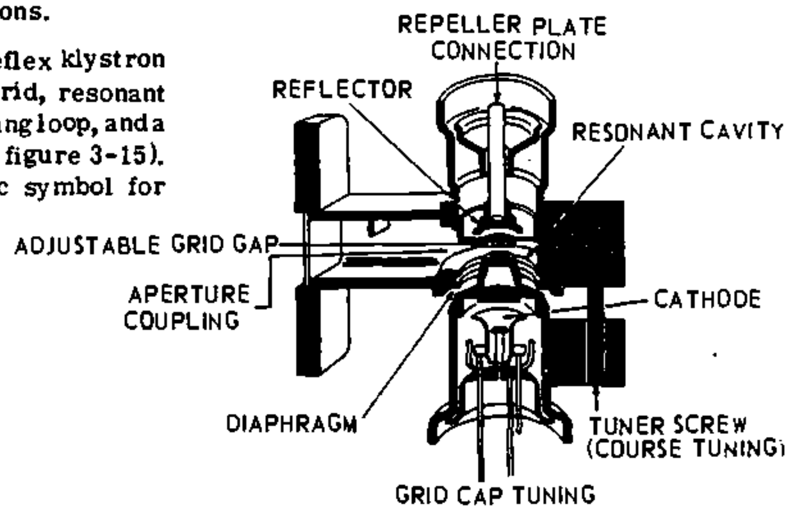

Figure 3-16. Cutaway, Reflex Klystron

3-69. As the electrons pass through the grid gap toward the repeller, they will either accelerate, decelerate, or be unaffected. Again, the voltage polarity across the grid gap determines the effect on each electron's velocity. Figure 3-17 shows the three possible effects on an electron passing through the grid gap. Because the resonant cavity is oscillating, its grid potential is an alternating voltage.

3-70. This means the strength of the electrostatic field between the two grids will follow a sine-wave curve as shown in figure 3-17. As a result, the velocity of the electrons that pass through the grid gap is not changed uniformly. It is only changed by that amount determined by the instantaneous grid voltage.

3-71. Because of the varying grid voltage, the electrons enter the space between the upper grid and the reflector at various speeds, depending on the instant they passed through the grid gap. In figure 3-17 the electron at time 1 is speeded up as it passes through the grid. At time 2, the field passes through zero and the electron is not affected. At time 3, the grid field has reversed and the electron loses energy and velocity as it passes through the grid.

3-72. The distance these electrons will travel into the space between the grid and repeller depends on their velocity. Those that move at the slower speeds (such as the electron at time 3) will go only a short distance from the grid gap before they are overcome by the repeller voltage. When the electron reaches the point where its velocity is overcome by the field set up by the negative reflector, it stops, and reverses its direction. The electron traveling at a higher speed (the electron at time 1) goes farther beyond the grid gap before reversing its direction. This is because of its greater momentum.

3-73. If the repeller voltage is correct, the electrons will form into a bunch around the constant-speed electron and return to the grid gap at the instant the RF field is at its maximum decelerating point (grid A maximum positive with respect to grid B).

3-74. Power is coupled from a resonant cavity by one of two methods--aperture coupling or magnetic coupled. In figure 3-16 cutaway, the reflex klystron, aperture coupling is shown. Figure 3-18 shows magnetic loop coupling.

3-75. There are two tuning adjustments for the reflex klystron's resonant frequency. The coarse frequency tuning is a mechanical adjustment; fine frequency tuning is a electrical adjustment. See figure 3-18.

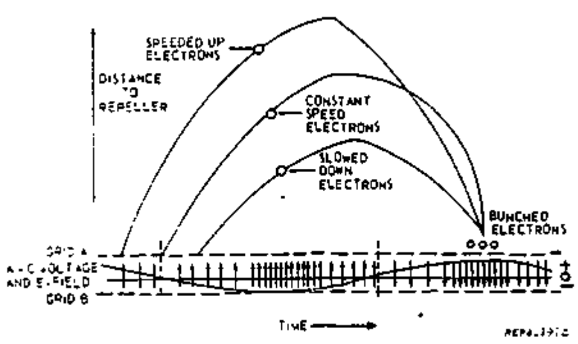

Figure 3-17. Electron Bunching in the Reflex Klystron

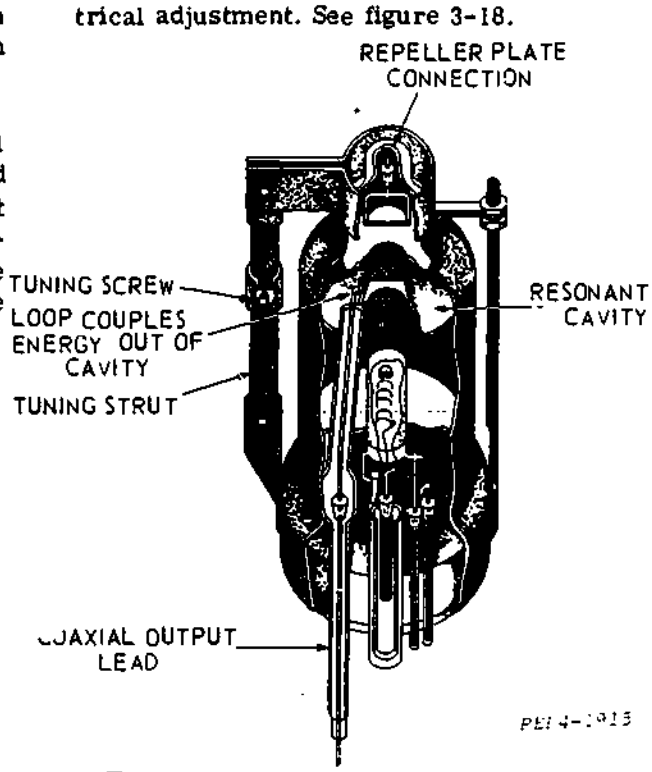

Figure 3-18. Reflex Klystron Cutaway Showing Magnetic Coupling

3-76. For mechanical (coarse) tuning, a tuning screw lengthens or shortens a tuning strut. Note that the resonant cavity is small and doughnut shaped. The upper shoulder of the metal tube envelope is part of the cavity wall. It is also made to be flexible. If adjustment is made to the tuning strut so that pressure forces the top of the tube down, the upper cavity grid is moved closer to the lower cavity grid. This increasees cavity capacitance and lowers the resonant frequency of the cavity.

3-77. Electrical (fine) tuning is done by making a small change in the repeller plate voltage. For example, if the repeller plate voltage is greater than that required to bring the electrons back to the cavity grids at the instant of peak positive cavity signal, the electrons return to early. The reactance is capacitive because the current between the grids leads the voltage. This would be the same as decreasing the capacitance between the grids. The smaller capacitance would result in a higher resonant frequency.

3-78. If the repellerplate voltage were made less negative, the reactance would be inductive. The oscillation frequency would be lower than the cavity's resonant frequency. The advantage of electrical tuning in the reflex klystron makes this tube desirable in automatic frequency control (AFC) circuits of microwave equipment.

3-79. Traveling-Wave Tube (TWT).

3-80. The traveling-wave tube is another microwave frequency device. It compares favorable with other microwave tubes as to gain, noise, and simplicity. The major advantage is its greater bandwidth; as much as one octave. (A bandwidth of one octave has an upper frequency that is twice the lower frequency.) Other microwave amplifiers have limited bandwidths. The Klystron's bandwidth is no greater than that of a low-frequency pentode. As the klystron's bandwidth is increased, its gain diminishes to zero. The traveling-wave tube completely overcomes these limitations because it has no resonant circuit or lumped input capacitance.

3-81. Basically, the TWT is a transmission line with a negative attenuation in the forward direction and a positive attenuation in the backward direction. Negative attenuation causes an exponential increase of voltage in the direction of wave travel. Positive causes an exponential decrease of reflected voltage. The bandwidth is limited to a small extent by the input and output transducers connected to the tube. The transducers have been designed, however, to successfully cover a bandwidth greater than one octave.

3-82. The TWT has an electron gun at one end. The entire tube is surrounded by a solenoid magnet which produces magnetic focusing. In this way, the electron stream from the gun is confined in a tight beam. The weight of the electromagnet and its power supply add to the overall weight, size, and complexity of the traveling-wave tube.

3-83. Figure 3-19 is a cutaway of a traveling-wave tube. It also includes a functional diagram and the electronic symbol. Note how the parts of the electronic symbol can be compared with the cutaway and functional drawings.

3-84. The electrons are accelerated in two ways. First, they are produced and accelerated by a specially-designed electron gun. In the electron gun, the heater boils off electrons from a parabola-shaped cathode. This tends to focus the electron stream, as the small accelerator anode adds to the electron velocity.

3-85. The result is a narrow electron beam that has been accelerated by 1500 volts. The positive potential on the helix and collector anode at the end of the tube continues to speed the electron flow. The electron beam flows down the long, central axis of the loosely wound helix on its way to the collector. A long, wire-wound, magnetic solenoid completely surrounds the loosely wound helix part of the tube. This is the focusing system. The axis of the solenoid's magnetic field conicides with the central axis of the helix.

3-86. This magnetic field keeps the electron beam focused into a narrow beam because of the current through the magnet. The greater the solenoid's current, the tighter it squeezes the beam. If the magnetic field of the solenoid were lost for an instant, the electron beam would spread, intersect the helix, ionize, and destroy the traveling-wave tube.

3-87. A TWT must have an RF input and output. As shown in figure 3-19, both are transformer coupled. An attenuator is located between the couplers. The attenuator prevents the output signal from returning to the input coupler and causing oscillations.

3-88. The operation of the TWT can be compared with that of the klystron. Both tubes velocity modulate a high-velocity electron beam. The electron beam absorbs energy from the DC power through the acceleration of the electrons. An RF signal along the electron beam's path changes the electron velocity. Some are slowed down and some are speeded up. By changing the individual velocities of the electrons, they are shaped into bunches. At the output end of the tube, the electron bunches decelerate and give up their energy to an output circuit. In a klystron, the RF signal that decelerates the electrons comes from a resonant cavity; in the traveling-wave tube, the RF signal comes from the helix. Here the similarities between the klystron and the traveling-wave tube end.

3-89. A major difference between a TWT and a klystron is that the electrons interact as a TRAVELING wave rather than as a STANDING wave. This interaction is spread along the helix rather than being localized as in a klystron. Because there are no high-Q resonant circuits in the traveling-wave tube, it can easily amplify over a broadband of frequencies.

3-90. The effects of a simple traveling wave are shown in figure 3-20. The RF signal is applied to a straight-wire horizontal) transmission line at the input side and an electron beam passes along, parallel to, the straight-wire line. If the output of the straight-wire line ends in its characteristic impedance, the line is nonresonant and will pass a braodband of frequencies. When an RF signal is applied to the straight-wire line, part of its electric field is parallel to the direction of the RF signal and the direction of electron beam travel. This causes an interaction between the RF signal and the electron beam.

3-91. If the beam's electrons could be accelerated to travel faster than the RF signal (electromagnetic wave) on the straight wire, bunching would occur because of the RF signal on the wire. Some of the decelerated bunches give up energy to the RF signal on the straight-wire line and increase the amplitude of the original RF signal. This action can happen over a wide range of frequencies: it allows the traveling-wave tube to act as a broadband amplifier.

3-92. As figure 3-20 now stands, the simplified traveling-wave tube will not work. This is because the RF signal travels at the speed of light and the electron beam cannot be accelerated beyond this velocity.

3-93. Because of this, the traveling-wave tube is designed with a transmission line that will delay the RF signal so the electron beam will be accelerated to a higher speed than the RF signal. The transmission line used to delay the RF signal is the helix. The helix is a nonresonant line that delays the axial velocity (straight-line travel) of the RF signal to where it is only one-tenth the axial velocity of the straight-wire line. This can control the axial velocity of the electron beam to make it equal to, or greater than, the axial velocity of the RF signal. The helical design of the delay line permits greater concentration of the RF field that runs parallel to the axis of the helix. It also causes better velocity modulation of the electron beam.

3-94. Figure 3-21 describes velocity modulation in a TWT. If an electron beam is directed through the center of the helix and an RF signal is applied to the RF input, the traveling-wave tube will amplify the signal. (Although the focusing magnet is a vital part of the tube, it is not shown here.) The RF signal is coupled to the helix through the transformer coupling and forms bunches as shown by the waveshape. Amplification of the RF signal on the helix begins as the

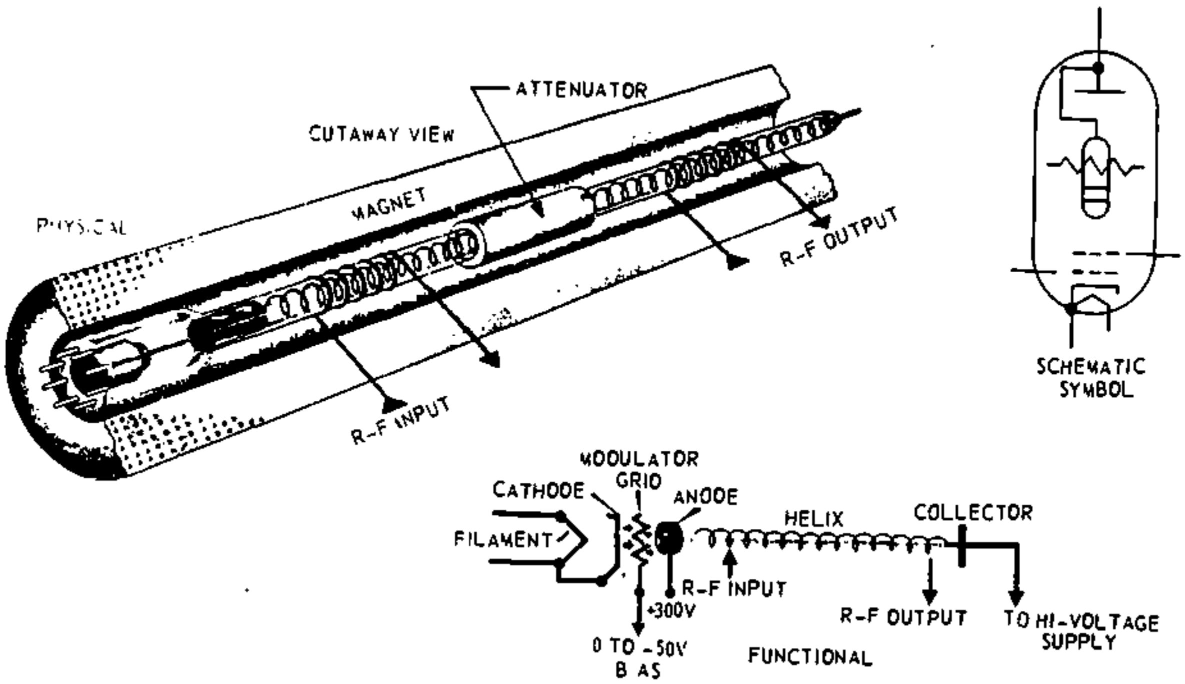

Figure 3-19. Traveling-Wave Tube

field formed by the bunches interacts with the field from the RF signal. Each newly formed electron bunch adds a small amount of RF energy to the RF signal on the helix.

3-95. The slightly amplified RF signal causes more electron bunching. This, in turn, adds more energy to the RF signal. The process is continuous along the helix as both RF signal and electron bunches interact. Notice how the RF signal amplification increases as the electron bunches become more in phase with the negative field of the RF signal. This happens when maximum deceleration occurs and the electron beam gives up maximum energy to the helix. This energy is coupled from the helix by the output coupler of the tube.

3-96. The attenuator, near the center of the helix, reduces the RF signal on the helix. This prevents the signal at the output side from feeding back to the input side and causing oscillations. The forward-going signal, however, is also attenuated as the waveshape shows. This has little overall effect because the electron bunches are not changed by the attenuator. The bunches that leave the attenuator induce a new RF signal on the helix which will be at the same frequency as the input signal. The electron bunches and the newly induced RF signal again begin to interact and amplify.

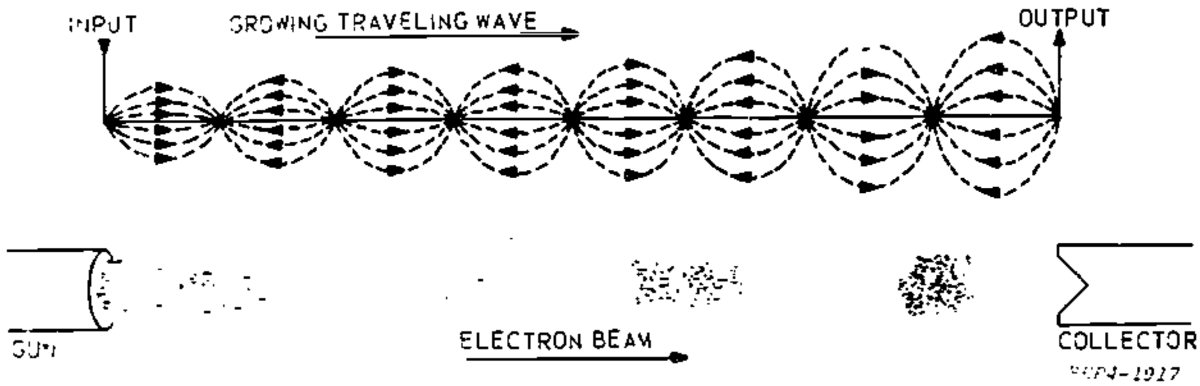

Figure 3-20. Simplified Traveling-Wave Concept

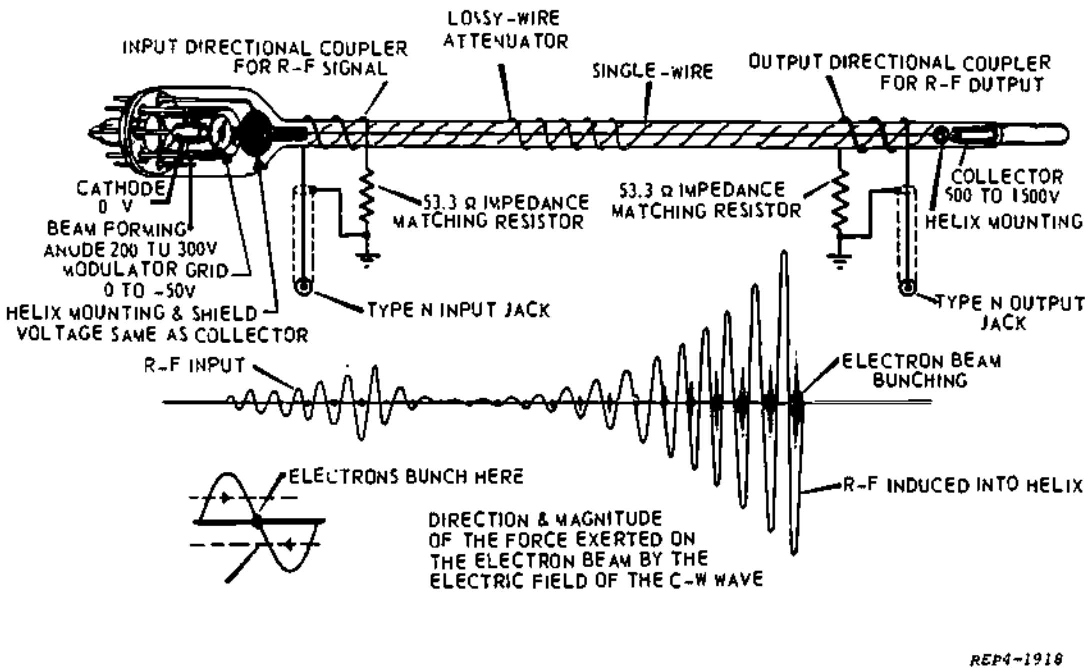

Figure 3-21. Velocity Modulation in a Traveling-Wave Tube

Chapter 4

PARAMETRIC AMPLIFIERS AND MAGNETRONS

4-1. Noise is created in any device where heat is generated. The heat is generated whenever current flows through a resistance. The advantage of the parametric amplifier over the conventional vacuum-tube amplifier is the almost complete lack of noise generated in the stage. It is designed with a low-noise amplification factor.

4-2. The name -- "parametric" -- suggests the principle of operation; the time-varying parameter of capacitance. The parametric amplifiers covered here use semiconductor diodes.

4-3. A parametric amplifier differs from the earlier vacuum-tube amplifiers you have studied. The conventional tube amplifier is basically a variable "resistance" that uses a DC energy source to increase AC energy. A parametric amplifier uses a variable "reactance" to supply energy from an AC source to the load. This comparison tells us why parametric amplifiers generate less noise than vacuum-tube amplifiers. Unlike resistance, a reactance will not add thermal noise to a circuit.

4-4. Noise.

4-5. Noise is a main limiting factor in reliable communications. Consider the two factors that determine the minimum reception level of a received signal. They are the propagation medium and the receiving equipment.

4-6. The incoming signal must exceed the noise entering the receiver through the antenna as well as the noise generated inside the receiver itself. The limitation on a signal's amplification then is decided by the amount of incoming and internally generated noise that accompanies the signal through the receiver.

4-7. Sensitive microwave receivers that can detect weak signals are always in demand, but little can be done to eliminate the atmospheric and man-generated noises put into the propagation medium. The improvement in the signal-to-noise ratio (and sensitivity) must come with the use of low-noise receivers.

4-8. The receiver most used in the microwave region is the crystal-mixer IF amplifier combination. The noise generated within this receiver combination is still large when compared to the noise brought in from the antenna. The use of solid-state PN diodes in the parametric amplifier will result in low-noise amplification. As well as having noise-free characteristics, the parametric amplifier is simpler than the vacuum-tube amplifier. Its cost is also lower.

4-9. Operation.

4-10. An example of parametric amplification is a child on a swing. The child learns to maintain the oscillations by "pumping." He lowers his center of gravity on the downswing and raises it on the upswing. Pumping occurs at twice the frequency of each swing. The "pumping action" can occur in parametric amplifiers because of the variable-capacitance (vari-cap) diode. The theory of parametric amplification centers around a time-varying capacitance.

4-11. Consider the simple series circuit shown in figure 4-1. When the switch is closed, the capacitor will charge to a value of Q coulombs. If the switch is opened, the

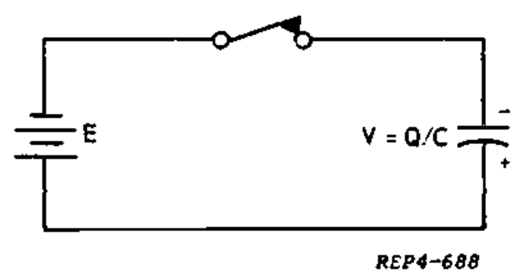

Figure 4-1. Capacitor Charge in a Simple-Series Circuit

61

isolated capacitor with cahrge Q has a voltage V, determined from the equation $V = Q/C$. From this relationship you can see that if we either increase the charge Q or decrease the capacitance C, we will increase the voltage across the capacitor. The capacitance can be easily decreased by increasing the separation between the plates. (This method of varying capacitance is commonly employed in mica trimmer capacitors.)

4-12. Thus, a voltage increase, or amplification, results from mechanically varying the distance between the capacitor's plates. The plates cannot be mechanically varied fast enough for operation, however. In practice, an electronic method of varying the capacitance is used; a voltage-variable capacitor. The energy needed to vary the capacitance comes from an electrical source called a "pump."

4-13. Figure 4-2 shows the time-varying capacitance principle applied to a circuit.

4-14. The variable capacitor receives input signal (A). If the pump acts to decrease the capacitance each time the signal across it reaches a maximum (frequency of the pump equals twice the frequency of the signal), a voltage buildup occurs. This is shown by the dashed line in figure 4-2B. Figure 4-2C shows that each time the capacitance is decreased by the pump, energy will be transferred from the pump and added to the incoming signal in figure 4-2D.

4-15. Figure 4-2D suggests the energy transfers will increase indefinitely, when in actual practice it cannot. It will eventually reach a limit due to energy dissipation in the circuit and in its load. Proper phasing between the input signal and the pump must be maintained; the capacitance must be decreased when the voltage is maximum and increased when the voltage passes through zero. This demands a pump frequency that is exactly twice that of the input signal (Pump FP = 2FS).

4-16. The varactor diode is biased so that it never conducts; therefore, its only effect on the circuit is that of variable reactance.

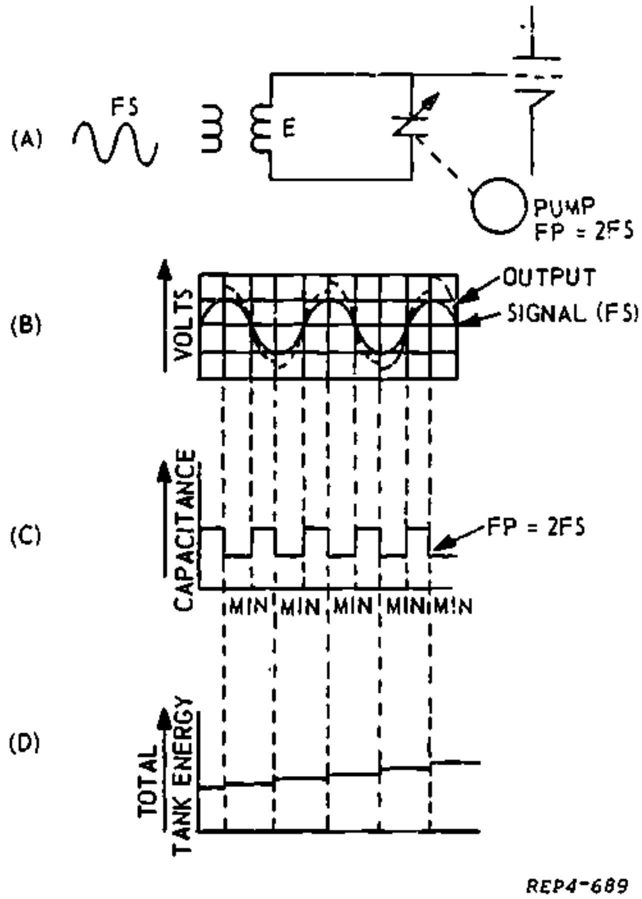

Figure 4-2. Pump Energy Transfer

The resulting noise figure is extremely low. It is far superior to any electron-tube circuit that has an equivalent gain in the microwave frequencies.

4-17. Use of a Junction Diode.

4-18. The capacitance of an ordinary junction diode can be varied electronically. When this is done, it will act as a capacitor.

4-19. When two types of material are brought together to form a PN junction diode (figure 4-3A), the diffusion of the electrons from the N-material fills the holes in the P-material, while the holes diffuse into the N-material. When diffusion stops, the diode is left with a small area on either side of the junction (called the depletion area) which contains no mobile electrons or holes. The PN diode now has the electrical characteristics of a capacitor.

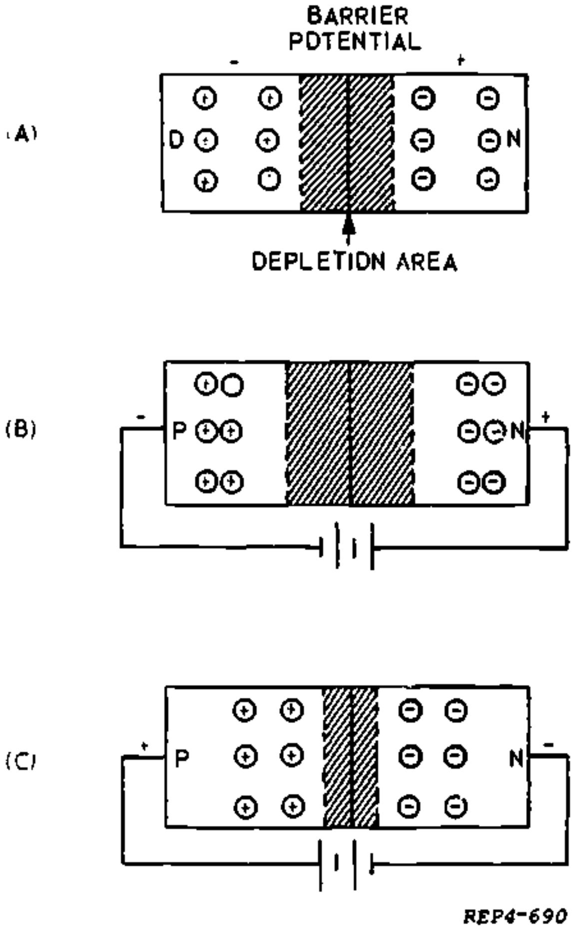

Figure 4-3. A Junction Diode as a Variable Capacitor

4-20. With reverse bias applied to the diode by connecting a low-voltage battery as shown in figure 4-3B, the holes in the P-material are attracted to the negative terminal. The electrons in the N-material are attracted to the positive terminal. The depletion region widens. Conversely, with forward bias applied to the diode, as in figure 4-3C, the depletion region gets narrower as the electrons and holes move away from the negative and positive terminals of the battery. By keeping the bias voltage within limits, so that no forward or reverse current flows, the width of the depletion region can be easily controlled to change the capacitance of the diode.

4-21. Physical Characteristics.

62

4-22. Because parametric amplifiers are mostly used in the microwave region, resonant cavities replace inductors and capacitors, and waveguides replace conventional transmission lines.

4-23. Compared to conventional amplifier circuitry, parametric amplifiers are simple in concstruction. The only component is a PN diode, placed in an arrangement of cavities and waveguide sections. The most elaborate feature of the device is the tuning mechanism. Figure 4-4 shows an actual parametric amplifier.

4-24. There are two basic designs of parametric amplifiers--the nondegenerative and the up-converter types.

4-25. The Nondegenerative Parametric Amplifier.

4-26. In the nondegenerative type, the output frequency equals the input frequency. You recall that we increased the capacitor voltage by pulling the plates apart electrically (pumping) twice each cycle when the signal voltage approaced maximum. Electrical pump action occurs by applying a sinusoidal voltage to a PN diode located within a tank circuit. This system is phase sensitive, however, and slippage will cause the applied sine wave and the capacitor variation to be out of phase for short periods.

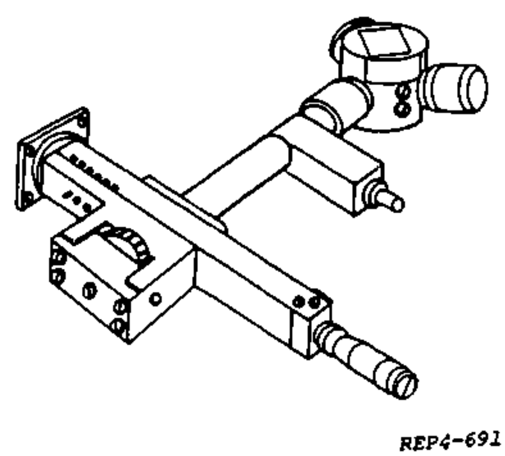

Figure 4-4. A Parametric Amplifier

4-27. An operational method (not phase sensitive) pumps more often than twice each cycle of the input. In this case, the pump energy would be transferred to the additional frequencies that would be produced (the sum and the difference of the signal and pump frequencies).

4-28. Figure 4-5A is a typical nondegenerative parametric amplifier diagram with its equivalent circuit (figure 4-5B). The pump signal input (FP is applied to the varactor diode. The cavity on the left is resonant to the antenna input frequency (FS), and the cavity on the right is resonant to the difference frequency (FP-FS). The difference frequency is called the "idler" or lower sideband. The diode, or voltage-controlled capacitor, is located at the high voltage points of the two cavities and is reverse biased by a small battery. The signal from the pump oscillator varies the bias above and below the fixed bias.

4-29. Assume the pump energy causes the capacitance to vary the frequency about 12 GHz (figure 4-5A). The 3-GHz input signal from the antenna enters the amplifier through a four-port ferrite circulator. The input signal is developed in the signal cavity, which is tuned to the input frequency, and applied across the diode. With two frequencies applied, nonlinear action of the diode results in the production of a difference frequency signal (the sum is not used in this case) whose energy content is greater than that of the original input signal of 3 GHz.

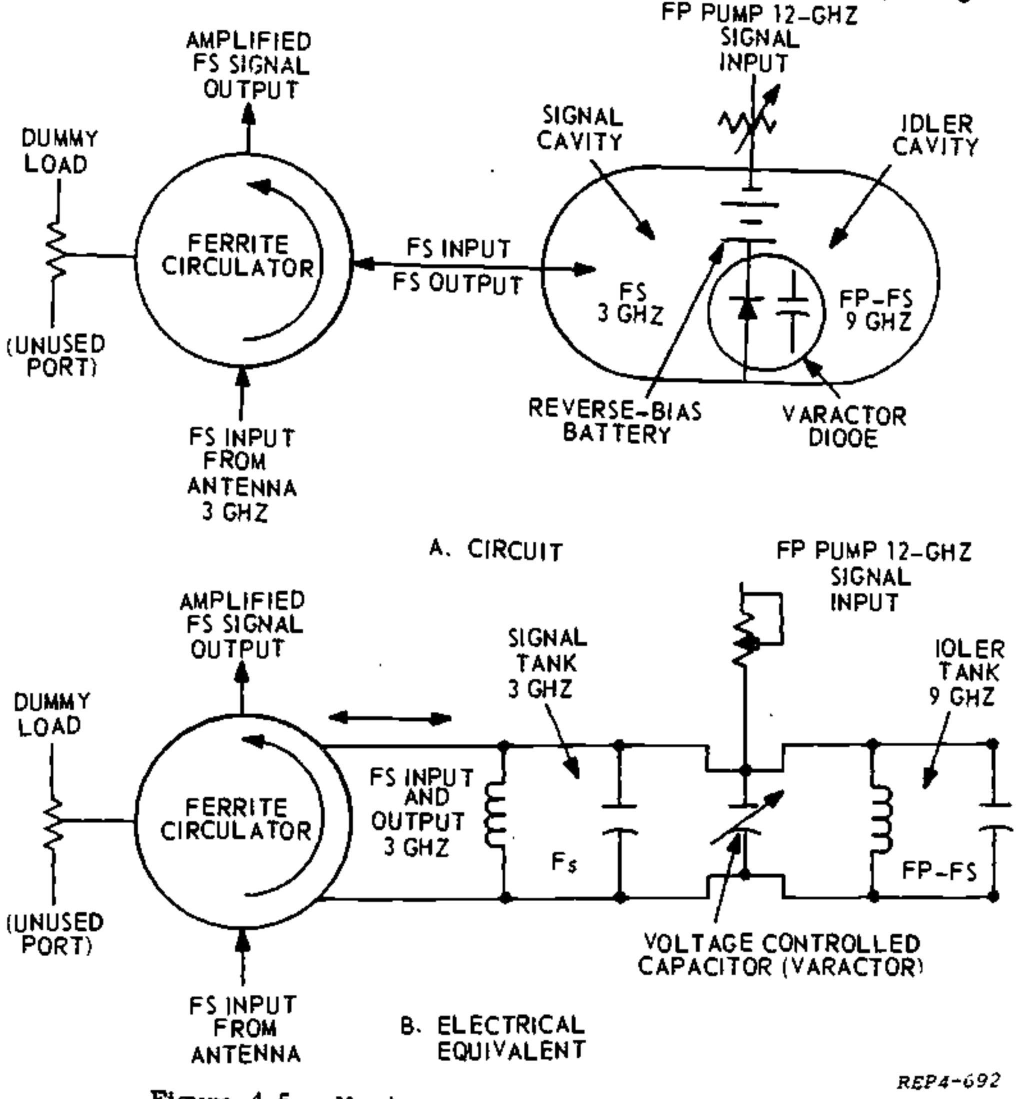

Figure 4-5. Nondegenerative Parametric Amplifier

4-30. The difference (idler) frequency (9 GHz) could be used directly, but we can get more gain by reapplying it to the varactor. The 9 GHz recombines with the pump voltage (12 GHz) to produce a 3-GHz difference signal of a much greater amplitude than the original input signal. The amplifier signal is now sent through the FS OUTPUT and the ferrite circulator to the next stage.

4-31. A ferrite circulator is unidirectional: energy travels through it in only one direction. It has three or more parts: INPUT, OUTPUT, and the part that couples the signal to and from the parametric amplifier. The energy direction is indicated by the arrow within the circular diagram (figure 4-5A). The unidirectional circulator greatly improves the stability by preventing reflection of the amplifier signal back into the parametric amplifier. Any reflection would be reamplified, causing uncontrolled oscillations. The ferrite circulator also prevents source and load impedance changes from affecting the gain, and it prevents noise generated in the output stages from being amplified in the parametric amplifier. Thus, the circulator provides isolation.

4-32. The typical gain of a parametric amplifier is about 20 dB. The gain is controlled with the variable attenuator between the pump and the diode, which varies the amount of pump power fed to the varactor.

4-33. The Up-Converter Parametric Amplifier.

4-34. In this design, the output frequency is higher than the input frequency. Figure 4-6 shows the schematic of an up-converter parametric amplifier. When the pump signal and the incoming signal are simultaneously impressed across the nonlinear capacitance of the parametric amplifier diode, the two signals mix to produce the sum and difference frequencies. The "up-converter" parametric amplifier uses the sum and the difference frequency (FP plus FS or FP minus FS) as its output. The up-converter is really a mixer with gain but, unlike the usual mixer (as in a super-heterodyne receiver), the idler output frequency is higher than the input frequency (FS). A circuit of this type is shown in figure 4-6 followed by a conventional crystal mixer stage. The pump frequency is made as high as practical, because the gain of the device is proportional to the ratio:

$$\frac{FP + FS}{FS} \quad \text{or} \quad \frac{FP - FS}{FS}$$

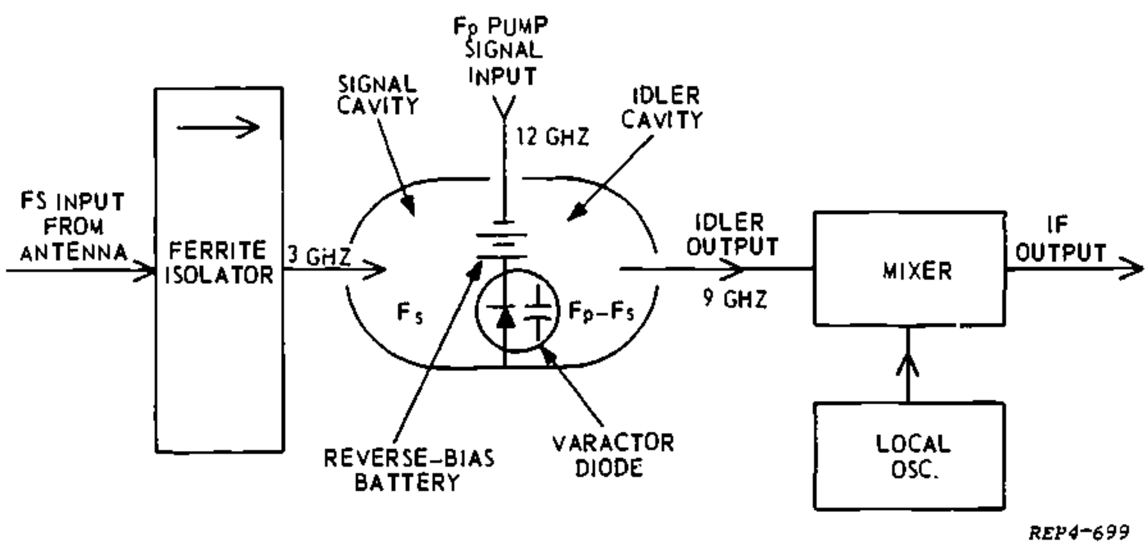

Figure 4-6. The Up-Converter Parametric Amplifier

4-35. The Magnetron.

4-36. The magnetron produces high-power, high-frequency electromagnetic energy. High-power pulses enable long-range detection (radar) equipment to identify and resolve the target. Target resolution is the ability to distinguish between two or more targets.

4-37. Like the klystron, the magnetron (a microwave oscillator) is velocity modulated. The magnetron can be pulse modulated or operated as a continuous wave (CW) oscillator. They can operate up to 30,000 megahertz and produce power levels up to 6 megawatts.

4-38. Construction.

4-39. The anode is a solid block of copper (figure 4-7). It is cylindrical and its external surface is connected to cooling fins. Air, forced between the fins, carries heat away to prevent the anode from overheating. The center of the anode is drilled to make an interaction space and to provide space for mounting the cathode. Other cavities are drilled in the anode block. They are resonant circuits that have openings into the center interaction space. The size of each resonant cavity primarily determines the operating frequency.

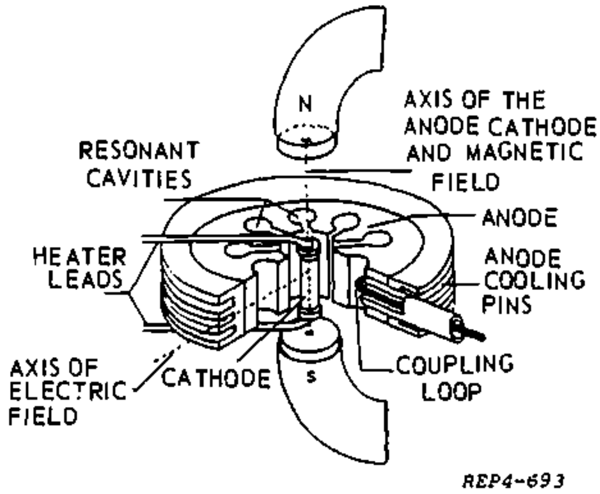

Figure 4-7. Magnetron Cutaway

4-40. The number of cavities is determined by the diameter of the anode. Large diameter anodes produce more power and have a greater number of cavities.

4-41. The most common anode design is the cylindrical hole and slot type shown in the preceding figure. Other anode designs are shown in figure 4-8.

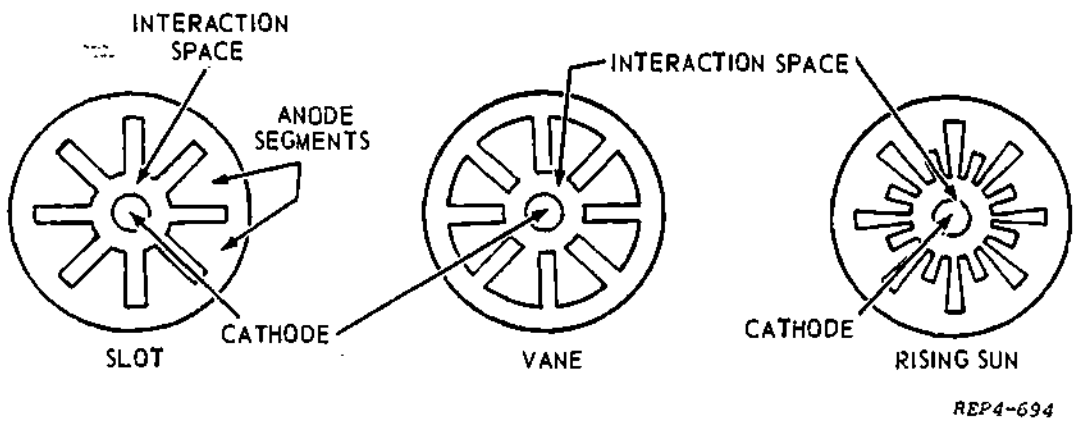

Figure 4-8. Anode Designs

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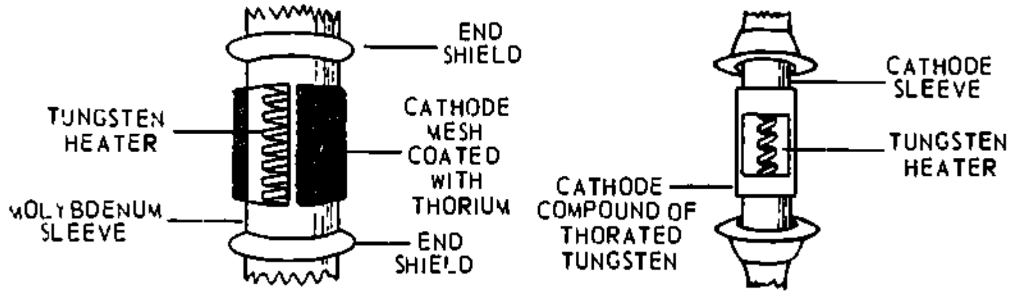

Figure 4-9. Typical Magnetron Cathodes

4-42. Magnetron cathodes are either directly or indirectly heated but most of them are indirectly heated. They vary in detail, but basically they are a metal sleeve coated with the emitting substance. Inside the sleeve is a heating element--normally a coil of tungsten wire. Figure 4-9 shows two typical magnetron cathodes.

4-43. The peak emission from the cathode could be as great as 100 amperes. Although the cathodes in figure 4-9 are indirectly heated, they are electrically connected to the filament. This prevents arcing between the filament and the cathode. The cathode is mounted in the central space of the anode and on the same axis. It is held in position by the heavy heater leads.

4-44. The magnet, used to produce the constant magnetic field, completes the magnetron construction. It is usually separate from the anode cathode structure, but is part of the whole magnetron.

4-45. The magnet is a permanent alloy type, the elements of the alloy are aluminum, nickel, and cobalt. The magnetic field of the magnet, which is several thousand gauss, is parallel to the cathode axis. The magnet pole pieces are centered on the cathode axis and mounted as close as possible to the ends of the cathode. The flux density of the field across the magnetron must stay constant. Because the anode-cathode structure is of nonmagnetic copper, it has no effect on the flux density. As shown by figure 4-10, the magnet has a horseshoe shape.

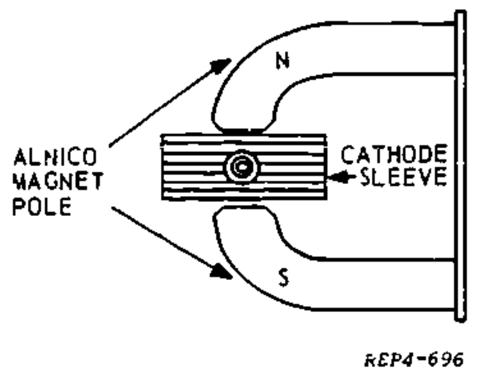

Figure 4-10. Anode-Cathode and Magnet

4-46. Some magnetrons are supplied with the magnet as an integral (built-in) part. They are called PACKAGED magnetrons. When the magnet is not an integral part of the magnetron assembly, they are called UNPACKAGED magnetrons. In figure 4-11, A and B are packaged magnetrons; C and D are unpackaged.

4-47. Magnetrons vary in design. A common type has a coaxial output and a permanent magnet. The electronic symbol for this type is shown in figure 4-12.

4-48. A magnetron uses the effects of an electric field and a magnetic field on a moving electron. This principle was introduced in velocity modulation. Any moving electron will generate its own magnetic field. The direction of the field is found by using the left-hand rule, in the same manner as

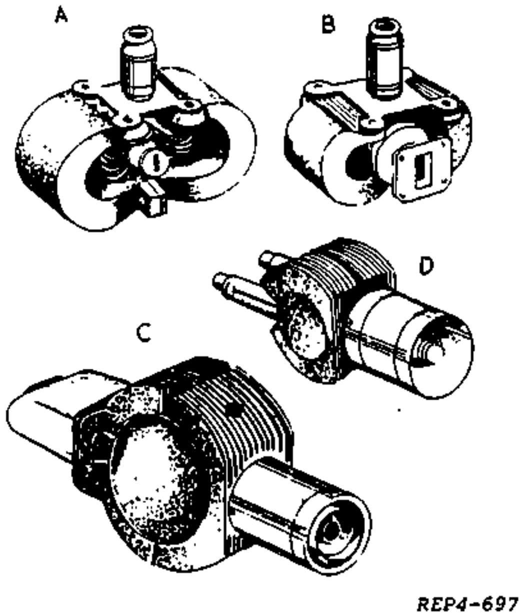

Figure 4-11. Typical Packaged and Unpackaged Magnetrons

the field around a conductor is determined. The STRENGTH of the magnetic field is directly proportional to the electron VELOCITY.

4-49. Figure 4-13 shows the action of low- and high-velocity electrons as they pass through a stationary field. The direction of the magnetic field is into the page, as shown by the X's. In each drawing, the electron moves from the bottom of the page toward the top. Notice that the magnetic field around the moving electron itself will interact with the stationary magnetic field. This interaction of the two fields causes a stronger field on the left of the accelerating electron and a weaker field on the right. As a result, the stronger field moves the electron to the right as shown in figure 4-13.

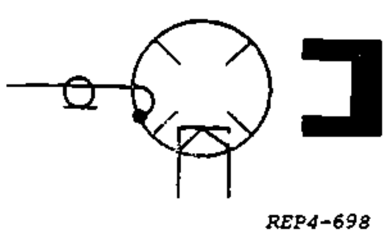

Figure 4-12. Electronic Symbol for a Magnetron Equipped with a Permanent Magnet

4-50. The amount of electron deflection depends on: (1) the strength of the stationary magnetic field and (2) the strength of the field around the electron (which depends on electron velocity). As an electron increases its velocity, a stronger field is generated on the left of the electron and its deflection is greater.

4-51. This is shown by figure 4-13B, which represents an electron with a higher velocity than the one in figure 4-13A. (In each drawing, the strength of the magnetic field is the same.) The higher deflection of the electron in figure 4-13B is caused by the greater interaction between the stationary magnetic field and the stronger magnetic field of the faster-moving electron. The opposite condition could also exist; reducing the electron's speed would decrease the amount of curvature.

4-52. The electron path may curve for another reason. If the electron velocity is constant but the stationary magnetic field strength is varied, the amount of electron curvature also varies.

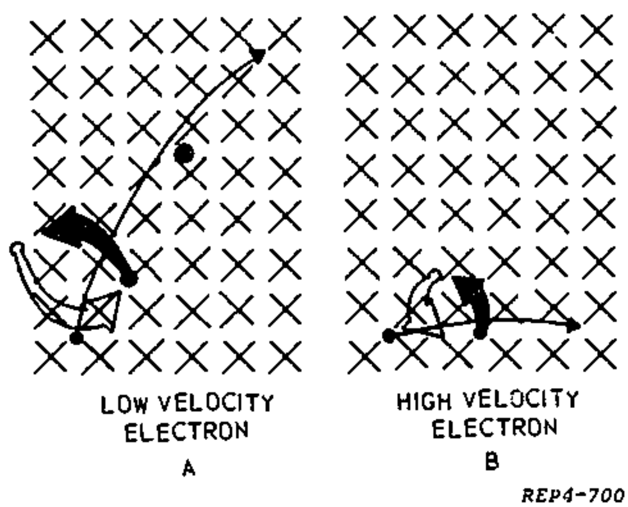

Figure 4-13. Electron Velocity Versus Electron Path Curvature

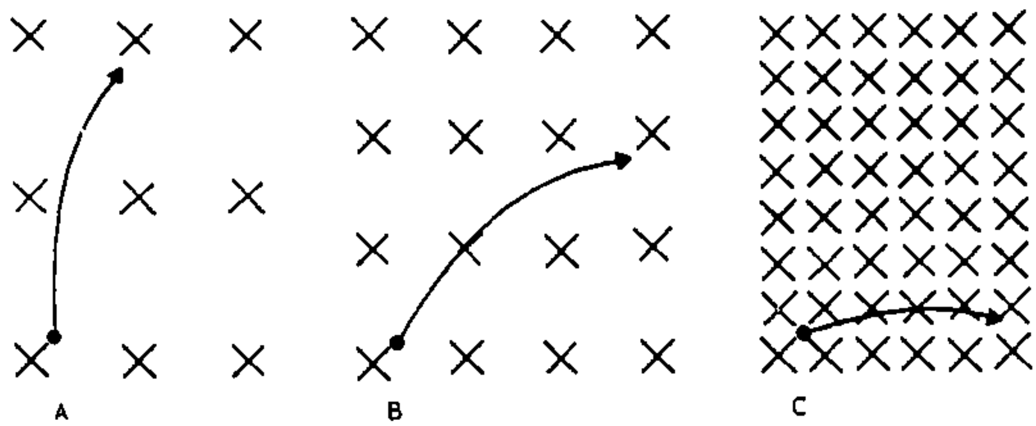

Figure 4-14. Magnetic Field Strength Versus Electron Path Curvature

4-53. Figure 4-14 shows three electrons at the same velocity. Each, however, is influenced by the different strengths of the stationary magnetic fields. Clearly, electron C has greater path curvature because of the stronger field. The stronger the field; the greater the curvature.

4-54. In a magnetron, the permanent magnetic field produced by the magnet is perpendicular to an electric field through which the electrons must move. The electrons will not follow a straight path through the field; they move in a series of loops and arcs. This is called a CYCLOIDAL path. The number of cycloids is determined by the strength of the permanent magnetic field and the strength of the electric field. The stronger either or both fields, the greater the number of cycloids. This is shown in figure 4-15, where the permanent magnetic field is directed into the paper (indicated by the X), and the electric field extends from the positive anode to the negative cathode (indicated by the dashed lines). The electron, without the influence of the permanent magnetic field, will move (in a straight path) from negative to positive. The direction of the magnetic field around the moving electron is shown by the small curved black and white arrows around the solid line. The field enters the paper at a small X. The dot (·) shows where it leaves the paper. Notice that on the left side of the electron's cycloidal path, the permanent magnetic field, and the electron's magnetic field are in the same direction. The electron's path then, will curve to the right.

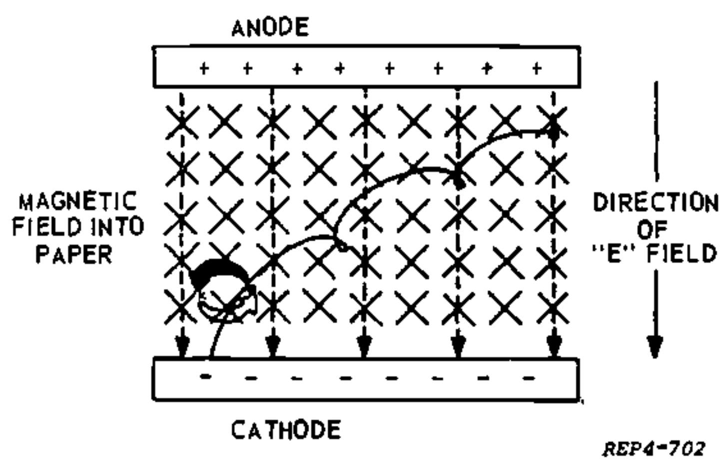

Figure 4-15. Electron Movement in a Crossed Electric and Magnetic Field

4-55. As the electron is accelerated by the electric field, the magnetic field around it increases. This causes the electron path to curve more to the right. When the force on the electron, due to its magnetic field and the permanent magnetic field, becomes greater than the force exerted by the steady electric field, the electron curves back toward the negatively charged cathode. In following this path, the electron will move with the electric field and slow down. As the electron slows, its magnetic field decreases and the force around it becomes less than that exerted by the electric field. The electron's path is reversed, and it starts to accelerate back toward the positively charged anode. As mentioned previously, the number of cycloids is determined by the strength of the permanent magnetic field and the electric field. This controls the time it takes for an electron to move from cathode to anode. This time is called *transit* time.

4-56. In the magnetron, figure 4-16, the electric field (DC) is between the anode and cathode. A high-negative potential applied to the cathode makes the anode positive with respect to the cathode, and the direction of the electric field (DC) is from the anode to the cathode.

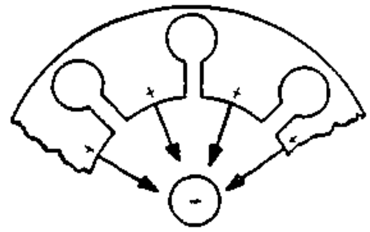

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Figure 4-16. The DC (Electric) Field in the Magnetron

4-57. The magnetic field from the permanent magnet passes perpendicularly through the electric field (DC) in the space between the cathode and anode. This is called the INTERACTION SPACE, because it is in this space that the magnetic field and the electric field interact with, and affect the movement of, the electron. Under certain conditions, a single electron will take a cycloidal path from the cathode to an anode segment as in figure 4-17.

4-58. Remember the resonant circuit is part of the anode. The cavities in the anode act as an LC tank circuit. The equivalent circuit of the magnetron anode is illustrated in figure 4-18.

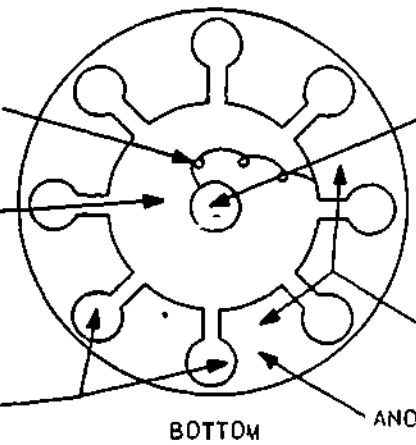

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Figure 4-17. Electron Movement in the Interaction Space of a Magnetron (Looking down into Magnetron with Permanent Magnetic Field)

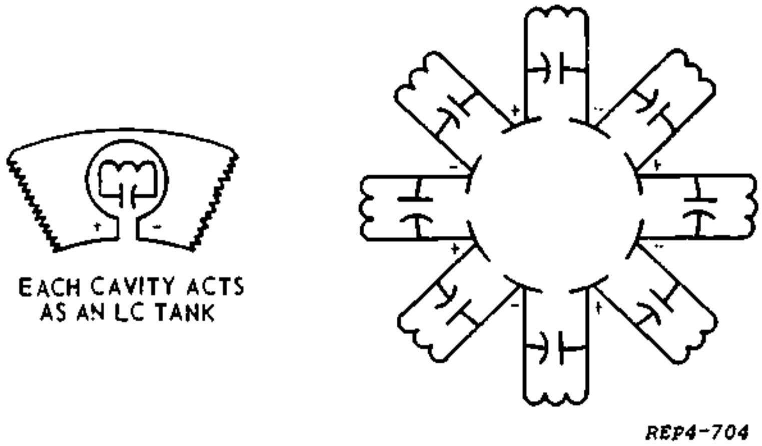

Figure 4-18. Equivalent Circuit of an Eight-Cavity Magnetron

4-59. Similar to common vacuum-tube oscillator circuits, the magnetron cavities are shocked into oscillation when the required difference of potential is applied across the tank circuit. Notice in figure 4-18 that the alternate anode segments are of opposite polarity. This is because each of the oscillating cavities produces an RF voltage. The RF voltage establishes an electric field (AC) which extends into the cavity and into the interaction space. That portion which extends into the interaction space is important and is shown in figure 4-19.

4-60. The direction of the AC field is shown by arrows. The fields will reverse direction every half-cycle. Each cavity oscillates at the same frequency, but is 180 degrees out of phase with the adjacent cavity because each has a common side. That is, on the alternation, when one cavity has an electric field in one direction, the electric field of the two adjacent cavities will be in the opposite direction. This particular mode of operation is called the "Pi" mode.

4-61. When an electron emitted from the cathode enters the interaction space, it will not only be acted upon by both the magnetic field and the DC field but also by the AC field. If the AC field is in the direction of the electron path, the velocity of the electron is reduced and the electron gives energy to the AC field. An electron that adds energy

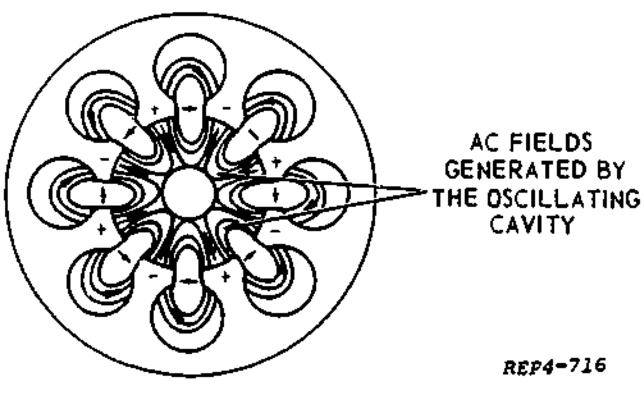

Figure 4-19. AC Field Pattern in an Eight-Cavity Magnetron

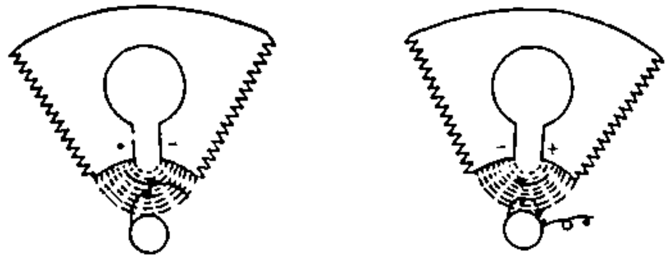

Figure 4-20. AC Field Effect on an Electron Emitted from the Cathode

to the AC field and to the cavity is called a "useful" electron. This is shown in figure 4-20A. If an electron enters an AC field that is opposite to the direction of the electron movement, the electron is accelerated. This additional velocity makes the electron return quickly to the cathode. This electron is said to be "nonuseful"; it removes some energy from the AC field. The amount of energy that is removed is negligible compared with the energy delivered by the useful electrons. The action of returning to the cathode, called "back bombardment," causes greater emission of electrons from the cathode. Figure 4-20B shows the path of a nonuseful electron.

4-62. The AC fields change direction at twice the frequency of the cavity oscillations. This rate is such that an electron will encounter successive opposing fields during its cycloidal path and deliver energy to each field. WITH THE PROPER VALUES OF FLUX DENSITY FROM THE PERMANENT MAGNET AND DC FIELD STRENGTH, THE CYCLOIDAL PATH OF THE USEFUL ELECTRON WILL BE IN PHASE WITH THE CAVITY OSCILLATIONS. During the movement of the electron around the cathode, it continues to give up energy until the DC field strength has a greater effect on it than does the magnetic flux density. The electron finally strikes the anode. The action of the electron, in releasing energy to the RF fields, sustains the oscillations in the cavities. This is shown in figure 4-21. Note that there are three polarities on each anode segment, labeled top to bottom A, B, C. In conditions A and C, the AC fields are indicated by the dashed line. An electron leaving the cathode goes into the field of cavity 1 when it is in condition A, is decelerated, and gives up energy to the field. When this electron enters the field of cavity 2, which has changed in direction to condition B, the velocity of the electron is decelerated again and it delivers energy to the field of cavity 2. Each time the electron's velocity is reduced, it drifts closer to the anode. When the electron reaches the field of cavity 3, which has changed to condition C, the velocity is again reduced, and energy is delivered to this field. By this time, the velocity of the electron is reduced to the point where its own magnetic field and the permanent magnetic field of the magnet are overcome by

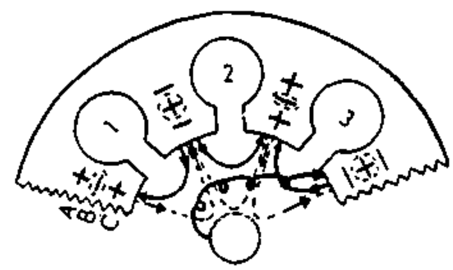

Figure 4-21. The Path of a Single Electron

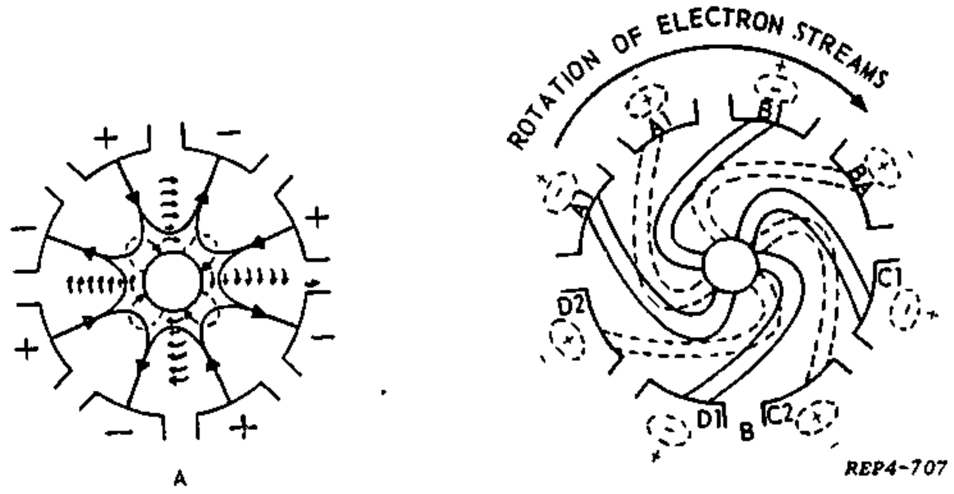

Figure 4-22. Electron Bunching

the DC electric field which forces the electron to the anode. THE CONTROL OF TRANSIT TIME HAS ALLOWED THE ELECTRON TO DELIVER ENERGY TO THREE CAVITIES AND SUSTAIN THE OSCILLATIONS OF EACH.

4-63. So far, we have only been concerned with a single electron. However, the cathode emission in some magnetrons may reach 100 amperes. The electrons emitted from the cylindrical surface of the cathode will group together and continue toward the anode or return to the cathode. The path they take when they are emitted depends upon the AC field's direction when they enter it. The grouping of electrons is called BUNCHING. Electron bunches, due to the changing AC fields, revolve around the cathode in phase with the oscillating frequency. The bunch or stream of electrons appears to travel a fairly straight line to the anode. But remember that all electrons do not leave the cathode at the same time. Their transit time is controlled; there are many electrons in the stream which pass through several AC fields delivering energy to each. Figure 4-22A illustrates this bunching action. In this figure, notice there are eight fields. There are only two possible directions for the fields, so four exist in each direction.

4-64. Four of the AC fields accelerate the nonuseful electrons. This causes them to return to the cathode. The other four AC fields decelerate the useful electrons, allowing them to enter the interaction space and bunch together. An eight-cavity magnetron will have four bunches or streams which appear as spokes of a wheel. This is shown in figure 4-22B. Each electron within the stream or bunch moves in a cycloidal path. Due to the oscillating cavities, the anode segments change polarity and cause the stream of electrons to move in a clockwise direction.

NOTE. By reversing the direction of the permanent magnet field, the direction of rotation of the electron stream is also reversed.

4-65. The overall effect will be a powerful transfer of energy from the electrons to the AC field of each cavity. This is how a microwave oscillator delivers the power required for transmitters. In explaining the operation of the magnetron, we have assumed that the anode segments are 180 degrees out of phase. This has been called the pi mode of operation. In this mode,

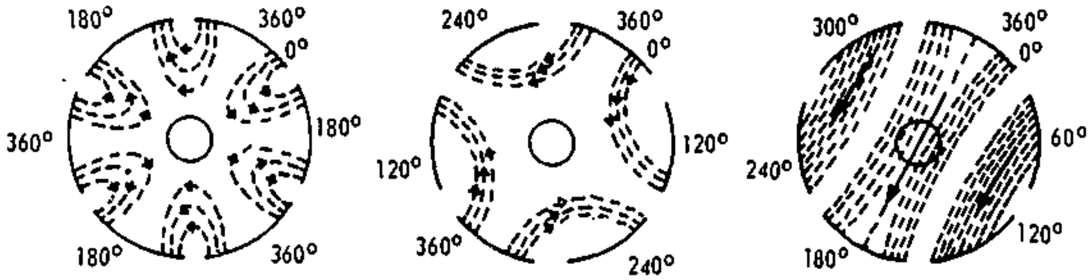

Figure 4-23. AC Field Pattern of a Six-Cavity Magnetron

the cavity fields are shown in figure 4-23. The magnetic fields illustrated in figure 4-24 assume pi-mode operation. In this particular six-cavity magnetron, the electron makes one revolution around the cathode for every three cavity oscillations. Magnetrons can oscillate in a number of different modes, with the number determined by the number of anode cavities. If the anode has six cavities, there are three possible modes of operation. The AC-field patterns for the three modes are illustrated in figure 4-23. The desired mode of operation is mode 3 in which there is a 180-degree phase difference between anode segments (the pi mode). This is the desired mode because it allows the greatest magnetron efficiency. The presence of more cavities results in N/2 possible modes of operation where N is the number of cavities. A different mode means a different frequency. Under some operating conditions, a magnetron may shift from one mode of operation to another. This causes frequency instability.

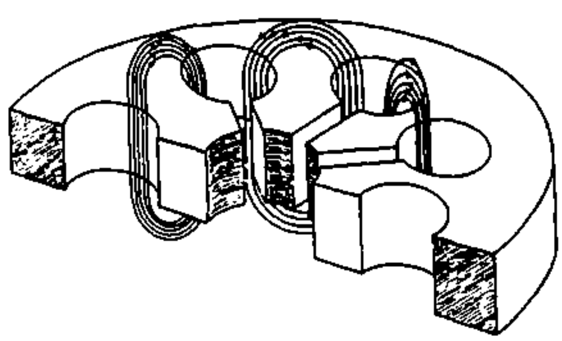

Figure 4-24. Magnetic Field Generated by Oscillating Cavities

4-66. There are two ways to prevent mode shift (change) in a magnetron. One way is to design a magnetron with an anode of the rising sun configuration (see figure 4-8). This design is primarily used in magnetrons that operate at wavelengths shorter than 10 centimeters. The other way to prevent mode changes (and the most common) is by strapping. Strapping connects alternate anode segments with straps of equal size. Two methods of strapping are Ring Strapping (figure 4-25) and Echelon Strapping (figure 4-26). Strapping improves the stability of operation because it separates the desired frequency from the undesired frequencies. This results in increased efficiency, because higher power can be obtained without the possibility of mode changes.

4-67. The RF output from a magnetron can be taken from any cavity because the power available from each of the cavities is the same. Therefore, the only consideration that determines the cavity from which the output

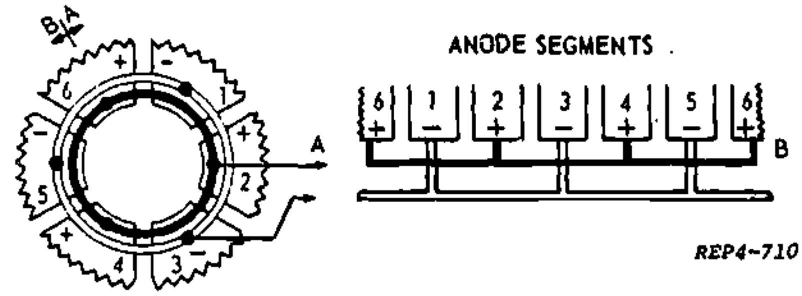

Figure 4-25. Ring Strapping

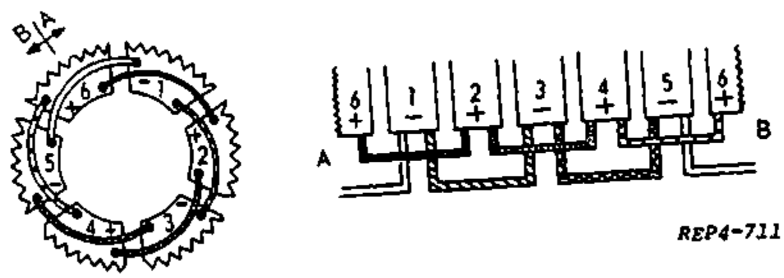

Figure 4-26. Echelon Strapping

will be taken is the physical construction of a specific magnetron. One method of taking an output from a magnetron is by inserting a coupling loop into a cavity. This arrangement is known as the concentric line output (figure 4-27). The concentric line or coax can be connected directly to an antenna or a waveguide through another coupling loop in the waveguide. The center conductor of the concentric line is attached to the loop. The center conductor and loop are insulated from the anode block where they enter the magnetron. This insulating material also seals the vacuum in the magnetron.

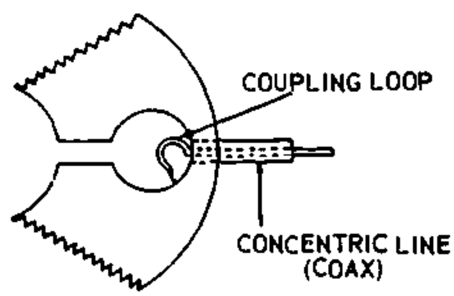

Figure 4-27. Output Coupling Loop

4-68. The other method is to connect a waveguide transformer section directly to the anode. The cavity RF energy is connected to the waveguide through a slot or window. The window is sealed or covered with glass (which is bonded to the anode) to prevent loss of the vacuum. This method of obtaining an output is shown in figure 4-28.

4-69. In each coupling method, the anode block is directly connected to the outer conductor of the concentric line or waveguide. Therefore, for safety of maintenance personnel, the anode and waveguide are kept at ground potential. This is why a high-negative potential is applied to the cathode.

4-70. Figure 4-29 is the schematic of a typical pulse-modulated magnetron. Notice from the schematic symbol that the anode is grounded, and the filament and cathode are connected to prevent arcing between them. A high-negative potential, in the form of a negative pulse, is applied to the cathode through the pulse transformer.

4-71. The magnetron will oscillate for the duration of the negative pulse, producing the desired frequency in the UHF or SHF spectrum at power levels that can be in excess of 6 megawatts.

4-72. Operation Summary.

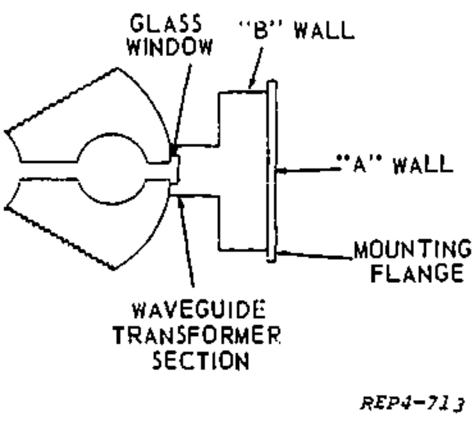

Figure 4-28. Waveguide Output Coupling

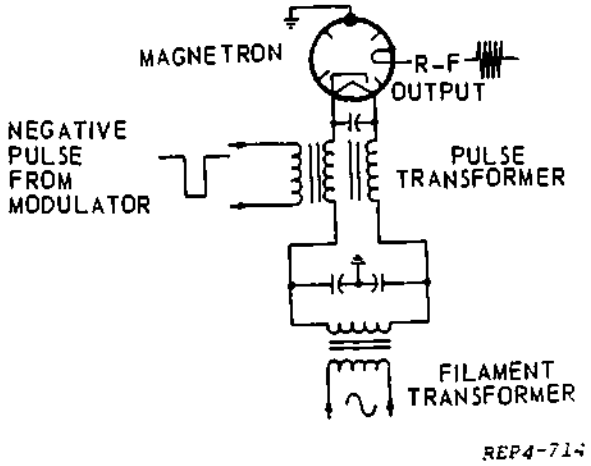

Figure 4-29. Circuit of a Pulse-Modulated Magnetron

4-73. The magnetron is a diode oscillator that delivers high-power RF energy in the UHF and SHF range. Its main features are a tuned circuit integral with an anode and a strong magnetic field perpendicular to the DC field that exists between the anode and the cathode.

4-74. Three fields within the magnetron influence its operation. They are:

a. THE DC ELECTRIC FIELD. This field exists between the anode and cathode. A high-negative potential applied to the cathode establishes the direction of the field to be from the anode to the cathode.

b. The PERMANENT MAGNETIC FIELD. The axis of this field is perpendicular to the DC electric field.

c. THE AC ELECTRIC FIELD. This field is produced by the RF oscillating cavities. It extends from the anode segments of a cavity into the interaction space and exists in the same plane as the DC electric field.

4-75. The electrons emitted from the cathode are acted upon by the permanent magnetic field. This causes the electrons to travel to the anode in a cycloidal path. The time that

76

it takes for the electron to travel to the anode, transit time, is controlled by the proper relationship of the magnetic field and the DC electric field. Proper control of this transit time allows electrons to deliver energy to several cavities, sustaining the oscillations in each.

4-76. Figure 4-30 shows the magnetron's anode and cathode with the three fields that influence its operation.

4-77. The AC fields, which change direction every alternation, cause the electrons to bunch. The bunches revolve around the cathode in phase with oscillating frequency. Electrons which deliver energy to the AC fields are called useful electrons; those which are returned to the cathode are called nonuseful electrons. The physical size of the cavity is the primary frequency determining factor. The larger the cavity, the lower the frequency. The number of cavities in the anode is determined by the physical size of the anode. An anode for a high-power magnetron will be larger than one for low power. It will always be evenly divisible by two. The magnetic field strength is a critical factor in the control of transit time. If the magnetic flux density decreased from normal, the electron transit time also decreases. That is, the electrons will strike the anode earlier without delivering energy to the required number of AC fields. The net effect is a loss in operating efficiency or a decrease in power.

4-78. The permanent magnetic field strength will also affect the phase of the revolving streams of electrons and result in a slight change in frequency. A decrease in the magnetic field strength will cause a slight frequency decrease. For example, in some magnetrons, a drop of 50 percent in magnetic field strength reduces the frequency by 1 percent or less. The magnetron is not

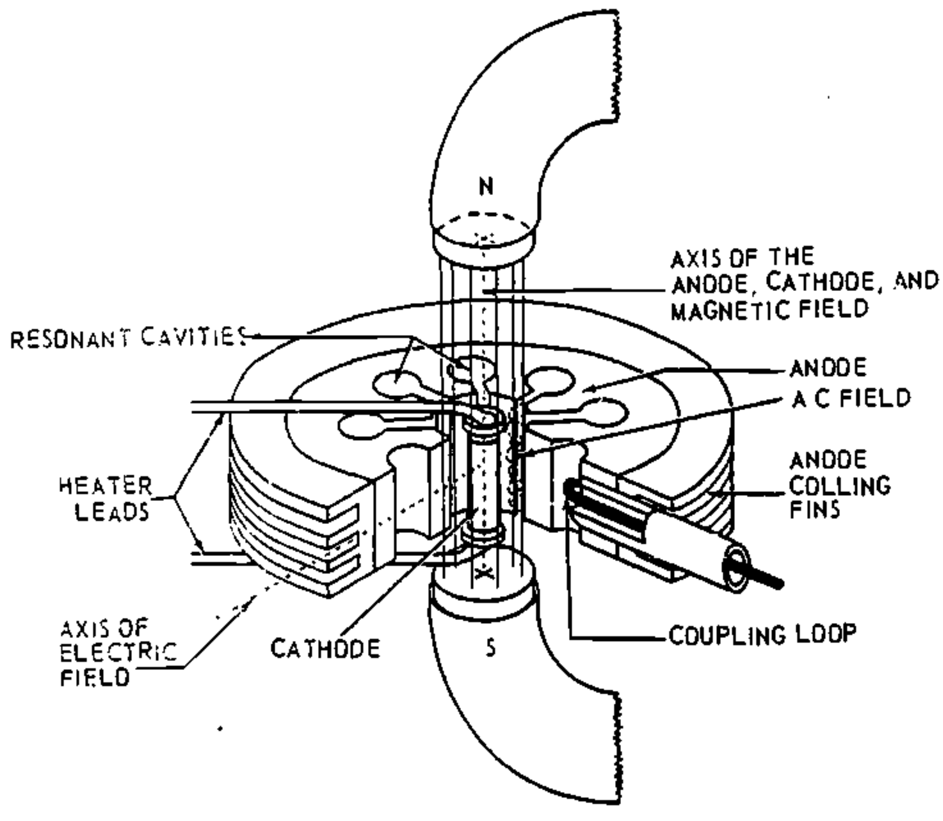

Figure 4-30. The Three Fields in the Magnetron

used as a voltage-tuned oscillator. Magnetron structure and strapping are two methods used to prevent frequency change, thereby increasing stability and efficiency.

4-79. Magnetron power can be taken from any of the cavities. Loop or waveguide transformer section coupling methods take power from the magnetron.

Chapter 5

SOLDERING TOOLS AND MATERIALS

5-1. Soldering.

5-2. In this area of electronic maintenance training, you will learn how to bond together electronic components, such as capacitors, resistors, transistors, wires, and terminals. The connections are made with a fusible metal alloy called solder, which is applied by the use of a heated soldering iron.

5-3. Soldering is not welding. Soldered metals are held together by a liquified metal alloy that hardens as it cools, and the same connection can be separated by desoldering. In welding, no solder is used and the metals themselves are fused together under extremely high temperature to form a permanent bond. Electronic components are rarely welded together.

5-4. Safety.

5-5. Caution in the soldering area will prevent burns, cuts, and electrical shock. Careless work will damage equipment. Follow these safety practices:

1. Keep a neat, clean work area.

2. Place the soldering iron to one side where you will not have to reach over or around it.

3. Disconnect the electrical power from the chassis before working on any circuit.

4. Make certain the soldering iron plug is free of wire strands or metal. Connect the soldering iron to the proper electrical outlet and arrange the cord so it will not interfere with your work.

5. Place the open side of the wire cutters away from you body when you cut wires. Keep all wire scraps together at one side of your work area.

6. When using cleaning solvent, work with a limited amount stored in a small, airtight safety can. Work in a well-ventilated area. Do not spill the solvent, breathe its vapor, or smoke when the can is open nearby.

7. Before desoldering a wire, remove all spring tension from it by clamping the wire during the operation. Otherwise, hot solder may be thrown into the air when the connection separates.

5-6. Solder.

5-7. Solder is a conducting alloy, a mixture of metals such as tin, lead, and silver. The makeup of the solder determines whether it is a "soft" or "hard" type. Soft solders are made of tin and lead in various ratios. A common soft solder is made of 60% tin and 40% lead and melts at 370°F. Hard solder contains silver and is often called "silver solder."

5-8. When solder is used to make a connection, the metal alloy passes through three conditions--liquid, plastic, and solid. Once heated to its liquid state, solder flows easily. In its melted state, solder will chemically dissolve part of the metal surfaces to be joined. As it cools, it passes through a plastic state, and with further cooling, it becomes a solid again.

5-9. The Tin-Lead Ratio chart, figure 5-1 shows how heat affects the different combinations of tin and lead solder as it passes through the three conditions.

5-10. The chart shows that pure tin will change from a solid to a liquid at 450°F while pure lead needs a temperature of 620°F. Between these extremes, several tin-lead alloy ratios are shown, each with corresponding temperature and solder conditions.

5-11. When a ratio of 30% tin and 70% lead (30/70) is used, during the cooling of a soldered joint, this alloy changes from liquid to platic at 500°F and then from the plastic to the solid state condition at 361°F. This alloy ratio allows the solder to remain in a plastic state over a wide temperature range of 139° and is undesirable.

5-12. With solder made of a 60/40 tin-to-lead ratio however, the solder remains in the plastic condition from 370°F to 361°F, which is a comparatively small temperature change. This change from the liquid to the solid state within a narrow temperature range is desirable in solder, because any movement of the metal parts while the cooling solder is a plastic will fracture and weaken the connection. The narrower the temperature range from liquid to solid, the less chance for fracture.

5-13. A good mechanical connection is made before the melted solder is applied to the joint and insures a good electrical connection. Solder will not conduct electrons as well as copper, so the surfaces of every joint must be in direct contact with each other. If solder is allowed to flow between loose conductors and terminals, circuit resistance will increase.

5-14. Bar-type solder is too heavy and awkward for use with small, compact electronic circuits. Electronic repair shops use wire-type solder which is rolled on small spools. It may be bent to any shape and the technician can easily control the amount of solder applied to a connection. Wire solder normally has a core that is filled with flux.

5-15. Flux.

5-16. Flux is a compound used to coat the metal surfaces as they are soldered. As the flux melts, it removes the tarnish or metallic oxide. It also prevents more oxide from forming as the metal is heated to soldering temperature. Without flux, the heated metal would combine with the oxygen in the air to form an oxide film which would prevent the solder from bonding with the metal parts. Flux will not allow the oxide film to form.

5-17. A liquid flux can be used with hollow-wire solder having a flux core. Prevent oxidation by cleaning the metal parts before soldering, then coat them with a thin film of liquid flux. The melted solder will adhere easily to the coated metal surfaces and bond them together.

5-18. There are two classes of soldering flux--corrosive and noncorrosive. Zinc chloride, hydrochloric acid, and sal ammoniac are corrosive types of flux. They should not be used in electronic soldering because any trace of these corrosives on the connection will, in time, eat through it and destroy the circuit. Rosin is a noncorrosive flux, available as a paste, liquid, or powder. Rosin flux is used in the flux-cored wire solder which must be used for all electronic soldering.

5-19. Solvents.

5-20. Liquid cleaning solvents are used in soldering work to dissolve wax, flux, and oil from the soldered connection. They must be noncorrosive and nonconductive; they must not dissolve or damage any parts on which they are used. The following solvents are approved for cleaning soldered connections.

1. Dry cleaning solvent

2. Isopropyl alcohol

3. Aliphatic Naphtha

5-21. Apply the solvent with a swab or brush, allow it to dissolve the residue, then wipe the area clean with absorbent material. Prevent the solvent from carrying dissolved flux onto switch, relay, potentiometer contact surfaces, or connectors. CAUTION! These solvents are poisonous, flammable, and have harmful vapors. Follow these precautions.

1. Keep the container closed and away from heat or flames.

2. Use with adequate ventilation and do not breathe the vapors.

3. Avoid prolonged contact with the skin.

5-22. Tools and Materials.

5-23. The proper use of soldering tools will result in the best work. This section will identify the basic soldering tools and explain their use.

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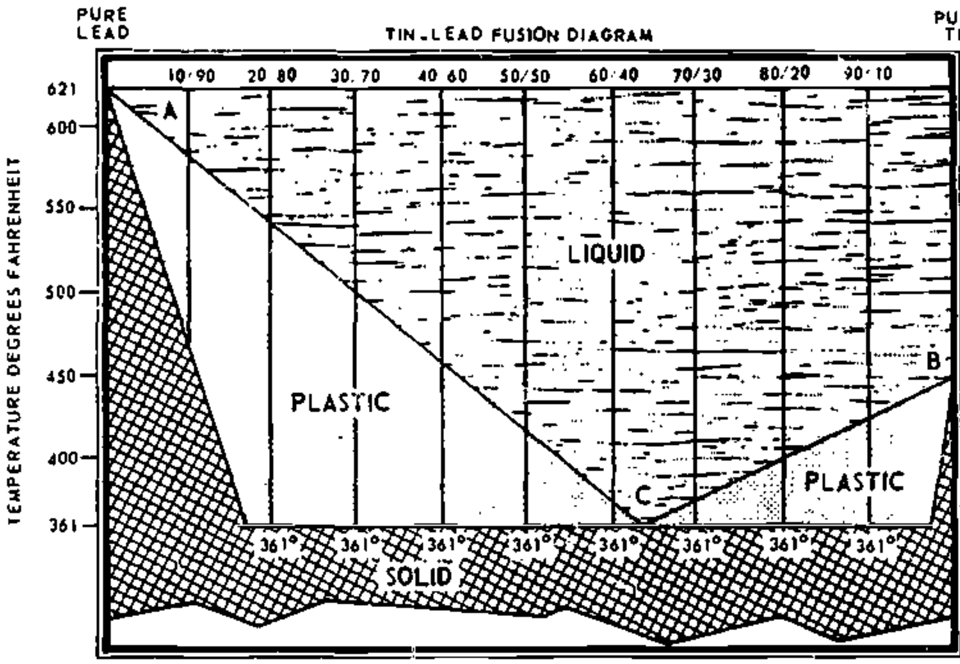

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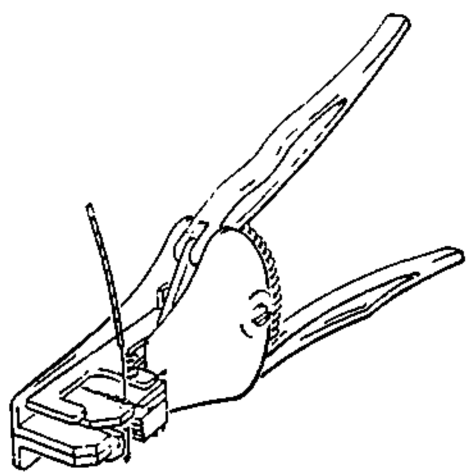
Figure 5-1. Tin-Lead Ratio

5-24. Wire Stripper.

5-25. Figure 5-2 shows a type of wire stripper most commonly used in electronic maintenance. An insulated wire has been inserted in one of the grooves. By closing the handles, the insulation is cut and pushed from the wire. Use only a wire stripper to remove the insulation. A knife or other cutting tool will nick the wire and make a weak point. The nick will also destroy the thin protective coating on the wire and hasten corrosion. All wire sizes are identified with an American Wire Gauge (AWG) number. The grooves in the wire stripper match these numbers. For example, if the wire gauge number is AWG 16, the wire will match a numbered 16 groove in the wire stripper.



NCS13-24

Figure 5-2. Wire Strippers

5-26. To strip its insulation, simply place the wire in the groove marked #16, at the place on the wire where you want the insulation to be stripped, and close the handle. Never strip wire unless the tool has a groove size to match the wire size. If it does not, find another stripper with the proper size.

5-27. Heat Sinks.

5-28. Heat-sensitive transistors and diodes can be damaged by the heat of soldering. To direct excessive heat away from the part, a

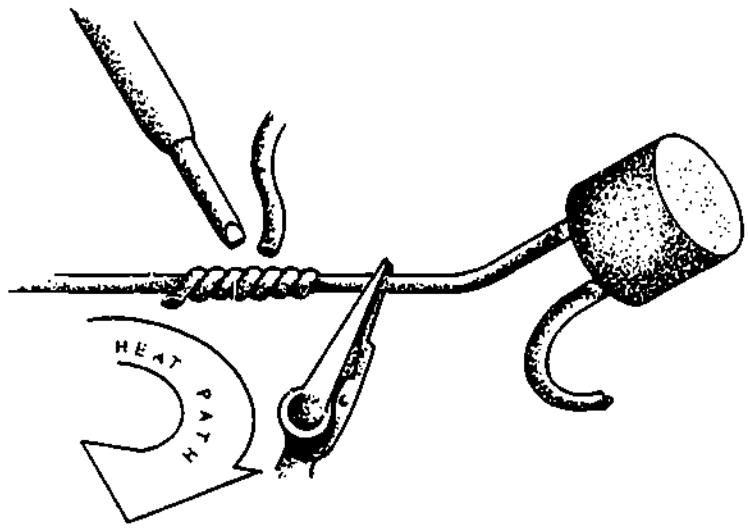


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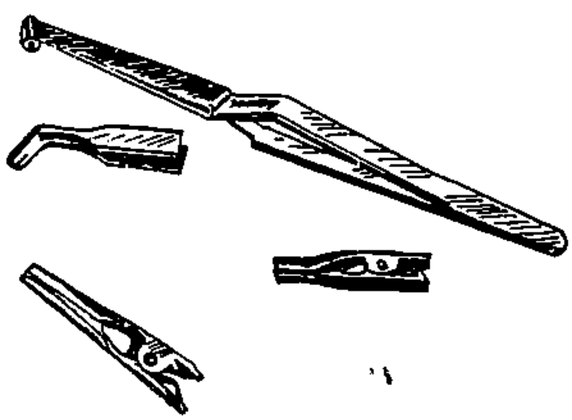
Figure 5-3. Use of a Heat Sink

heat sink, shown by figure 5-3, is used. It is clamped between the components and the joint to which it is soldered. When the solder is applied, the excess heat conducted toward the transistor is absorbed by the heat sink. Figure 5-4 shows some typical heat sinks. Their sizes, shapes, and material allows protection of the parts with minimum interference during soldering. All can be attached and removed quickly.



REP4-19

Figure 5-4. Heat Sinks

5-29. Bending Tools.

5-30. Bending tools shape wires and component leads. They should have smooth bending surfaces that will not nick or flatten the wires. Tools used for bending are shown in figure 5-5 and include long-nose pliers (A), roundnose pliers (B), aluminum (C) and plastic (D) bending devices. Needle-nose pliers may be used if the jaw tips are encased in copper tubing covers.

5-31. Cutting Tools.

5-32. Two cutting tools are generally used in electrical work. They are diagonal-cutting pliers and side-cutting pliers. Both are designed to cut wire, but the side-cutting pliers are used for only cutting heavy wires.

5-33. Diagonal cutters are used to cut light wire up to #16 hard steel or #14 copper. The jaws have two angled cutting edges which can cut a wire closer to its connection than can side-cutting pliers. Diagonal-cutting pliers are often misused by forcing them to cut heavier wire than that for which they are designed. Figure 5-6 shows the different designs of diagonal-cutting (A) and side-cutting (B) pliers.

5-34. File.

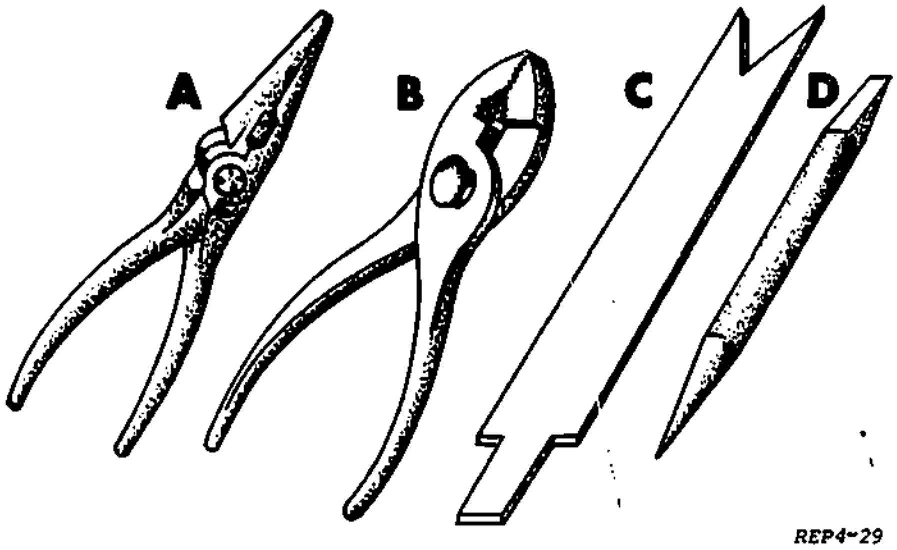


Figure 5-5. Bending Tools

5-35. In soldering work, a smooth, flat file as shown in figure 5-7 is sometimes needed. A file is a metal-shaping tool used to shape soldering iron tips that are made of copper. The file has a smooth single cut and its face is flat. The wooden handle allows a better grip and protects the hand.

5-36. Soldering Irons.

5-37. Soldering unites metals with a fusible alloy by applying heat to the parts being joined. An electric soldering iron supplies the heat. In the field, you may use a soldering iron on maintenance jobs that needs occasional tip shaping with a file. The W-TCP-L iron you will use in training here, however, has an iron-aluminized tip which requires only that it be cleaned but never shaped. This iron has a plated tip and is permanently tinned. Its temperature is automatically regulated. Figure 5-8 shows an iron of this type.

5-38. When a soldering tip has been "tinned," it means that it has been covered with a thin coating of solder. This allows a smoother flow of solder when making a connection.

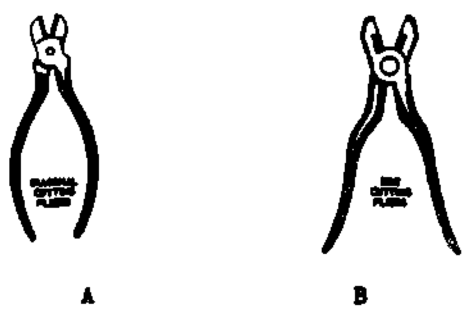


Figure 5-6. Wire-Cutting Pliers

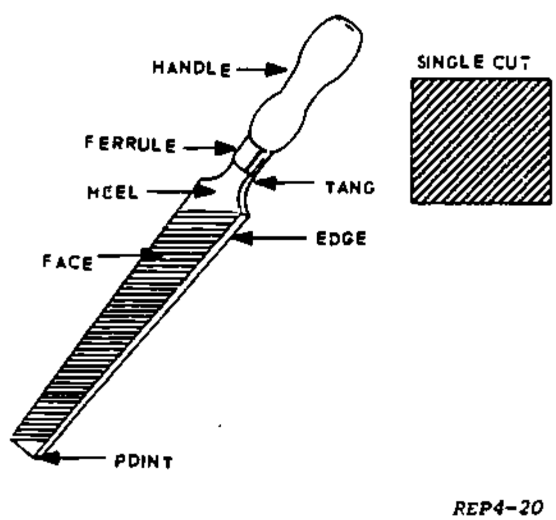


Figure 5-7. A Single-Cut Flat File

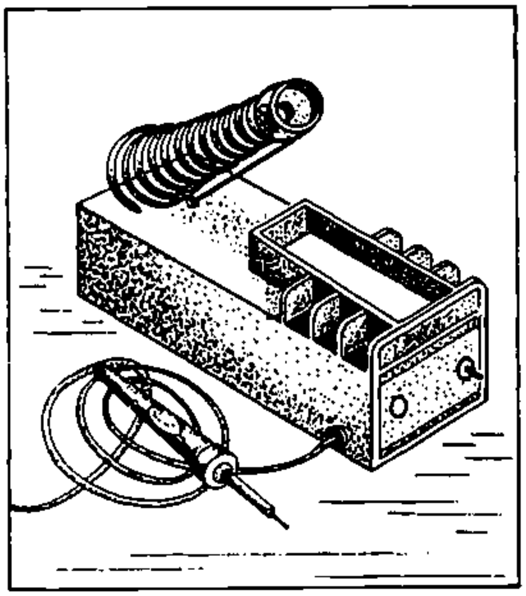


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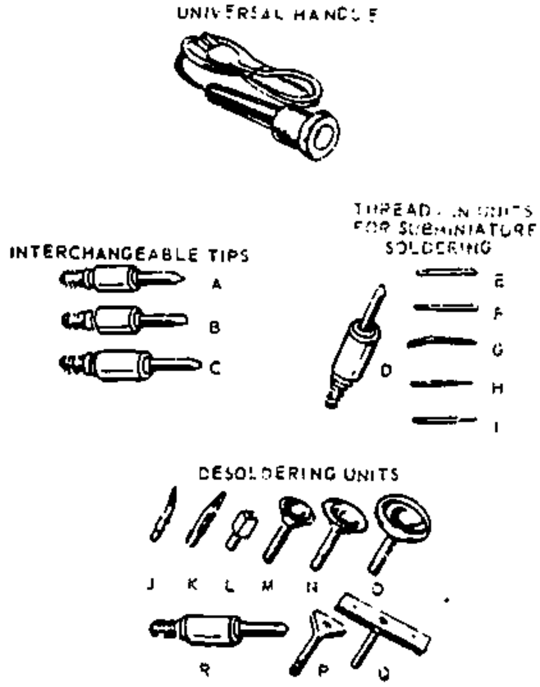
Figure 5-8. Soldering Iron

5-39. Soldering irons used for electrical circuit repair have interchangeable tips and thread-in units for subminiature soldering and desoldering. This is shown by figure 5-9 which also lists the specialized attachments needed for certain types of soldering activities.

5-40. All irons are delicately constructed and may be damaged by rough handling. Carelessness can cause painful burns and, if they are left unattended, they may start a fire. A hot iron is needed to make a good solder connection, but solder will not stay on the tip of an overheated iron. The high temperature can also damage the heating element.

5-41. During lengthy soldering operations, you should occasionally wipe the excess solder from the tip of the iron with a damp cloth or sponge. Do not swing or jerk the iron to remove the solder; the hot metal may strike nearby workers. Do not strike the iron against the bench or any other solid object; this can crack the heating element or damage the insulation. Do not file or reshape any iron with a plated tip. Always clean the iron before you put it away.



THREAD-IN UNITS
FOR SUBMINIATURE SOLDERING
A. PYRAMID TIP, 5/16" DIA
B. CHISEL TIP, 3/8" DIA
C. CHISEL TIP, 1/4" DIA
D. ELEMENT FOR THREAD-IN TIPS
THREAD-IN TIPS
E. STRAIGHT CONE, 3/8" DIA
F. STRAIGHT CHISEL, 3/8" DIA
G. BENT CONE, 3/8" DIA
H. STRAIGHT NEEDLE, 3/8" DIA
I. MICRO TIP
DESOLDERING TIPLETS FOR
SUBMINIATURE REPAIR
J. OFFSET SLOTTED
K. STRAIGHT SLOTTED
L. HOLLOW CUBE
M. 5/8" DIA CUP
N. 3/4" DIA CUP
O. 1" DIA CUP
P. 5/8" DIA TRIANGLE
Q. 1-1/2" X 3/8" BAR
R. ELEMENT FOR DESOLDERING TIPLETS

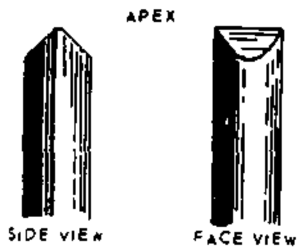
Figure 5-9. Soldering Iron Parts

5-42. Care of Copper-Tipped Irons.

5-43. A copper-tipped iron must be shaped, cleaned, and tinned before use. The iron's tip should be shaped like a chisel tip as shown by figure 5-10.

5-44. Note that the two surfaces make an angle of 90° and that the point is slightly flattened. Each surface must be flat and smooth. If the tip needs shaping, allow the

84



REP4-17

Figure 5-10. Proper Tip Shape

iron to cool, then remove the copper tip to prevent damage to the heating element.

5-45. Put the tip in a vise, then carefully file the surfaces until they are flat and clean. Polish the tip with emery cloth. Do not touch the copper tip with your fingers, as the oils from your skin will prevent the solder from adhering to the surface of the tip. After polishing the tip, replace it in the iron and heat the iron to operating temperature. Apply flux and solder to the tip. Remove excess solder with a damp cloth or sponge.

5-46. Emery Cloth.

5-47. Emery cloth has an abrasive surface of powdered emery. It is used on metals as sandpaper is used on wood and can put a fine polish on a newly filed soldering tip. When the cloth wears out, replace it.

5-48. Erasers, Brushes, and Wiping Materials.

5-49. Dust, lint, protective coatings, and oxides will prevent good soldering bonds between metal parts. Erasers are used to clean the surface to be soldered by loosening unwanted material. Brushes remove the material from the area.

5-50. Damp sponges are useful in removing excess solder quickly from the tip when it is pulled across it. A damp cloth may also be used. Absorbent lint-free wipes are best used with solvents to clean the areas before and after soldering.

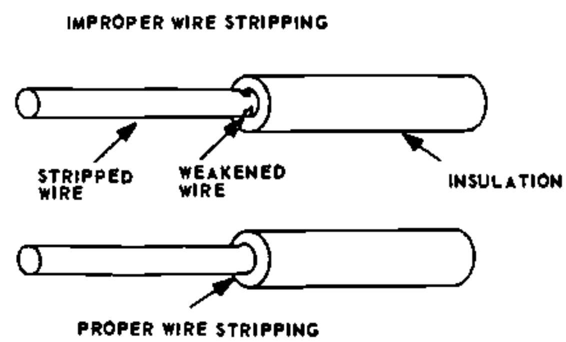
5-51. How to Prepare Conductors and Leads.

5-52. Clean metal is the key to reliable soldering. All dirt, grease, oxides, scale, and laquer must be removed from the surfaces to be soldered. No matter how shiny a lead may appear, it must be cleaned. This is because manufacturing often leaves invisible oxides on component leads.

5-53. Strip the insulation from the wire with a nonadjustable, factory-set wire stripper. Do not use a knife, adjustable wire strippers, or diagonal-cutting pliers. The upper half of figure 5-11 shows what will happen if you do. Improper tools will cut, nick, or scrape the wire and weaken it. The lower half of the figure shows a properly stripped wire.

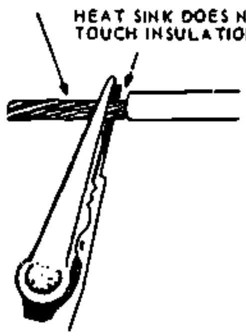
5-54. If, when stripping stranded wire, the strands separate or become disarranged, twist them back onto the main part of the conductor in their original direction of rotation. For ease in soldering, all stranded conductors are tinned before they are soldered to terminals or components. (Solid wire should also be tinned for better bonding.)

5-55. "Wetting" is the ability of liquid solder to adhere to a conductor. To assure good wetting action, remove all impurities by first cleaning with an eraser or a solvent. Good wetting action will result in a well-tinned stranded wire ready for soldering.



REP4-16

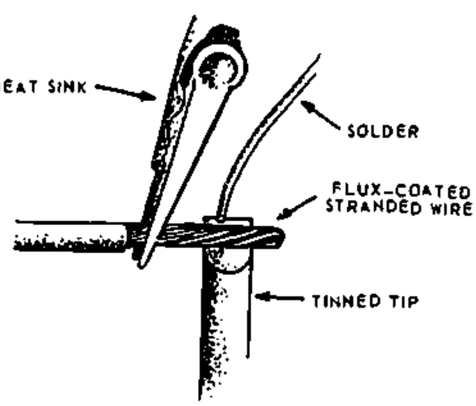
Figure 5-11. Wire Stripping



REP4-23

Figure 5-12. Properly Placed Heat Sink

5-56. To tin a stranded wire, first apply a heat sink as shown in figure 5-12. It will prevent the liquid solder from flowing under the insulation while tinning and soldering. Coat the exposed strands of wire with a small amount of flux. Place the soldering iron on a holder with one face of the tip up. Apply a small amount of rosin core solder to the face of the iron. Hold the wire with one hand and hold a piece of solder with the other. Lay the wire on the face of the iron. Begin at the heat sink and apply the solder along the length of the wire as shown by figure 5-13. Roll the wire across the face of the iron until the solder is absorbed and



REP4-33

Figure 5-13. Tinning a Stranded Wire

REP4-15

Figure 5-14. Properly Tinned Stranded Wire

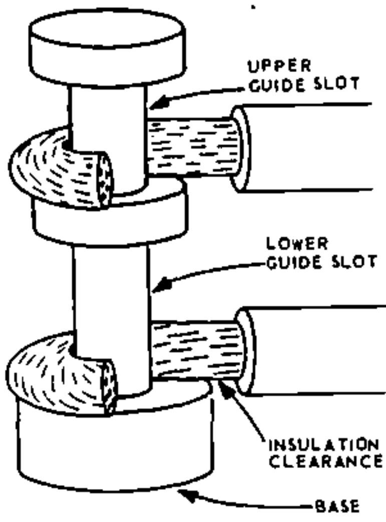
wets the entire area to be tinned. Do not apply too much solder because the strands of wire must be visible to have a properly tinned conductor as shown in figure 5-14.

5-57. Remove the solder from the wire, then lift the wire from the iron. When the tinned wire has cooled, dissolve the excess flux with alcohol and wipe the conductor clean with lint-free tissue. Wipe excess solder from the iron tip.

5-58. Making Soldered Terminal Connections.

5-59. Keep these simple principles in mind when making any soldered connection. The iron must heat the metal to the solder-melting temperature before soldering can occur. Hold the flat, tinned side of the soldering tip directly against each part to be soldered. The melting temperature of the solder is reached in seconds; therefore, the iron and the solder must be applied at the same time. Apply the solder to the point of the iron's contact, not to the soldering iron tip itself. "Wipe" (touch and move) the solder into the area to be bonded with solder.

5-60. When soldering turret and slotted terminals, keep alert in regard to the soldering iron's temperature. The terminal or component may be mounted on Bakelite or similar material that will melt or burn easily. Apply the iron carefully; it should touch the work no longer than necessary to vaporize the flux and melt the solder. Too little heat will make a cold solder joint--one in which the solder does not melt evenly. A cold solder joint is also weak and will increase circuit resistance. Too much heat will burn the plastic mounting and the insulation on the adjoining wires. With transistors, always use a low-wattage soldering iron and solder the leads quickly to prevent damage from overheating.



RAV27-91

Figure 5-15. Turret Terminals

5-61. Figure 5-15 shows a turret terminal with tinned leads mechanically attached and ready for soldering. A turret terminal may have grooves and ferrules to position the leads snugly around the post.

5-62. Strip and pretin the conductor and, as shown in figure 5-15, wrap it around the groove on the terminal post a minimum of 180° and a maximum of 270°. The pretinned part of the conductor lies flat on the surface of the terminal base and the conductor should be perpendicular with the terminal post. Wires with a total outside diameter of 1/32nd of an inch or more will have a minimum insulation clearance of 1/32nd of an inch and a maximum insulation clearance of the outside diameter plus 1/32nd of an inch. Wires with a total outside diameter of less than 1/32 of an inch will have a minimum insulation clearance of 1/32nd of an inch. Connect a heat sink to prevent solder from flowing under the conductor insulation. You are now ready to solder the connection.

5-63. As shown in figure 5-16, touch the tinned tip of the iron to the terminal base at a 45° angle. This permits the greatest heat transfer to the wire and the terminal. Keep the conductor flat on the terminal base.

5-64. Complete a heat bridge between the iron and the work by applying a small amount of solder to the wire at point A. A heat bridge is a small pool of liquid solder between the iron tip and the wire; it acts to transfer maxi-

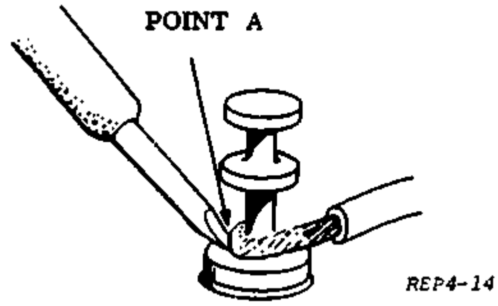


Figure 5-16. Making a Heat Bridge

mum heat to the work. Do not melt solder against the soldering iron tip or allow liquid solder to flow over the joint.

5-65. When the joint readily melts the solder, for a slight fillet between the wire and the terminal base at Point B as shown in figure 5-17. (A fillet is a slight buildup of solder where the two surfaces make contact.) Apply solder to point C also and wipe it toward point D, covering the wire tip. Quickly remove the solder and iron. Do not disturb the joint until it cools; otherwise, the solder will crack or "fracture." When the connection has cooled, remove the heat sink and scrub the joint with alcohol. It must be free of flux residue after cleaning.

5-66. Inspect the soldered connection. The wire must form a good mechanical bond with the terminal. There must be a slight fillet between the conductor and the terminal base. The strands of the conductor must not be disturbed for their normal lay. The wire tip must be covered with solder to resist corrosion. No solder should appear on any surface of the terminal other than the two surfaces where the conductor touches. The

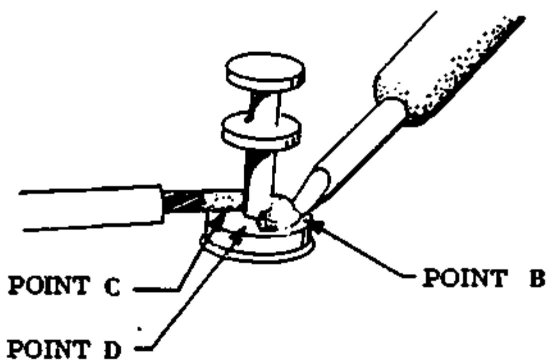


Figure 5-17. Solder Application

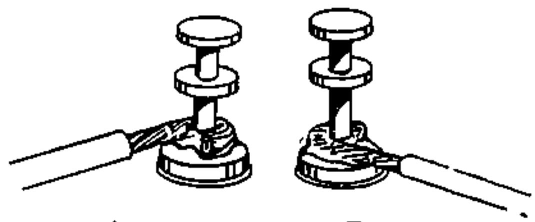


Figure 5-18. Acceptable Soldered Connections

solder joint must be clean, shiny, and smooth. Figure 5-18 shows acceptable solder connections or turret terminals.

5-67. Figure 5-19 shows how a bifurcated terminal is used. It has a slot into which wires and leads are placed before soldering.

5-68. To connect a wire to a bifurcated terminal from the side, bend the pretinned conductor approximately 90°. This will help hold the wire in place during soldering. Position the conductor flat against the base of the terminal for a maximum-strength bend. Again, the insulation should be no farther from the terminal base than the diameter of the insulated part of the wire. When more than one connection is attached to a terminal, alternate the bent connections as shown by A and B in figure 5-20.

5-69. When the wire has been physically connected to the terminal, touch a properly tinned iron to the base of the terminal at a 45° angle. Keep the conductor flat on the terminal base and against the terminal post. Complete a heat bridge and form a fillet between the wire and the terminal. Wipe the connection with the solder, making sure the wire tip is covered.

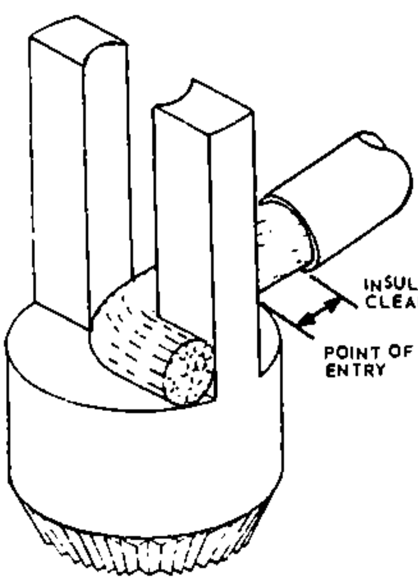


Figure 5-19. Bifurcated Terminal Connection

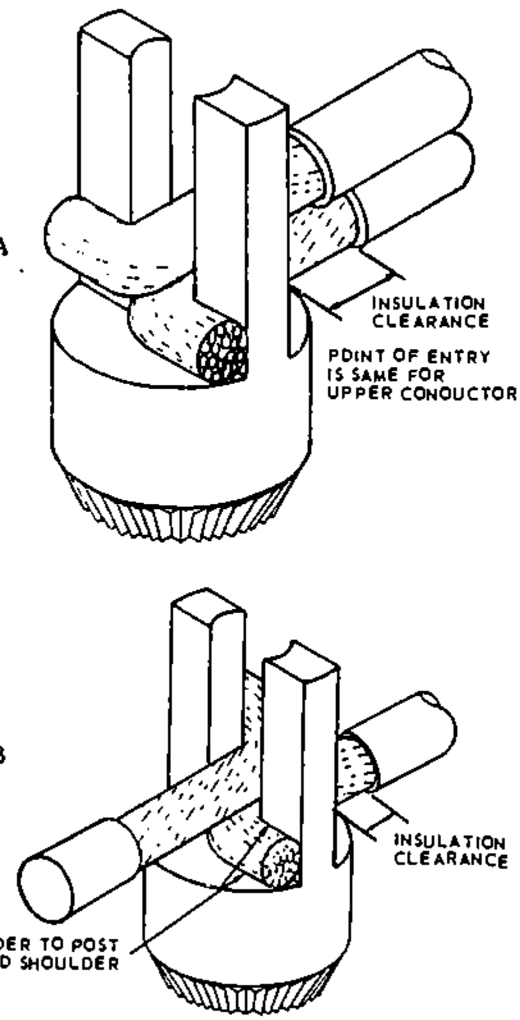


Figure 5-20. Multiple-Terminal Connections

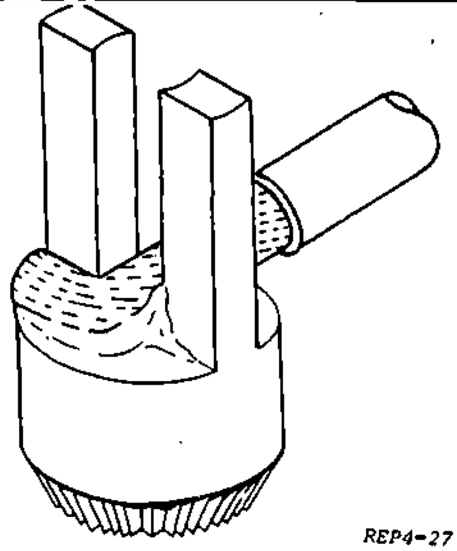


Figure 5-21. Properly Soldered Bifurcated Connection

5-70. Clean and inspect the connection. Make sure there is a slight fillet between the wire and the terminal and that the wire tip is covered with solder. All solder on the bonded terminal must be clean, shiny, smooth, and appear as shown by figure 5-21.

5-71. Soldering on the Printed-Circuit Board.

5-72. You will use simplified circuit boards in you soldering practice. They are made of Fiberglass or phenolic insulating material on which printed conducting lines and pads have been etched. The pads are perforated to hold component leads and provide a soldering base for wires and conductors. A circuit board can reduce a circuit's size, weight, and cost. Figure 5-22 shows printed circuit boards.

5-73. The heat of a soldering iron can damage a printed circuit board if the iron is improperly used. The important factor is not the iron's temperature (most irons heat to the same temperature range), but rather, the length of time the iron is in contact with the work. In theory, any iron can be used if it is not applied too long. To minimize the chance of overheating, however, it is best to use a light-duty pencil iron with a rating of not more than 40 watts. The same small diameter 60/40 rosin-core solder used for heavier terminal connections can also be used on the printed circuit boards you will work with here. First, mount the components on the printed circuit board and make the mechanical connections before soldering. Always mount the components so their printed or lettered part identification

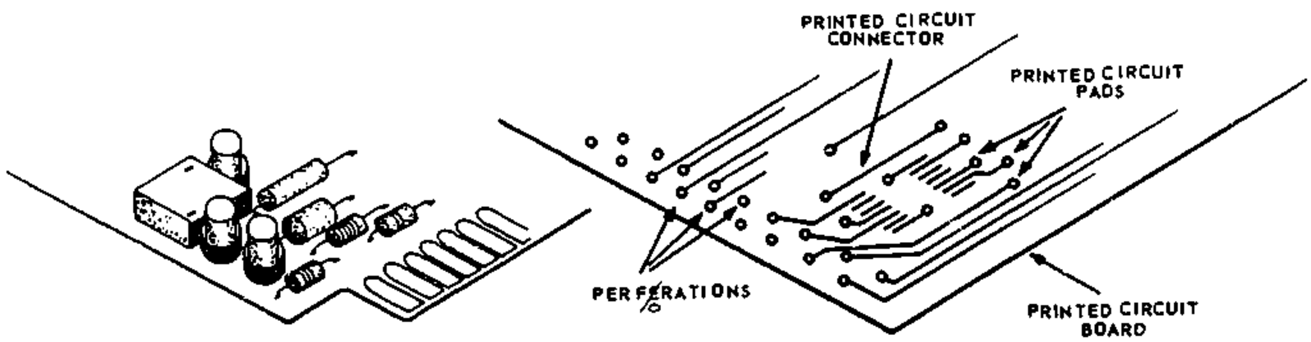
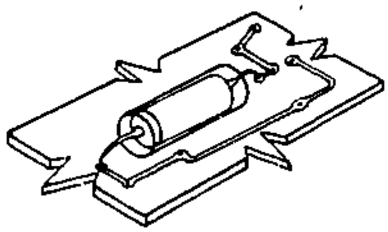
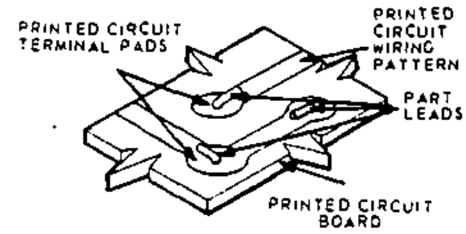


Figure 5-22. Circuit Boards



REP4-31

Figure 5-23. A Component Crossing Conductive Lines



NCS13-27

Figure 5-25. Properly Cut and Clinched Leads

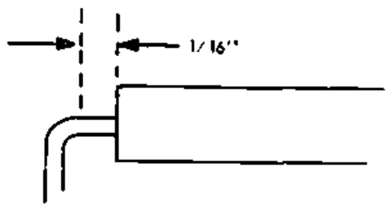
is visible after their leads are soldered. Those parts that have conductive cases, such as metal-cased capacitors, must be insulated from the conductive lines. An example is shown in figure 5-23.

5-74. Some boards are wired (printed) on both sides. When a component lead or a wire connects pads on opposite sides of the board, the pads must be soldered on both sides.

5-75. Use roundnose pliers, long-nose pliers with protected jaws, or other suitable tools to bend the component leads and wires. The bending tools should not flatten, nick, or damage the leads. To prevent cracking the end seals of a component, allow a minimum clearance of the 1/16th of an inch between the bend and the body of the part as shown in figure 5-24. The minimum inside radius of the bend should be equal to the lead diameter.

5-76. After the component leads have been inserted through the board, they should be cut to the proper length and "clinched". To "clinch" a lead, fasten it firmly to the board by flattening the cut end on the circular termination pad. The length of the clinched lead should not be less than the pad radius and not exceed the pad diameter. Clinch the lead in such a direction that it will not overhang the edge of the pad. On a round pad, this would be parallel to (and along) the circuit pattern as shown in figure 5-25.

5-77. Clinch the end of the lead with a non-metallic (plastic) clinching tool until the lead lies approximately parallel to the board's surface. A slight, natural, spring-back of the lead from the board is acceptable. Heavy leads that cannot be bent or clinched should be cleaned and tinned and then cut to a length that will allow the end of the lead to protrude 1/32nd of an inch beyond the solder pad. Figure 5-26 shows a clipped lead before and after soldering. Notice the solid, smooth fillet all around the short, protruding end of the soldered lead.



REP4-32

Figure 5-24. Minimum Bend

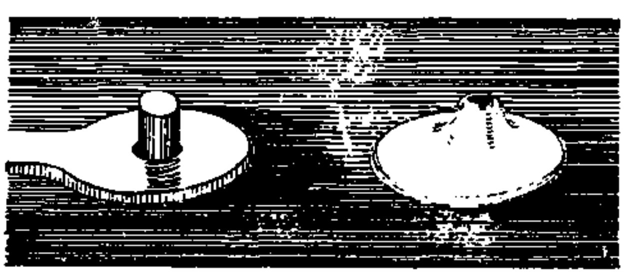
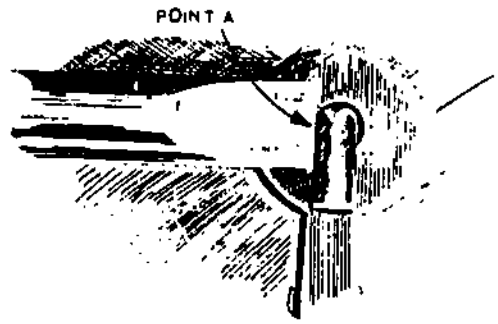


Figure 5-26. Clipped Leads REP4-22



REP4-21

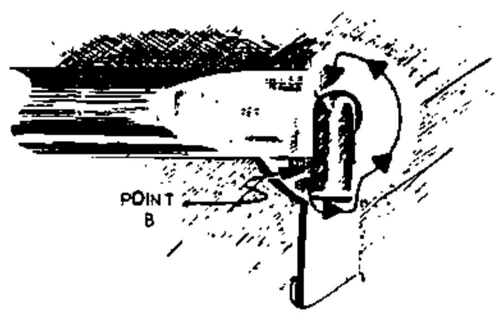
Figure 5-27. Forming a Heat Bridge

5-78. To make a solder joint on a printed circuit board, hold the iron at approximately 45° to the board's surface and touch the tip to both the lead and the pad. Apply a small amount of solder to the tip of the iron where the lead and tip meet (Point A, figure 5-27). This forms a heat bridge and promotes heat transfer. Next, move the solder carefully along the wire, across the tip, and around the pad (figure 5-28).

5-79. The finished connection should have a smooth even fillet on both sides of the clinched lead (figure 5-29).

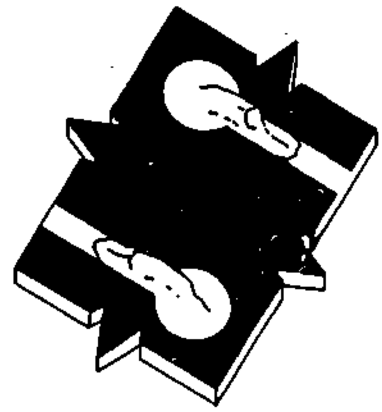
5-80. Wicking and Desoldering.

5-81. When it is necessary to desolder a connection, a short length of flux-coated, stranded wire and a soldering iron are used. The unsoldering operation is called "wicking." It causes the remelted solder at the



NCS13-32

Figure 5-28. Line of Solder Application



REP4-11

Figure 5-29. Satisfactory Solder Joint

terminal to flow freely onto the stranded wire and be absorbed by it. The amount of solder to be removed will determine the wire diameter to be used.

5-82. To wick, strip about 3/8th of an inch of insulation from the wire and dip in liquid flux. Place the wire on the soldered connection and lay the face of the iron on the wire. The solder will flow up the stranded wire by capillary action. As soon as the melted solder has wicked into the stranded wire, remove the iron and wire simultaneously. Figure 5-30 shows the three steps in wicking.

5-83. Electronic parts, such as capacitors, coils, resistors, and wires, may be desoldered by heating the soldered joint with an iron. When the solder melts, remove the lead from the connection, taking care to prevent solder splash. Some soldered leads and wires may be under tension. To prevent harmful splashing of hot solder, it may be necessary to clamp the lead while desoldering the connection. After desoldering the connection, clean it by wicking.

5-84. Vacuum Desoldering Tool.

5-85. Desoldering can also be done with a vacuum desoldering tool shown in figure 5-31. It will draw molten solder from a connection by vacuum. This tool makes desoldering a one-hand operation. The vacuum bulb on the

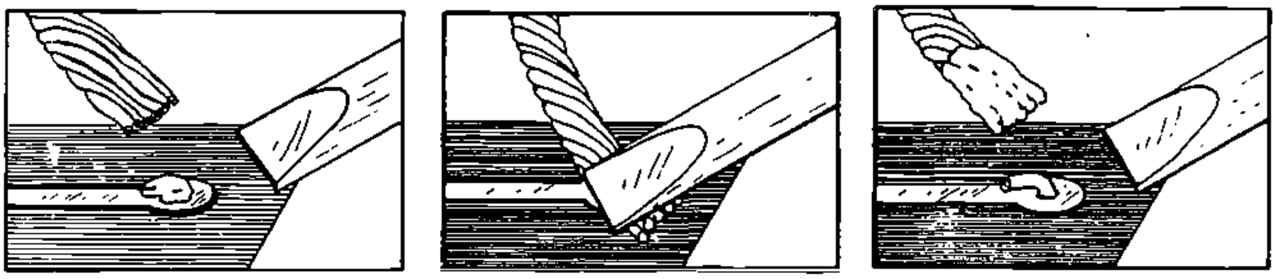


Figure 5-30. Wicking Operation

tool is held down with the thumb or index finger as the desoldering tip is placed against the connection to be desoldered. When the solder on the connection melts, the vacuum bulb is released quickly and draws the molten solder into the tube of the desoldering tip. The desoldering tip is then placed over a metal container and the bulb pressed rapidly to eject the solder.

5-86. The nozzle of the desoldering tool is made of a high-melting point material that will not be damaged by the liquid solder. Because the desoldering method puts a stronger "pull" on the solder than wicking, it can desolder connections through holes, eyelets, and funnelets.

5-87. Removing Components.

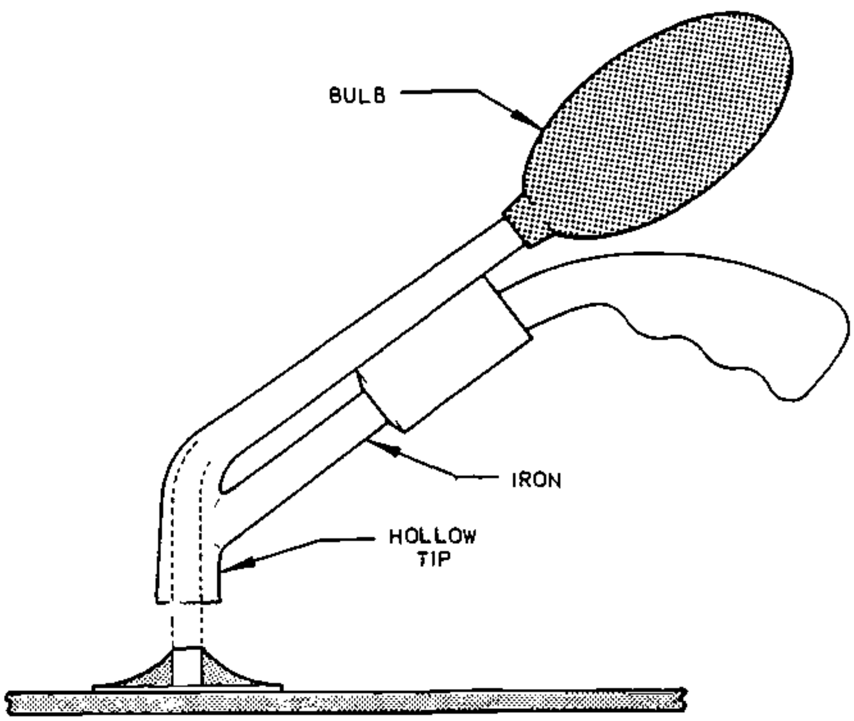


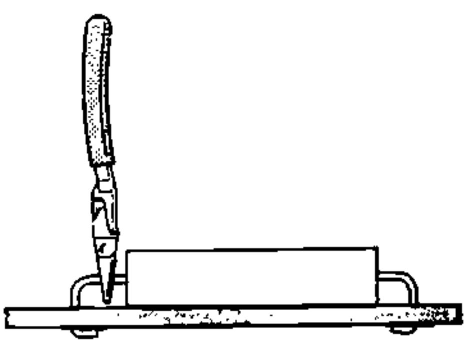
Figure 5-31. Vacuum Desoldering Tool

5-88. When the solder has been removed, the component should be loose enough to be removed easily. Some devices, however, are mounted in such a way as to require additional work. If it can be assumed that the part to be removed is faulty and further damage to it is not important, it can be destroyed if necessary. This is done to prevent damage to the conductive foil, board, or other components.

5-89. Diagonal cutters are used to cut the component leads when the leads are long enough and where there is enough space to use the cutters. The leads should be cut as close to the component body as possible to prevent strain on the printed circuit board. This is shown in figure 5-32.

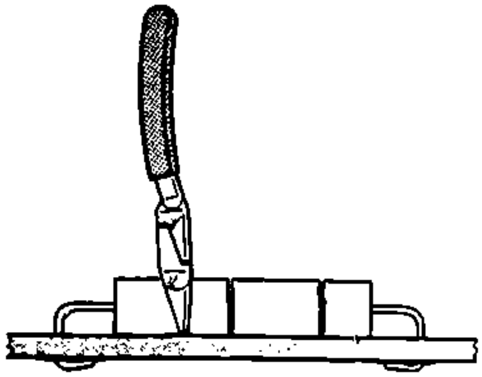
5-90. When it is not suitable to remove the component by cutting the leads because the foil, board, or other components may be damaged, the component may be crushed for safer and easier removal. Make sure the printed circuit board is secured in a holding device. Use diagonal cutters to cut completely through several sections along the length of the component body. Remove the separated parts until the entire body of the component has been removed from the printed circuit board. The procedure is shown in figure 5-33.

5-91. Assembling a Circuit.



REP4-3

Figure 5-32. Cutting Component Leads



REP4-2

Figure 5-33. Crushing a Component Body

5-92. Thus far, you have learned how to mount, solder, and desolder individual components and wires to terminals and printed circuit boards. Now you will be instructed in the procedure to follow when you mount and solder many components in assemblying a complete circuit. Certain steps should be followed in a definite sequence.

1. The first step before mounting and soldering the parts is to make sure you have all of the components required to complete the job. A list of the parts is supplied if the circuit to be assembled is in kit form. If the circuit is to be assembled from common stock parts, obtain them. The components may be identified by color code or by stamped or printed markings on the part. Common hardware items are normally identified by description only.

2. Make sure all the required tools are on hand. Some kits include tools used for special purposes; however, in most cases, standard shop tools may be used. The instructions with the kit will itemize all the tools needed.

3. Assemble the kit in a step-by-step procedure by following the instruction sheet. Follow the instructions exactly, and after you have completed each step, check it off. They will tell you which parts to mount first, where to mount them, and how to mount them. Preform the part leads for easier positioning on

the circuit board. If you do not follow the instructions, you may mount a component in the wrong place. You may install a part in the wrong sequence, which could affect parts to be installed later. If you follow the instructions carefully, however, and use proper soldering techniques, you will be able to assemble a kit that will be mechanically and electrically sound.

5-93. Evaluation of Solder Connections.

5-94. Every soldered connection must be visually inspected to assure that it meets the following standards (do not move parts and conductors to aid the inspection).

Satisfactory soldered connections will have:

1. A clean, smooth, undisturbed surface.

2. A concave fillet between the conductor and the terminal.

3. Conductor contour visible.

4. Complete wetting.

5-95. An unsatisfactory soldered connection will have one or more of the following faults.

1. Conductors and Components.

a. Parts damaged, crushed, cracked, charred, or melted.

b. Improper insulation clearance.

c. Improper tinning.

d. Separation of wire strands.

e. Improperly supported or positioned part.

f. Part marking not visible.

g. Loose conductors.

h. Wires or leads cut, nicked, stretched, or scraped.

i. Flux residue or other contamination.

j. Improper wrap on stranded wire.

2. Soldered Connections.

a. Cold joint.

b. Overheated joint.

c. Fractured joint.

d. Bare copper or base metal.

e. Improperly bonded joint.

f. Pitted or porous joint.

g. Excessive solder.

h. Insufficient solder.

i. Splatter of flux or solder on adjacent area.

j. Dirty connections.

k. Dewetting.

5-96. Compare the following illustrations, which show satisfactory and unsatisfactory soldered connections, with these standards.

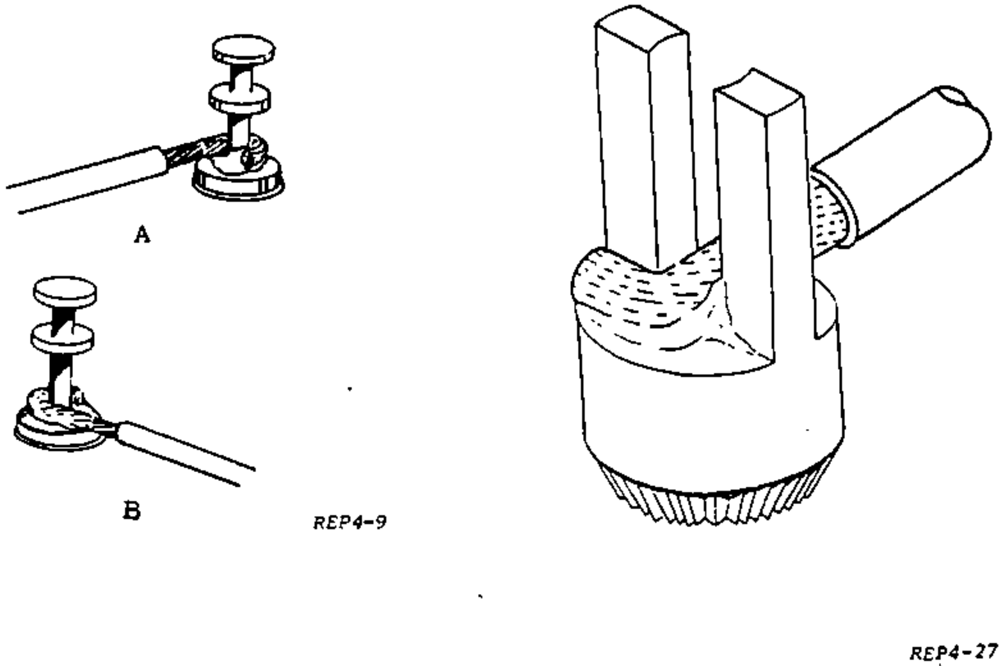


Figure 5-34. Satisfactory Soldered Turrett and Bifurcated Terminals

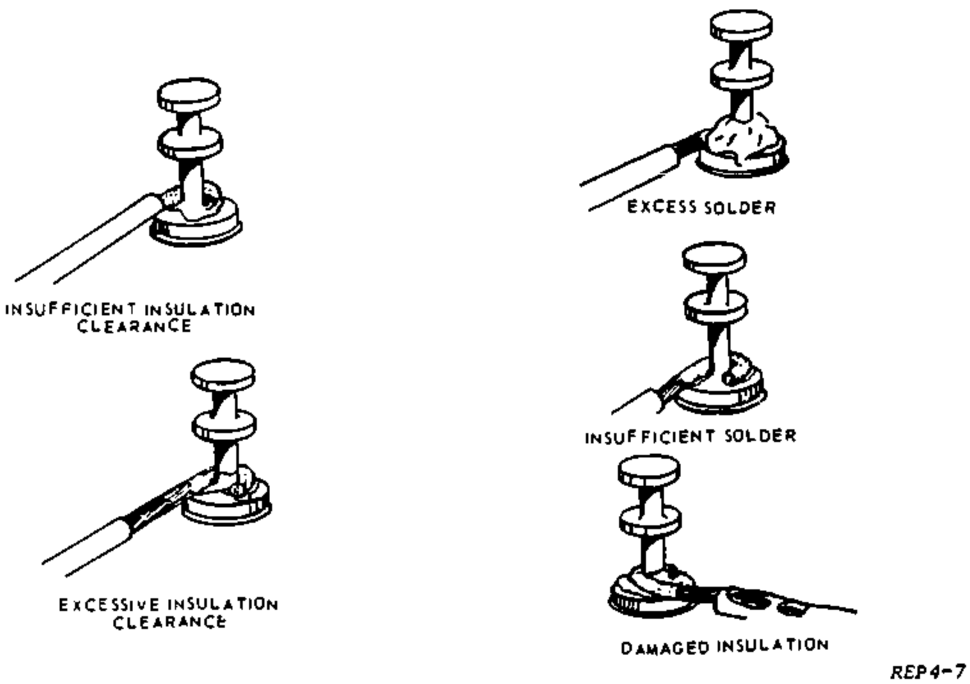


Figure 5-35. Unsatisfactory Soldered Turret Terminals

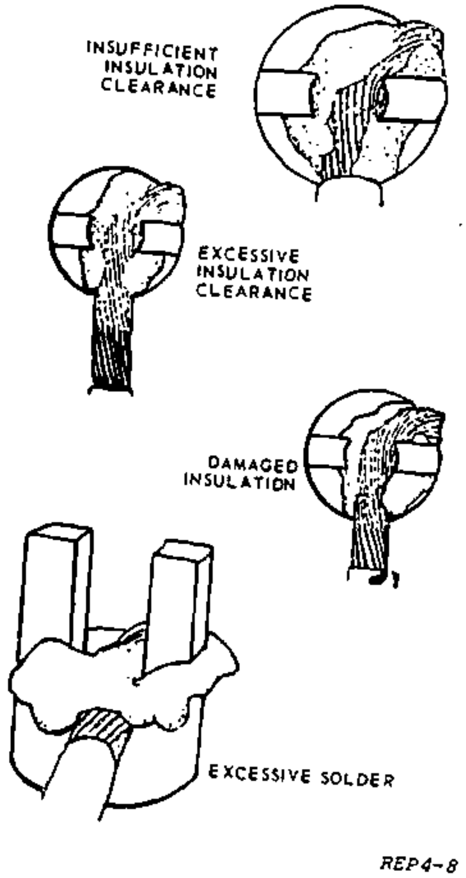


Figure 5-36. Unsatisfactory Soldered Bifurcated Terminals

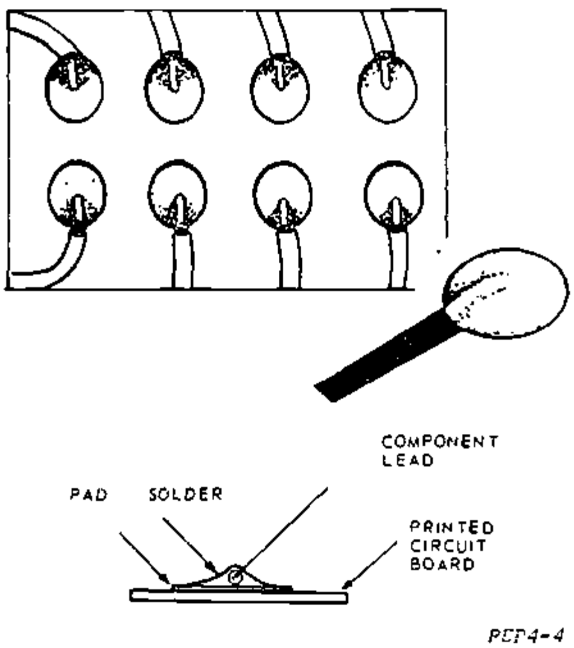


Figure 5-37. Satisfactory Printed Circuit Connections

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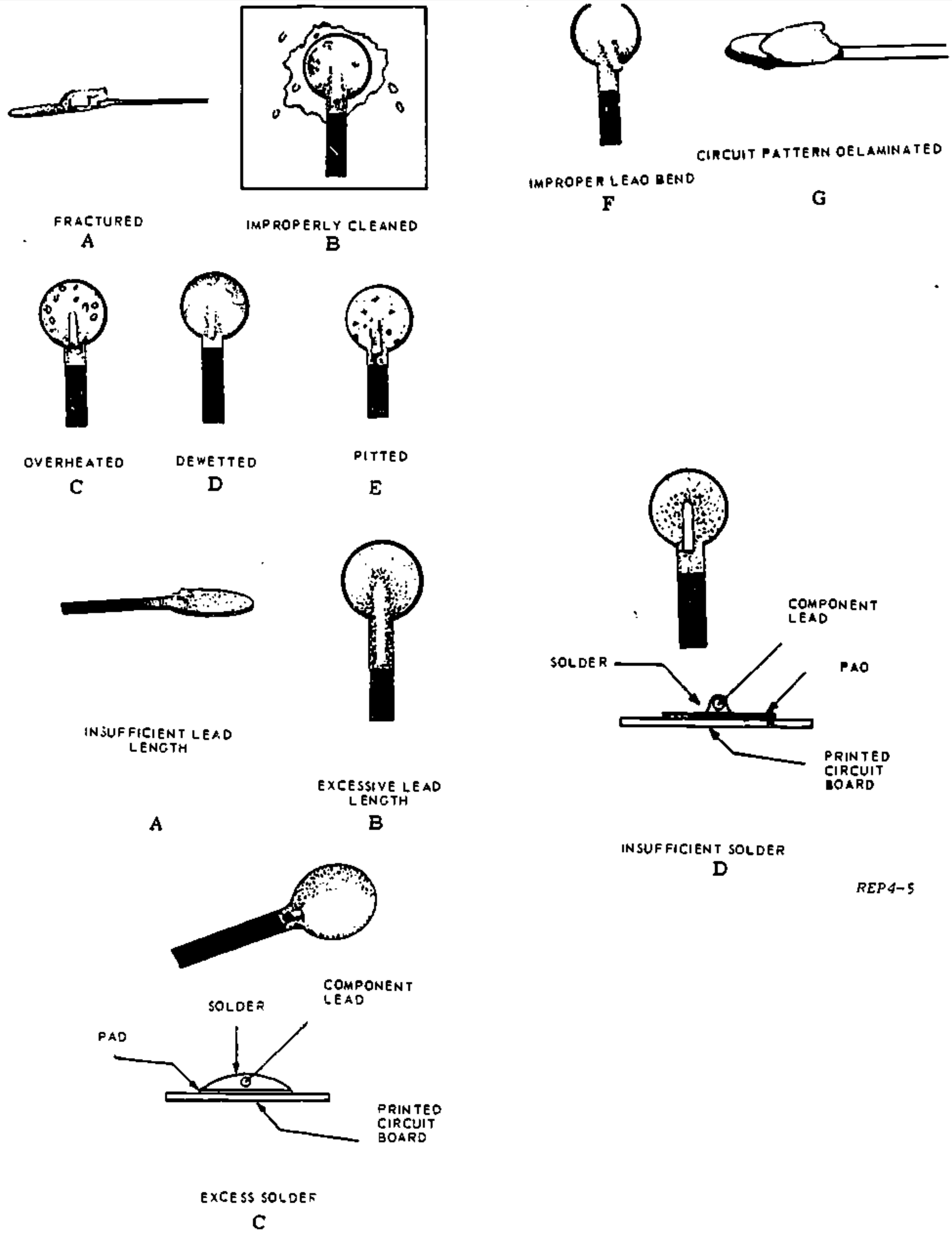

Figure 5-38. Unsatisfactory Printed Circuit Connections

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Modules 74-76

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CONTENTS

Supersedes Digest KEP-ST/Digest-X, 1 April 1975; stock on hand will be used.

WAVEGUIDES AND CAVITY RESONATORS

A waveguide is a round or rectangular metallic tube that conducts and guides electromagnetic energy. This tube is a transmission line for microwave frequencies. In this frequency range, common transmission line losses are too great and their power handling capability is too low.

In the rectangular waveguide, which is most commonly used, the wide side is called the B wall and determines the frequency. The narrow side is called the A wall and determines the power handling capability.

The electromagnetic wave is composed of electrostatic lines of force (E lines) and electromagnetic lines of force (H lines). The E lines always run from B wall to B wall changing directions on each half cycle of the RF signal. The H lines are perpendicular to the E lines and encircle them in closed loops. The H lines also change directions on each half cycle of the signal. (Refer to figure 74-1).

A waveguide is designed for operation at a specific frequency. If the frequency decreases, frequency cut-off occurs and the flow of energy down the waveguide stops. Most waveguides are designed so that the size of the B wall is 0.7 wavelengths of the operating frequency. The A wall is usually one half the size of the B wall, or 0.35 wavelengths of the operating frequency.

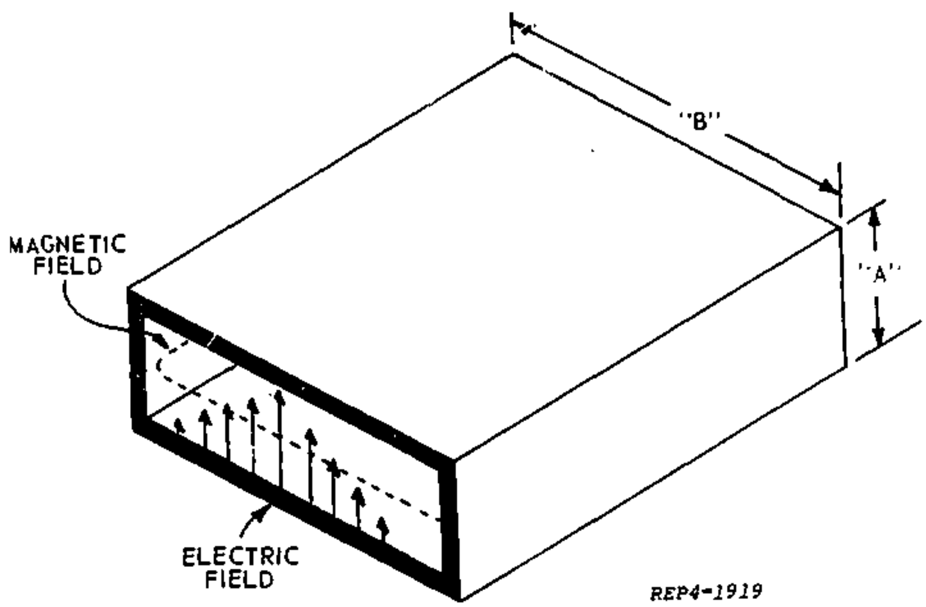


Figure 74-1

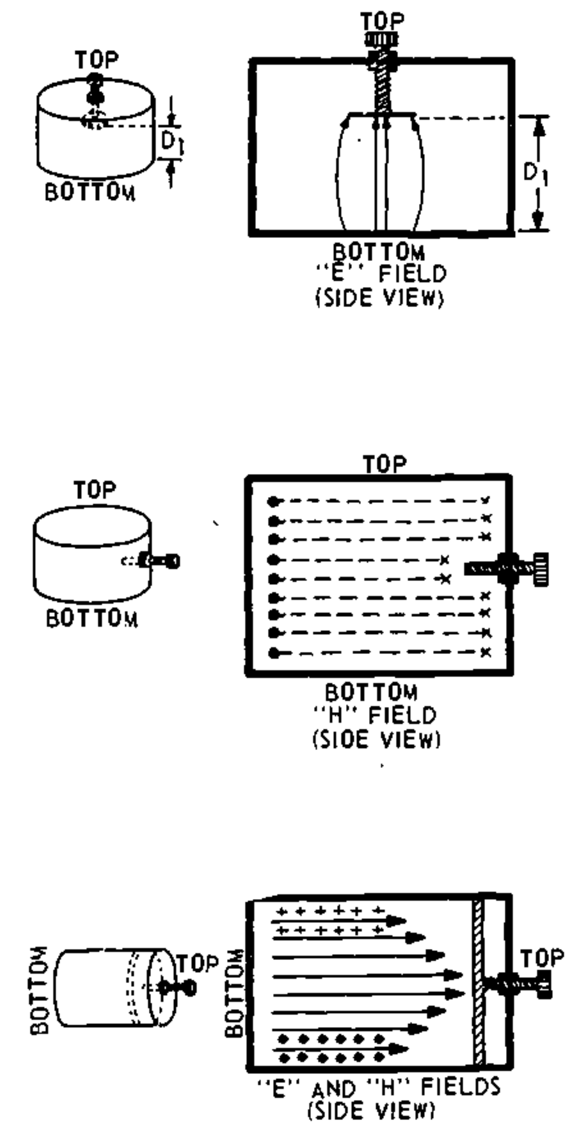


Figure 74-5

Resonant cavities may be tuned by varying the capacitance or inductance as shown in figure 74-5. Capacity tuning is accomplished by turning the screw in or out of the cavity at the point of maximum E lines. Inductive tuning is accomplished by varying the screw in or out at the point of maximum H lines. A third method commonly used is called volume tuning. In this method the size of the cavity is changed thereby varying both the inductance and the capacitance of the circuit.

There are three methods of coupling energy into and out of a waveguide. These are the electrostatic probe, the electromagnetic loop, and the window or iris. Refer to figure 74-2.

Changes in the direction of the propagated wave within the waveguide will cause reflections resulting in standing waves. Since the waveguides are rigid metallic tubes, various devices must be used to allow the energy to be transferred through the system. These devices fall into a category called waveguide plumbing. Some of these are E bends, H bends, flexible waveguide sections, the 90° twist, choke joints, dummy loads, and directional couplers. Refer to figure 74-3.

Some waveguide systems are pressurized with dry air or inert gas. This increases the voltage breakdown level allowing the system to handle greater amounts of power without arcing. Also, since the waveguide is sealed, foreign objects and moisture are prevented from entering the system. Moisture causes corrosion which in turn causes reflections creating standing waves.

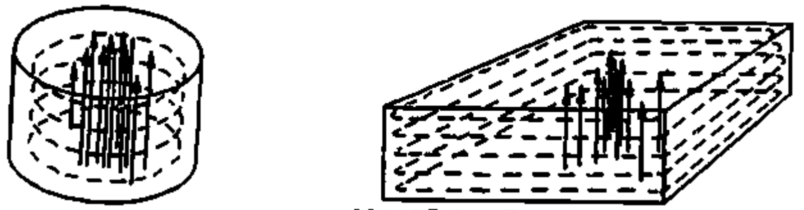
Another special device often used in a waveguide system is the duplexer. This is a device found in waveguide systems used in radar. Its purpose is to allow both the transmitter and receiver to use the same antenna. When the transmitter fires, reflected impedances electronically disconnect the receiver from the transmission line. During the receive time, reflected impedances disconnect the transmitter from the transmission line.

At mircowave frequencies, coils and capacitors in a tank circuit are inefficient. Therefore, it is necessary to employ a resonant microwave circuit. These are known as resonant cavities. A resonant cavity can be defined as any space completely surrounded by conducting walls that will resonate at a specific frequency.

Although resonant cavities are operated at microwave frequencies, they are very efficient. They have high power handling capability, high gain (Q), and a very narrow bandpass. They are commonly used in testing devices and microwave amplifiers and oscillators.

Resonant cavities are found in many forms. They may be cylinders, cubes, spheres, and even donut shaped. The two factors that determine their frequency is their size and shape. The smaller the size the higher the frequency. The shape determines frequency because the distance between the walls determines the capacity of the circuit.

The electromagnetic fields inside the cavity are composed of E and H lines just as those are in the waveguides. Refer to figure 74-4. The same three methods are used to couple energy into and out of the cavity as in the waveguide.



FIELDS IN CYLINDRICAL CAVITY

SQUARE CAVITY OR HALF WAVE LENGTH SECTION OF WAVEGUIDE

REP4-1892

Figure 74-4

When receiving very weak microwave frequencies, the amplification of noise is very important. The parametric amplifier has a great advantage over the conventional amplifier because it provides a very high signal to noise ratio. Conventional amplifiers are basically variable resistances and rely on a heated cathode for electron emission. This thermal agitation is magnified and results in a low signal to noise ratio. The parametric amplifier uses a variable reactance to supply energy from a source to the load. Therefore, it does not need the heat that would cause thermal noise. As a result, the signal level is high and the noise level is low.

In the parametric amplifier, a pump frequency is applied from an external source. The signal is applied to a voltage variable capacitance (vari-cap) diode that is located in a resonant cavity (LC tank circuit). The pump frequency causes the tank capacity to vary. When the capacitance decreases as the input signal increases, a voltage buildup occurs. The result is an amplified signal. The capacity must decrease as the signal voltage is maximum and increase as the signal passes through zero. This means the pump frequency must be exactly twice the signal frequency.

There are two types of parametric amplifiers. The non-degenerative and the upconverter types. In the non-degenerative amplifier, the output frequency is the same as the input frequency. In the upconverter amplifier the output frequency is greater than the input frequency. It is sometimes called a mixer with gain.

The magnetron is a high power, high gain, microwave oscillator. It is velocity modulated and may be operated to produce either a pulse or continuous wave output.

The magnetron is basically a diode since it consists of a cathode and plate (anode). The anode is a solid cylinder of copper with the center cut out providing an interaction space, and to permit the insertion of the cathode. The circumference of the anode is connected to cooling fins to dissipate the heat. Just inside the outer edge of the anode, holes are drilled that function as resonant cavities. Small slots connect the cavities with the interaction space in the center of the anode. The size of the cavities determine the operating frequency and the number of cavities is determined by the size of the anode. The larger the anode the greater will be its power handling capability. The more power the larger the anode and the greater the number of cavities.

There are three fields found in the magnetron. The DC field is formed by the potential difference between cathode and anode. The AC field is developed when the resonant cavities oscillate. Finally, a magnetic field is employed when a permanent magnet is placed across the anode. The fields interact and control the electron as it moves from cathode to anode. This results in the electron giving up energy to the oscillating AC fields sustaining the oscillations. The energy from the oscillating cavities is coupled from the magnetron as a high powered microwave frequency.

MODULE 75

MICROWAVE AMPLIFIERS AND OSCILLATORS

Conventional tubes are very inefficient at UHF and microwave frequencies. As the frequency increases, interelectrode capacitance and lead inductance increases. Also the transit time is too long and the losses are too great. The solution to this problem was to convert DC power into RF power. This principle is called velocity modulation.

When an electron is caused to move against an electrostatic field it gains in velocity and takes energy from the field. When an electron is caused to move with the electrostatic field, its velocity decreases and it gives up energy to the field. This is the principle used in microwave amplifiers and oscillators.

The klystron amplifier contains two cavities. The input cavity is called the buncher and the output cavity is called the catcher. The RF signal is fed into the buncher cavity which oscillates at the input frequency. This sets up alternating electrostatic fields in the cavity. The electrons flowing from cathode to plate are acted upon by the electrostatic fields. Some electrons are slowed down and others are speeded up resulting in a bunching of the electrons. The bunches travel toward the plate and pass through the catcher cavity. The catcher cavity is oscillating at the same frequency as the input signal. However, the electrostatic fields are such that the bunches will pass through at a time when the lines are in the same direction as the direction of electron travel. This will cause the electrons to be slowed down and give up energy to the field resulting in an output signal of the same frequency but greater in amplitude.

The klystron oscillator operates in a similar manner. The main difference is the input to the buncher cavity is removed and a feedback loop is placed between the catcher and buncher cavities. The signal is fed back in phase over the half wavelength loop to provide the necessary regenerative feedback.

The reflex klystron also works on the same basic principle. However, only the buncher cavity is used and a negative voltage is connected to the plate. The electrons are velocity modulated by the oscillations of the buncher cavity. As they travel toward the plate at various speeds, the plate repels them, consequently, they arrive back at the positively charged buncher cavity at the same time in bunches. The electrons arrive at the buncher cavity at a time when the electrostatic lines of force are in the same direction as the movement of the bunches. This slows down the bunches and they give up energy to the cavity. The necessary feedback is thus provided to sustain oscillations.

The traveling wave tube (TWT) is a microwave amplifier. The main advantage of this tube is its very wide bandwidth. Its bandwidth is one octave or more. This means that the highest frequency is twice that of the lowest frequency.

The TWT has an electron gun at the cathode end and a plate at the other. The electron stream that passes from the cathode to the plate travels through a spiral of wire called the helix. The RF signal is coupled into the helix close to the cathode and coupled out close to the plate. The interaction between the fields in the helix and the electron stream causes the electrons to bunch as they travel toward the plate. The bunches give up energy to the RF field resulting in a higher amplitude RF output power.

The entire TWT is enclosed in a cylindrical magnet. The magnetic field focuses the electrons into a tight beam as they travel through the helix.

An attenuator is placed around the helix near the center. This prevents the high amplitude signal from reflecting back to the input causing the tube to oscillate.

PREPARE THE MAN

ATC GP 3AQR3X020-X
Prepared by Keesler TTC
KEP-GP-74

Technical Training

ELECTRONIC PRINCIPLES (MODULAR SELF-PACED)

MODULE 74

WAVEGUIDES AND CAVITY RESONATORS

1 June 1974

7-14

Keesler Technical Training Center
Keesler Air Force Base, Mississippi

Designed For ATC Course Use

DO NOT USE ON THE JOB

107

Electronic Principles Department
Keesler Air Force Base, Mississippi

ATC GP 3AQR3X020-X
KEP-GP-74
1 June 1974

ELECTRONIC PRINCIPLES

This Guidance Package is designed to guide you through this module of the Electronic Principles Course. It contains specific information and references to other sources you may study, that will enable you to satisfy the learning objectives.

CONTENTS

Supersedes Guidance Package KEP-GP-74, 1 January 1974 which may be used until supply is exhausted.

WAVEGUIDES AND CAVITY RESONATORS

1. SCOPE: This module discusses the uses of waveguide devices and cavity resonators in communications and radar. You will study the basic principles of waveguides and the generation of microwave energy; the types, applications, and tuning of cavity resonators.

2. OBJECTIVES: Upon completion of this module, you should be able to satisfy the following objectives:

a. Given a list of statements on waveguides, select the ones that describe the physical appearance of waveguide components.

b. Given a list of statements on waveguides, select the ones that describe the electrical characteristics.

c. Given a list of statements, select those that describe the advantages of pressurizing waveguide systems.

d. Given the diagram of coupling devices in a waveguide system, identify the various types:

(1) Probe

(2) Loop

(3) Aperture

e. Given illustrations of a directional coupler and a bidirectional coupler, match each illustration with the statement that describes the purpose of each.

f. Given an illustration of a simplified parallel duplexing system and a list of related statements, select the statement that describes the purpose of the duplexer.

g. Given statements concerning resonant cavities, select the statement that describes capacitance, inductance, and volume tuning.

AT THIS POINT, YOU MAY TAKE THE MODULE SELF-CHECK.

IF YOU DECIDE NOT TO TAKE THE MODULE SELF-CHECK, TURN TO THE NEXT PAGE AND PREVIEW THE LIST OF RESOURCES. DO NOT HESITATE TO CONSULT YOUR INSTRUCTOR IF YOU HAVE ANY QUESTIONS.

LIST OF RESOURCES

WAVEGUIDES AND CAVITY RESONATORS

To satisfy the objectives of this module, you may choose, according to your training, experience, and preferences, any or all of the following:

READING MATERIALS:

Adjunct Guide with Student Text

AUDIO VISUALS:

TV Lesson, Waveguide Plumbing, TVK-30-906

TV Lesson, Cavity Resonators, TVK-30-908

TV Lesson, Directional Couplers, TVK-30-907

SELECT ONE OF THE RESOURCES AND BEGIN YOUR STUDY, OR TAKE THE MODULE SELF-CHECK.

CONSULT YOUR INSTRUCTOR IF YOU REQUIRE ASSISTANCE.

WAVEGUIDES AND CAVITY RESONATORS

A waveguide is a round or rectangular tube that conducts and guides electromagnetic energy. This hollow metallic tube is a transmission line for microwave frequencies. In this frequency range, common transmission line losses are too great and their power handling capability is too low.

In the rectangular waveguide, which is most commonly used, the long side is called the B wall and determines the frequency. The short side is called the A wall and determines the power handling capability.

The electromagnetic wave is composed of electrostatic lines of force (E lines) and electromagnetic lines of force (H lines). The E lines always run from B wall to B wall changing directions on each half cycle of the RF signal. The H lines are perpendicular to the E lines and encircle them in closed loops. The H lines also change directions on each half cycle of the signal. (Refer to figure 7 4-1)

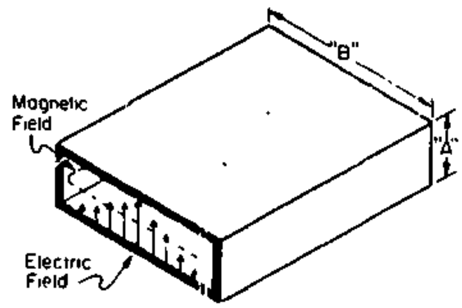


Figure 7 4-1

A waveguide is designed for operation at a specific frequency. If the frequency decreases, frequency cut-off occurs and the flow of energy down the waveguide stops. Most waveguides are designed so that the size of the B wall is 0.7 wavelengths of the operating frequency. The A wall is usually one half that size or 0.35 wavelength of the operating frequency.

There are three methods of coupling energy into and out of a waveguide. These are the electrostatic probe, the electromagnetic loop, and the window or iris. Refer to figure 7 4-2.

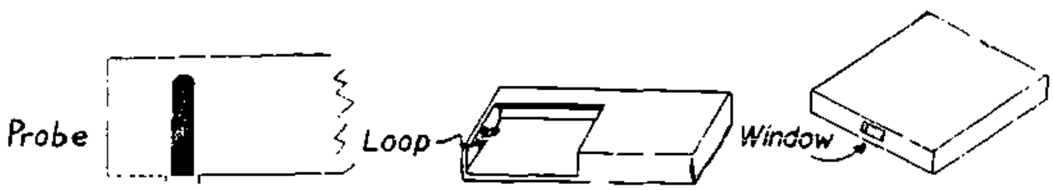


Figure 7 4-2

DIGEST

Changes in the direction of the propagated wave within the waveguide will cause reflections resulting in standing waves. Since the waveguides are rigid metallic tubes, various devices must be used to allow the energy to be transferred through the system. These devices fall into a category called waveguide plumbing. Some of these are E bends, H bends, flexible waveguide sections, the 90° twist, choke joints, dummy loads, and directional couplers. Refer to figure 7 4-3.

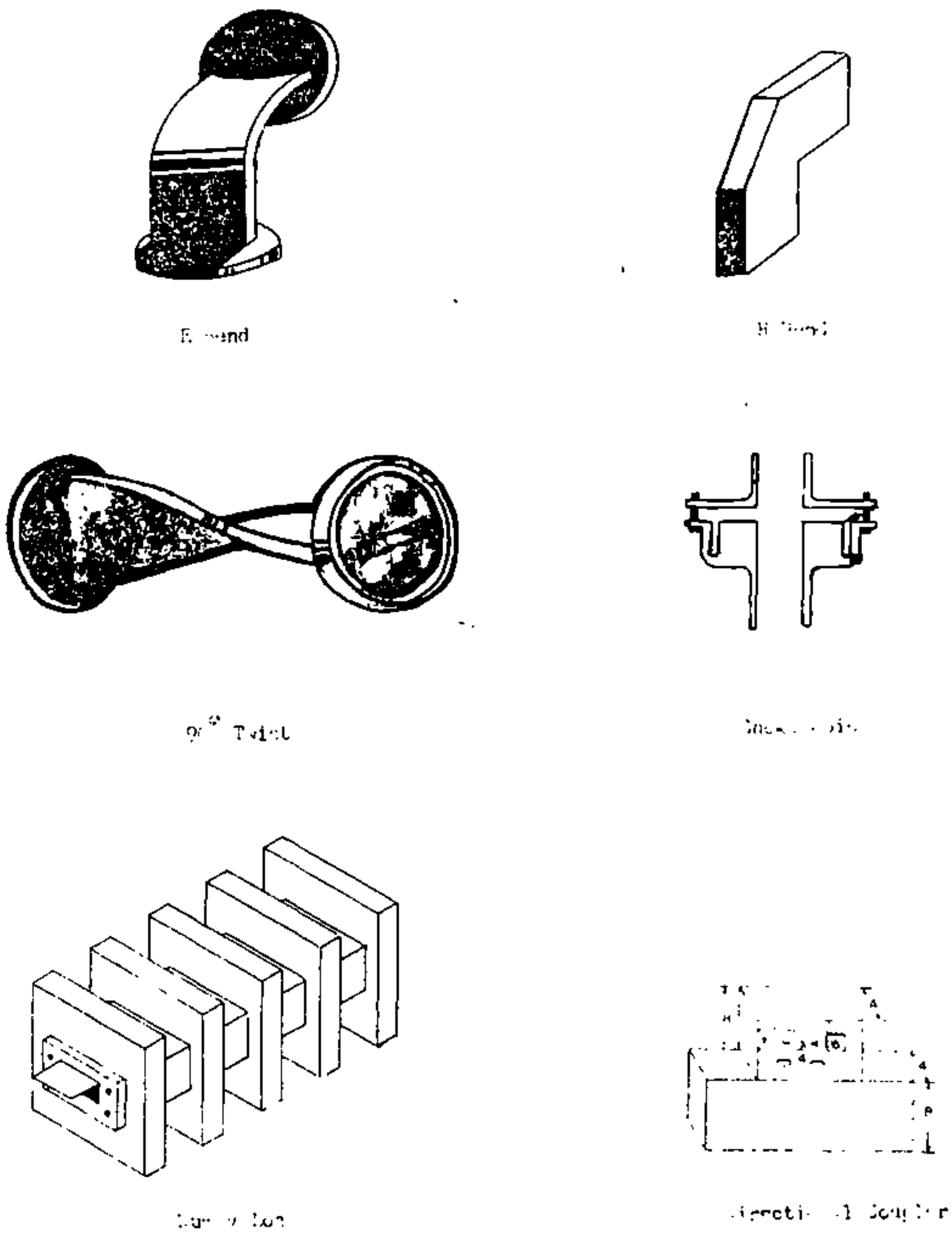


Figure 7 4-3

Some waveguide systems are pressurized with dry air or inert gas. This increases the voltage breakdown level allowing the system to handle greater amounts of power. Also, since the waveguide is sealed, foreign objects and moisture are prevented from entering the system. Moisture causes corrosion which in turn causes reflections creating standing waves.

Another special device often used in a waveguide system is the duplexer. This is a device found in waveguide systems used in radar. Its purpose is to allow both the transmitter and receiver to use the same antenna. When the transmitter fires, reflected impedances electronically disconnect the receiver from the transmission line. During the receive time, reflected impedances disconnect the transmitter from the transmission line.

At microwave frequencies coils and capacitors in a tank circuit are inefficient. Therefore, it is necessary to employ a resonant microwave circuit. These are known as resonant cavities. A resonant cavity can be defined as any space completely surrounded by conducting walls that will resonate at a specific frequency.

Although resonant cavities are operated at microwave frequencies, they are very efficient. They have high power handling capability, high gain (Q), and a very narrow bandpass. They are commonly used in testing devices and microwave amplifiers and oscillators.

Resonant cavities are found in many forms. They may be cylinders, cubes, spheres, and even donut shaped. The two factors that determine their frequency is the size and shape. The smaller the size the higher the frequency. The shape determines frequency because the distance between the walls determines the capacity of the circuit.

The electromagnetic fields inside the cavity are composed of E and H lines just as those are in the waveguides. Refer to figure 7 4-4. The same three methods are used to couple energy into and out of the cavity as in the waveguide. These are the electrostatic probe, electromagnetic loop, and the window or iris.

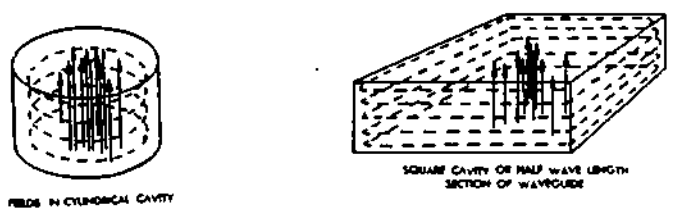
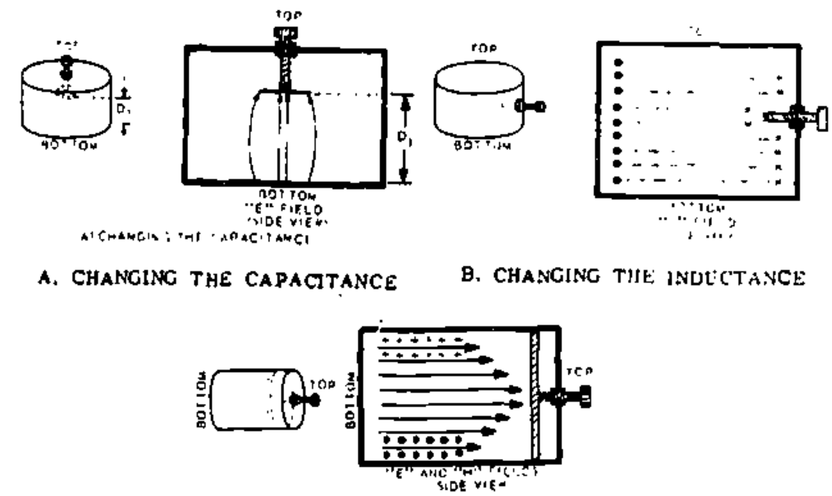


Figure 7 4-4

Resonant cavities may be tuned by varying the capacitance or inductance as shown in figure 7 4-5. Capacity tuning is accomplished by turning the screw in or out of the cavity at the point of maximum E lines. Inductive tuning is accomplished by varying the screw in or out at the point of maximum H. lines. A third method commonly used is called area tuning. In this method the volume of the cavity is changed thereby varying both the inductance and the capacitance of the circuit.

113

DIGEST



A. CHANGING THE CAPACITANCE B. CHANGING THE INDUCTANCE

C. CHANGING THE VOLUME

Figure 7 4-5

YOU MAY STUDY ANOTHER RESOURCE OR TAKE THE MODULE SELF CHECK.

119

114

WAVEGUIDES AND CAVITY RESONATORS

INSTRUCTIONS:

Study the referenced materials as directed.

Return to this guide and answer the questions.

Check your answers against the answers at the top of the next even numbered page following the questions.

If you experience any difficulty, contact your instructor.

Begin the program.

A. Turn to Student Text, Volume X, and read paragraphs 1-2 through 1-4. Return to this page and answer the following questions:

1. Waveguides conduct and guide

   a. electrical energy.

   b. electromagnetic energy.

   c. low frequency, low power RF energy.

2. Complete the blanks.

   a. This is a ____________ waveguide.

   b. This is a ____________ waveguide.

3. Of the two waveguide designs above which is the most widely used?

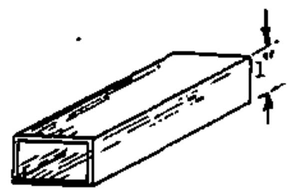
   a. ____________

   b. ____________

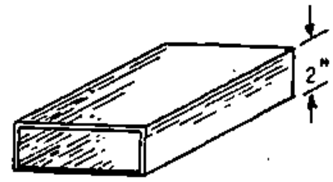
ADJUNCT GUIDE

4. Write "higher" or "lower" in the appropriate space to identify the frequency-carrying ability of the two sizes of rectangular waveguide shown below.

a. ____________



b. ____________



5. Which of the two rectangular waveguides above has the greater power-handling ability?

a. ____________

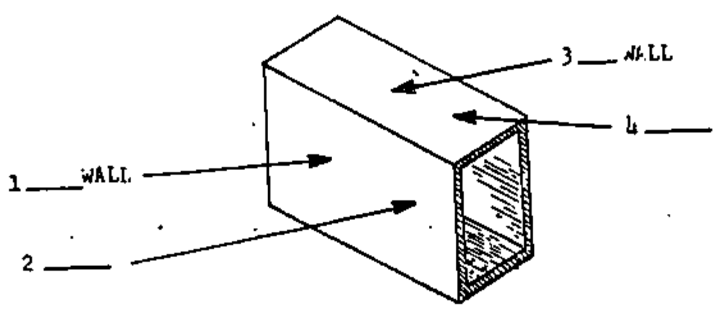
b. ____________

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

B. Turn to Student Text, Volume X, and read paragraphs 1-5 through 1-11. There are no exercises for this part.

C. Turn to Student Text, Volume X, and read paragraphs 1-12 through 1-17. Return to this page and answer the following questions.

Complete each blank on the figure with one of the terms listed on right.



A

B

power-determining

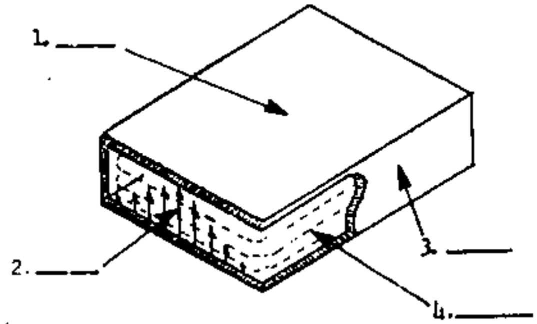
frequency-determining

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

D. Turn to Student Text, Volume X, and read paragraphs 1-19 through 1-21. No response is required.

E. Turn to Student Text, Volume X, and read paragraphs 1-23 through 1-35. Return to this page and answer the following question:

Complete the blanks using the symbols listed on the right.



A Wall

B Wall

E Line

H Line

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

F. Turn to Student Text, Volume X, and read paragraphs 1-36 and 1-37. Return to this page and answer the following question:

1. Check the statements that describe the advantages of pressurizing a waveguide system.

   a. Prevents foreign material from getting inside of waveguide.

   b. Standing waves and distortions of the wavefront are reduced.

   c. Greater power-handling ability.

   d. Decreases dielectric constant in high-power systems.

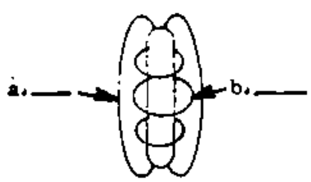
CONFIRM YOUR ANSWER ON THE NEXT EVEN NUMBERED PAGE.

G. Turn to Student Text, Volume X, and read paragraphs 1-38 through 1-43. Return to this page and answer the following questions.

1. Label the fields around this quarter-wave antenna probe.

   a. ____________________

   b. ____________________



ANSWES TO A:

1. b
2. a. circular
   b. rectangular (square)
3. b
4. a. higher
   b. lower
5. b

If you missed ANY questions, review the material before you continue.

ANSWERS TO C:

1. B
2. frequency-determining
3. A
4. power-determining

If you missed ANY questions, review the material before you continue.

ANSWERS TO E:

1. B Wall
2. E Line
3. A Wall
4. H Line

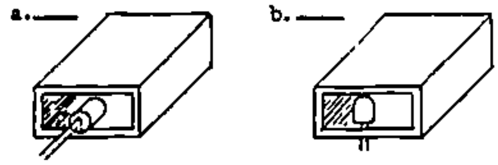
If you missed ANY questions, review the material before you continue.

ANSWERS TO F:

1. a
   b
   c

If you missed ANY questions, review the material before you continue.

2. Check the waveguide diagram in which the probe is correctly placed.



3. Use the words at right to complete the blanks in this paragraph.

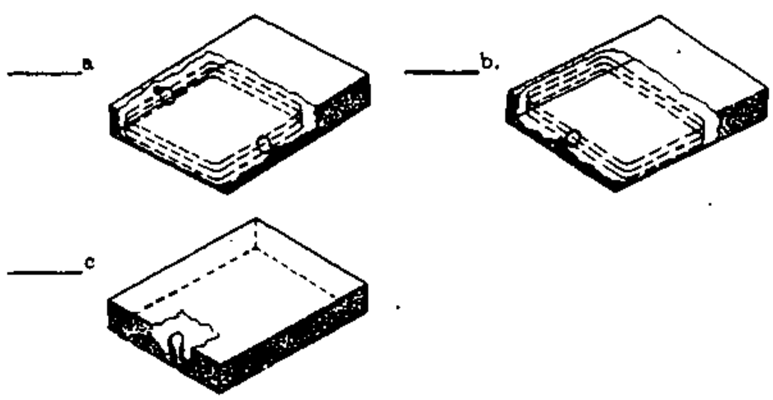
The probe is simply a ____________ ____________ antenna that radiates ____________ and ____________ fields. For maximum coupling between the probe and the fields, the probe is placed one-quarter wavelength from the end of the waveguide at the point of ____________ E field intensity. The probe's frequency, bandwidth, and power-handling ability is determined by its ____________ and ____________. The conical "door knob" shaped probe of large diameter handles ____________ power; the small probe handles ____________ power.

- high
- shape
- low
- maximum
- E
- size
- H
- quarter wave

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

H. Turn to Student Text, Volume X, and read paragraph 1-45. Return to this page and answer the following questions.

1. Check the diagram in which the loop is IMPROPERLY placed.



ANSWERS TO G:

1. a. E
   b. H
2. (b)
3. quarter wave
   E (H)
   H (E)
   maximum
   size (shape)
   shape (size)
   high
   low

If you missed ANY questions, review the material before you continue.

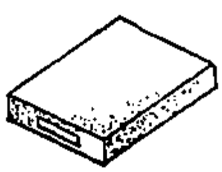
2. Complete the blanks in the following paragraph.

The loop is placed in the waveguide at the point of greatest __________ field strength. The circumference of the loop is a __________ wavelength. If the diameter of the loop is increased, its power-handling capability is __________ . Increasing the loop's diameter will __________________ the bandwidth.

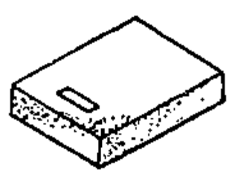
CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

I. Turn to Student Text, Volume X, and read paragraph 1-47. Return to this page and answer the following questions.

1. Check the waveguide that has the correctly placed aperture coupling.



_____a_____



_____b_____

2. Example ______________ of question number 1 is correct because the aperture is correctly placed with respect to the ______________ field.

3. The amount of coupling may be increased or decreased by varying the ______________ and ______________ of the aperture.

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

J. Turn to Student Text, Volume X, and read paragraphs 1-48 through 1-51. Return to this page and answer the following questions.

Check the TRUE statements:

______1. When the antenna is located some distance from the receiver, there is no reason for waveguide bends, twists, or sharp turns in the plumbing.

______2. Sudden bends or twists in waveguides result in a power loss because of an impedance change in the transmitted energy.

______3. A sudden change in the waveguide's size or shape results in reflections and standing waves.

______4. Gradual bends in a waveguide reduce the copper losses.

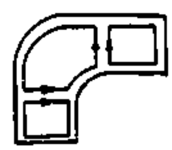
______5. A gradual bend in a waveguide will alter the spacing and size of waveguide walls.

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

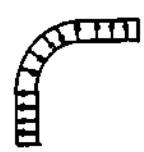
K. Turn to Student Text, Volume X, and read paragraph 1-52. Return to this page and answer the following questions.

1. under each illustration, write either E or H to identify the type of gradual bend indicated.

a. __________ 

b. __________ 

c. __________ 

d. __________ 

ADJUNCT GUIDE

ANSWERS TO H:
1. a.
2. H, one half, increased, increase

ANSWERS TO I:
1. a
2. a, E
3. size, location
If you missed ANY questions, review the material before you continue.

ANSWERS TO J:
2
3
If you missed ANY questions, review the material before you continue.

2. Illustration b of question 1 shows a gradual ________ (H/E) bend because the ________ (H/E) fields in the waveguide are distorted.

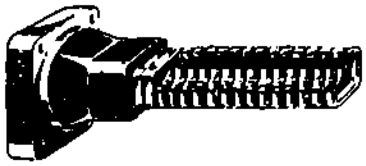
CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

L. Turn to Student Text, Volume X, and read paragraphs 1-54 and 1-55. Return to this page and answer the following questions.

1. A 90 degree twist in a flexible or rigidly twisted waveguide must occur through a distance of more than ________________ wavelengths.

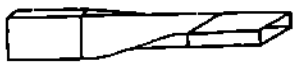
2. Refer to the illustrations below and match with the correct statement.

_____a.



_____b.

_____c.



1. Is a twisted waveguide.
2. Is a gradual H bend.
3. Is a gradual E bend.
4. Is a flexible waveguide.

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

M. Turn to Student Text, Volume X, and read paragraphs 1-58 through 1-60. Return to this page and answer the following questions.

1. the choke joint is used to

_____a. restrict the traveling waveguide energy.

_____b. permit operation of a rotating antenna.

_____c. make a narrow passage in the waveguide.

_____d. connect sections of waveguide.

2. True or False (T or F)

_____a. Waveguide systems that end with a rotating antenna must use a rotating joint between the waveguide and the antenna.

_____b. A rectangular waveguide is used in the rotating part of the joint.

_____c. Circular waveguides are attached to the fixed and rotating parts of the rotating joint.

_____d. Like the choke joint, the rotating joint permits a good mechanical and electrical connection in the waveguide system.

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

ANSWERS TO K:

1. a. E
   b. H
   c. H
   d. E

2. H, H

If you missed ANY questions, review the material before you continue.

ANSWERS TO L:

1. two

2. a. 4
   b. 2
   c. 1

If you missed ANY questions, review the material before you continue.

ANSWERS TO M:

1. d

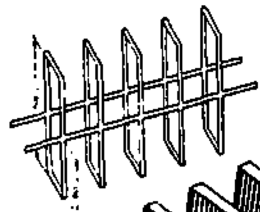
2. a. T
   b. F
   c. T
   d. F

If you missed ANY questions, review the material before you continue.

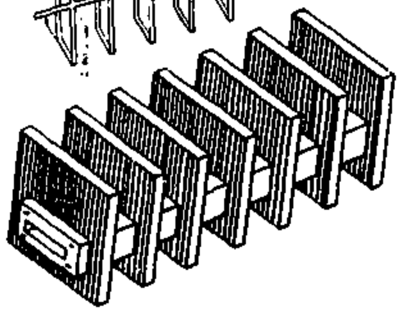
N. Turn to Student Text, Volume X, and read paragraph 1-62. Return to this page and answer the following questions.

1. Check the illustration that represents a dummy load.

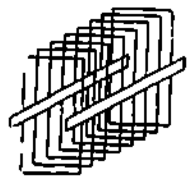
_____ a.



_____ b.



_____ c.



2. Check the statement that is NOT true with regard to the dummy load.

A dummy load:

_____ a. is a simulated resistive load.

_____ b. can absorb all of the waveguide's electromagnetic energy.

_____ c. prevents standing waves and mismatches.

_____ d. is a capacitive simulated load.

_____ e. allows maintenance to be performed on the radar system without its energy radiating into space.

_____ f. dissipates the electromagnetic energy in the form of heat.

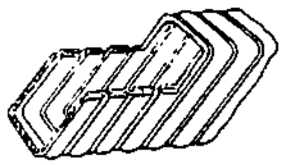
_____ g. uses cooling fins to radiate the absorbed heat into the air.

ADJUNCT GUIDE

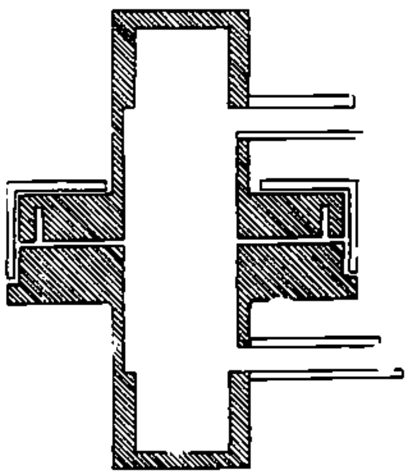
3. Match the illustrations in column A with the statements in Column B.

COLUMN A

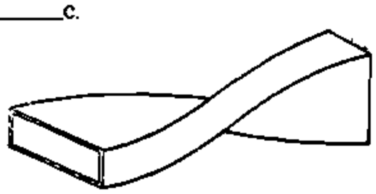
____ a.



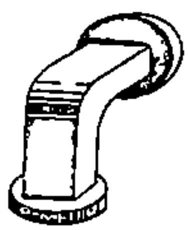
____ b.



____ c.



____ d.



COLUMN B

1. Dummy load, used to absorb electromagnetic energy and prevent mismatches and standing waves.

2. Gradual H bend, in which the radius of the bend must be greater than two wavelengths.

3. Rectangular waveguide section twisted through a distance of at least two wavelengths to properly polarize the antenna.

4. Gradual E bend in which the radius of the bend is greater than two wavelengths.

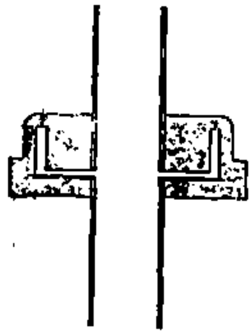
5. Waveguide designed for installations where special bends are required.

6. Sharp H bend in which the two 45 degree bends must be one-quarter wavelength apart.

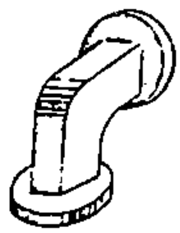
7. Waveguide device to allow antenna rotation without distortion or high impedance.

8. Waveguide device to assure a good electrical connection between waveguide sections.

______ e.



______ f.



CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

O. Turn to Student Text, Volume X, and read paragraphs 1-64 through 1-73. Return to this page and answer the following questions.

1. Match each directional coupler illustration on the following page with the condition described below.

______ a. Incident wave adding to provide a sample of transmitted energy.

______ b. Reflected wave canceled at probe and absorbed.

______ c. Reflected wave adding to provide a sample.

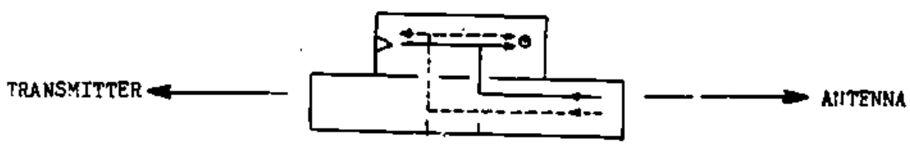
ANSWERS TO N:

1. b

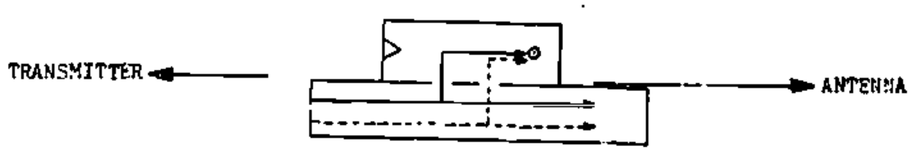
2. d

3. a. 5
   b. 7
   c. 3
   d. 4
   e. 8
   f. 2

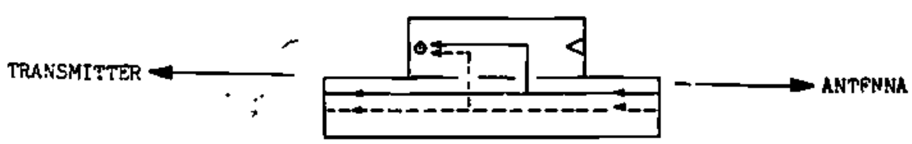
If you missed ANY questions, review the material before you continue.



1 ____



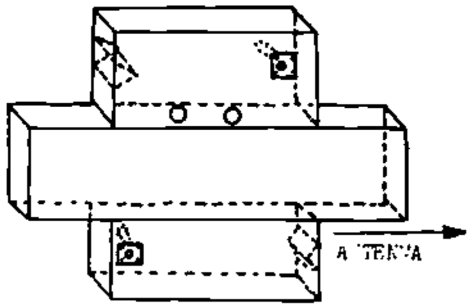
2 ____



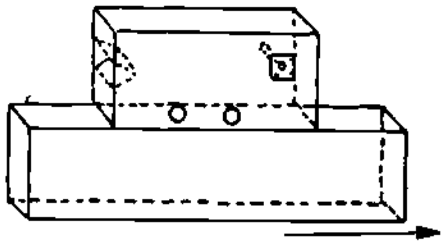
3 ____

2. Match each illustration on the left with the statement that corresponds to it.

_____a.



_____b.



1. Can sample a known portion of the overall transmitted (incident) and reflected energy wave traveling in both directions simultaneously.

2. Will sample only the known portion of the return wave.

3. Samples a known portion of the overall transmitted (incident) energy.

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

P. Turn to Student Text, Volume X, and read paragraphs 1-75 through 1-82. Return to this page and answer the following questions.

Refer to the illustration of the Simplified Duplexer System on the next page to answer these questions:

1. Select the statement that describes the purpose of the duplexer.

________a. A system that uses the transmitter to receive and transmit RF signals.

________b. A system that connects the transmitter to the waveguide during the time the antenna is receiving.

________c. A system that uses TR and ATR circuits to permit single antenna operation.

2. Match the letter of each statement below with the number of the simplified diagram to which it applies.

______a. A basic duplexer system showing all major components.

______b. Duplexer operation during transmission.

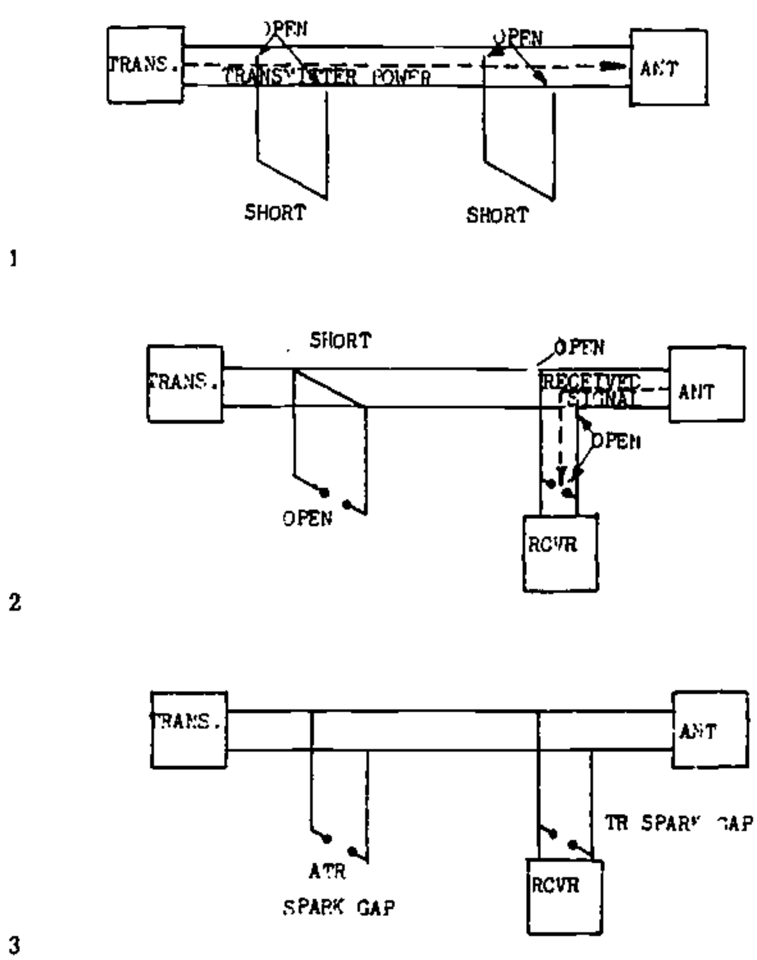
______c. Duplexer operation during receive.

ANSWERS TO O:

1. a. 2
   b. 1
   c. 3

2. a. 1
   b. 3

If you missed ANY questions, review the material before you continue.



Simplified Duplexer System

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

Q. Turn to Student Text, Volume X, and read paragraphs 2-1 through 2-3. Return to this page and answer the following questions.

1. Check those statements that describe the properties of a resonant cavity.

_____ a. Contains no inductive properties.

_____ b. Operating space is completely enclosed by conducting walls.

_____ c. Has resonant properties.

_____ d. Designed for use above 2000 MHz.

_____ e. Contains oscillating electromagnetic fields.

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

R. Turn to Student Text, Volume X, and read paragraph 2-5. Return to this page and answer the following questions.

1. Check the statements that describe the ADVANTAGES of a resonant cavity over an LC tank circuit.

_____ a. Can handle larger amounts of power.

_____ b. Operates at a lower frequency.

_____ c. Has a higher Q.

_____ d. Is larger and heavier.

_____ e. Permits more accurate tuning and has a narrower bandpass.

_____ f. More rugged construction.

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

S. Turn to Student Text, Volume X, and read paragraphs 2-7 and 2-8. No response is required.

ADJUNCT GUIDE

ANSWERS TO P:

1. c

2. a. 3
   b. 1
   c. 2

If you missed ANY questions, review the material before you continue.

ANSWERS TO Q:

1. b
   c
   d
   e

If you missed ANY questions, review the material before you continue.

ANSWERS TO R:

1. a
   c
   e
   f

If you missed any questions, review the material before you continue.

T. Turn to Student Text, Volume X, and read paragraph 2-10. Return to this page and answer the following question.

1. Which of these variables determine the primary frequency of a resonant cavity?

_____ a. Q

_____ b. Physical size

_____ c. Type of conducting material

_____ d. Coupling method.

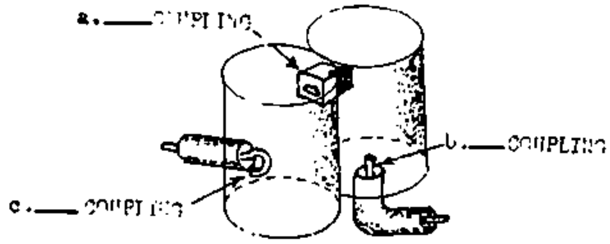
_____ e. Shape of the cavity.

CONFIRM YOR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

U. Turn to Student Text, Volume X, and read paragraphs 2-12 and 2-13. No response is necessary.

V. Turn to Student Text, Volume X, and read paragraphs 2-15 through 2-19. Return to this page and answer the following questions.

1. Identify the types of coupling in the composite illustration of the cavity resonators by writing "loop," "iris," and "probe" in the proper space provided.



CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

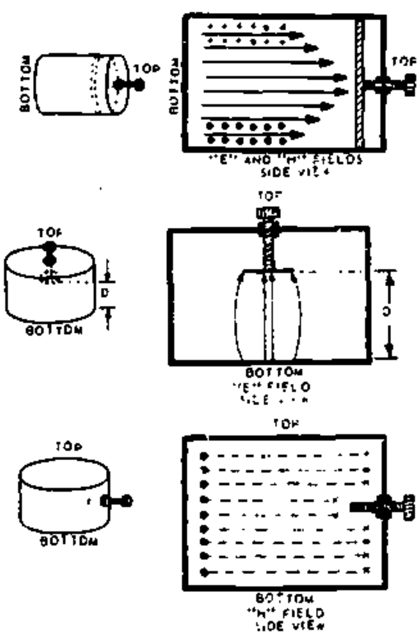
W. Turn to Student Text, Volume X, and read paragraphs 2-21 through 2-25, to learn the three ways by which a resonant cavity is tuned. Return to this page and answer the following questions.

1. Beside each illustration below, write either "capacitive," "inductive" or "volume" depending upon which method of tuning is used.

a. ______________

b. ______________

c. ______________



ANSWERS TO T:

1. b
   e

If you missed ANY questions, review the material before you continue.

ANSWERS TO V:

1. a. Iris
   b. Probe
   c. Loop

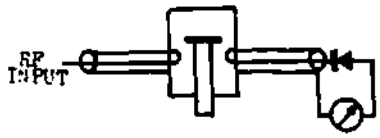
If you missed ANY questions, review the material before you continue.

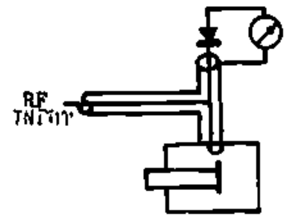
2. Match each method of cavity resonator tuning described in Column A with the description in Column B.

COLUMN A	COLUMN B
________ a. Inductive tuning	1. An adjustable screw placed in the area of maximum E line alters the distance between plates to vary the frequency.
________ b. Capacitive tuning	2. An adjustable plunger varies the inductance and capacitance in the cavity which changes the resonant frequency.
________ c. Volume tuning	3. A plunger is placed in the area of maximum H lines to alter the distance between cavity ends changes the frequency.
	4. A non-magnetic slug moved in the area of maximum H lines varies the magnetic field and the inductance to change the resonant frequency.

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

X. Turn to Student Text, and read paragraphs 2-27 through 2-28. Return to this page and answer the following questions.





Refer to the above wavemeter illustrations to complete this exercise.

1. Match each description in Column A with the wavemeter type listed in Column B.

COLUMN A	COLUMN B
_____ a. Has two terminals.	1. Transmission type
_____ b. Has one terminal.	2. Absorption type
_____ c. Transmits a minimum signal (minimum meter reading) at resonance.	3. Both transmission and absorption type.
_____ d. Uses a crystal probe and a micro ammeter to indicate the point of resonance.	
_____ e. Transmits a maximum signal (maximum meter reading) at resonance.	
_____ f. Measures the frequency in the cavity resonator.	

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE..

Y. Turn to Student Text, Volume X, and read paragraphs 2-29 through 2-32. No response is required.

YOU MAY STUDY ANOTHER RESOURCE OR TAKE THE MODULE SELF-CHECK.

ANSWERS TO W:

1. a. Volume
   b. Capacitive
   c. Inductive

2. a. 4
   b. 1
   c. 2

If you missed ANY questions, review the material before you continue.

ANSWERS TO X:

1. a. 1
   b. 2
   c. 2
   d. 3
   e. 1
   f. 3

If you missed ANY questions, review the material before you continue.

WAVEGUIDES AND CAVITY RESONATORS

1. What kind of energy do waveguides conduct and guide?

   _____a. electrical

   _____b. low frequency, low power RF

   _____c. electromagnetic

2. Waveguide "a" below is known as a ______________________ waveguide.

   Waveguide "b" is known as a ______________________ waveguide.

a b

3. Of the two waveguide designs of question 2, which is the one most widely used?

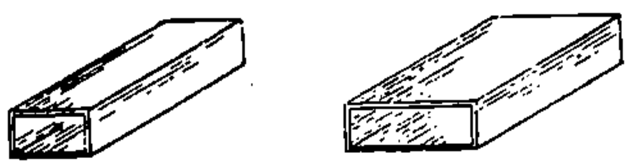
   _____ a.

   _____ b.

4. Which of the two sizes of rectangular waveguides shown below has a higher frequency-carrying ability?

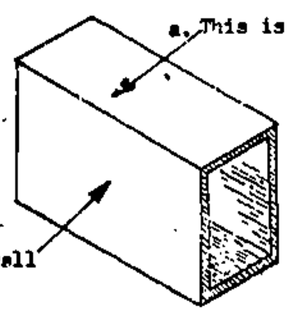
   _____a.

   _____b.



a b

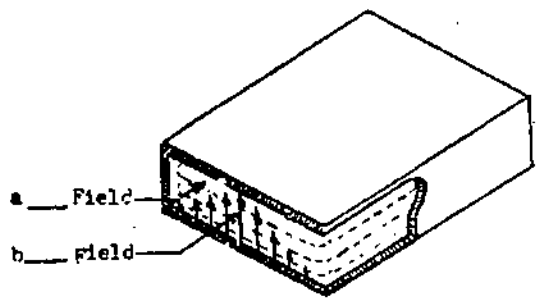
5. Complete the blanks on the illustration below.



MODULE SELF-CHECK

6. Referring to the illustration in 5 above, the ____________ (A/B) wall is the power-determining wall. The ____________ (A/B) wall is the frequency-determining wall.

7. In the illustration, label the magnetic (H) field and the electric (E) field.



8. Which item below is NOT an advantage of waveguide pressurization?

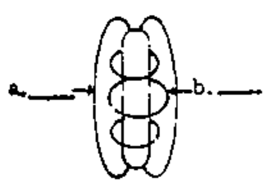
_____ a. Prevents foreign material from entering.

_____ b. Reduces standing waves and distortions.

_____ c. Decreases dielectric constant.

_____ d. Provides greater power-handling.

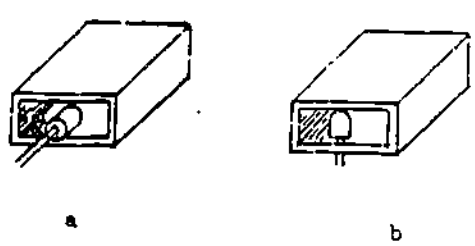
9. Label the E and H fields around this half-wave probe.



10. Which probe is INCORRECTLY placed in the waveguide?

_____ a.

_____ b.



11. A probe that puts energy into, or removes it from a waveguide

_____a. is placed one-half wavelength from the end of the waveguide.

_____b. is a quarter-wave antenna radiating E and H fields.

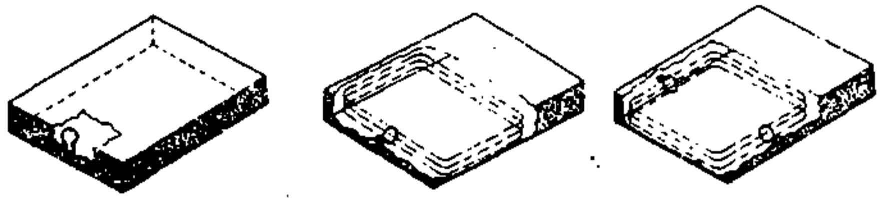
_____c. has its frequency, bandwidth, and power-handling ability determined by its density.

12. Which diagram has the loop IMPROPERLY placed?

_____a.

_____b.

_____c.



13. The loop is placed in the waveguide at the point of greatest

_____a. electric field strength.

_____b. E field strength.

_____c. H field strength.

14. Which waveguide below has the CORRECTLY placed aperture for coupling?

_____a.

_____b.

a. b.

139

MODULE SELF-CHECK

15. Waveguides have gradual twists and bends because

_____a. they match the impedance between transmitter and receiver.

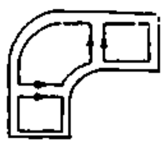
_____b. they reduce power losses and standing waves.

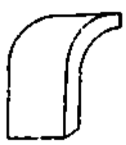
_____c. it reduces copper losses.

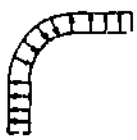
_____d. it will alter the spacing and size of the waveguide walls.

16. Identify the type of gradual bend (E or H) for each of the following waveguide illustrations.

a. _____ 

b. _____ 

c. _____ 

d. _____ 

17. A 90 degree twist in a flexible or rigidly twisted waveguide must occur through a distance of more than

_____a. one wavelength.

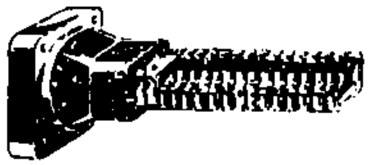
_____b. two wavelengths.

_____c. three wavelengths.

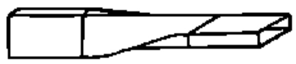
_____d. four wavelengths.

145

18. Write either: Twisted waveguide, flexible waveguide, gradual H bend, or gradual E bend for each illustration.

a. ______ 

b. ______ 

c. ______ 

19. A choke joint

_____ a. connects waveguide sections.

_____ b. makes a narrow passage in the waveguide.

_____ c. permits operation of a rotating antenna.

_____ d. restricts traveling waveguide energy.

20. A rotating joint

_____ a. uses a rectangular waveguide in the rotating part of the joint.

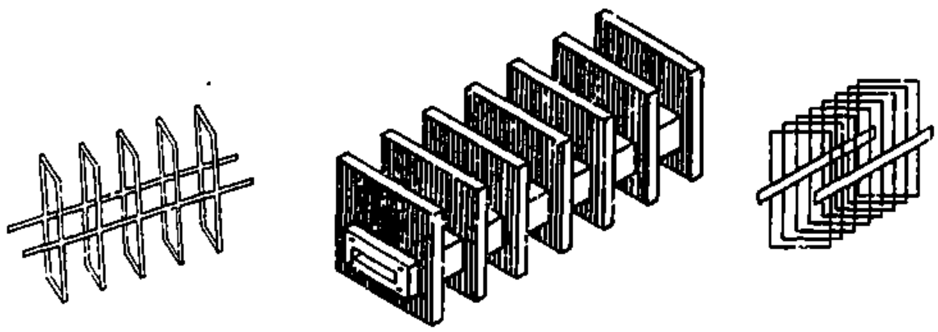
_____ b. restricts the traveling waveguide energy.

_____ c. permits a loose mechanical and good electrical connections in the waveguide system.

_____ d. makes a narrow passage in the waveguide.

MODULE SELF-CHECK

21. Which of the illustrations below represents a dummy load?



a.____ b.____ c.____

22. Which statement is NOT true about a dummy load?

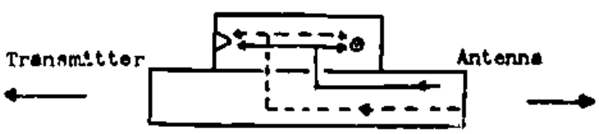
____a. A simulated resistive load.

____b. A capacitive, simulated load.

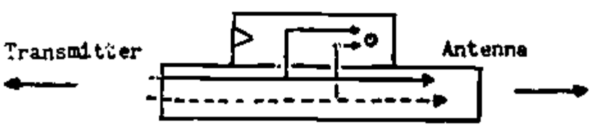
____c. Dissipates electromagnetic energy as heat.

____d. Prevents standing waves and mismatches.

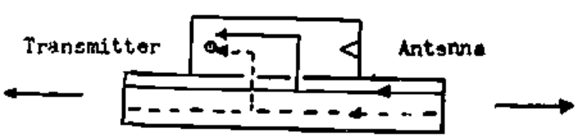
23. Match the illustrations on the left with the statement on the right that applies to each.



(a) ____



(b) ____



(c) ____

1. Incident wave adding to provide a sample of transmitted energy.

2. Reflected wave canceled at probe and absorbed.

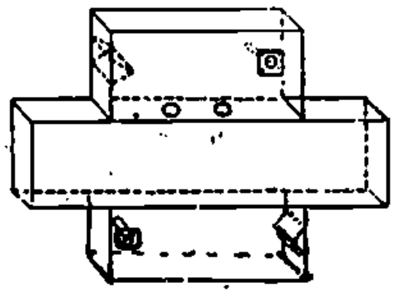
3. Reflected wave added for sampling.

24. The bidirectional coupler shown below will

_____a. sample a known portion of the overall transmitted (incident) energy.

_____b. sample only a known portion of the return wave that travels from the receiver to the antenna.

_____c. sample a known portion of the overall transmitted (incident) and reflected energy waves simultaneously.

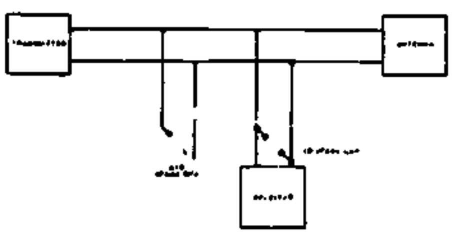


25. The purpose of the waveguide duplexer system shown below is to

_____a. use the transmitting line to transmit RF signals.

_____b. connect the transmitter to the waveguide while the antenna is receiving.

_____c. use TR and ATR circuits to permit single antenna operation.



26. A resonant cavity does (is) NOT

_____a. have its operating space completely enclosed by conducting walls.

_____b. have resonant properties.

_____c. contain oscillating electromagnetic fields.

_____d. designed for use above 2000 MHz.

_____e. contain inductive properties.

MODULE SELF-CHECK

27. Check the statements that describe the ADVANTAGES of a resonant cavity over an LC tank circuit.

_____a. rugged construction.

_____b. Has a higher Q.

_____c. Larger and heavier.

_____d. Operates at a lower frequency.

_____e. Permits accurate tuning and narrower bandpass.

_____f. Handles larger amounts of power.

28. Check the variables that will determine the primary frequency of a resonant cavity.

_____ a. Physical size.

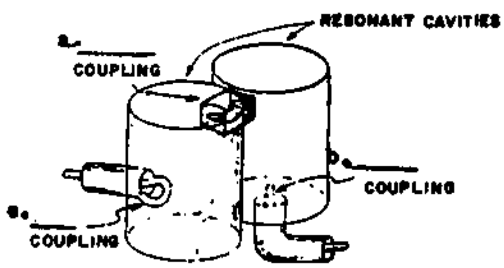
_____ b. Q.

_____ c. Shape of the cavity.

_____ d. Type of conducting material.

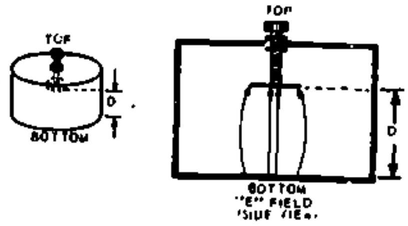
_____ e. Coupling method.

29. Identify the types of coupling in the illustration below by writing "loop," "iris," and "probe" in the proper space.

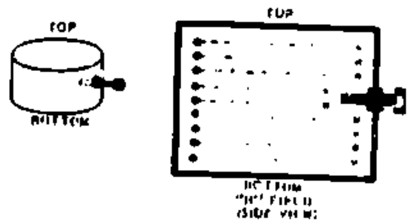


30. At the side of each illustration below, write either "capacitive," "inductive," or "volume" to identify the method of tuning shown.

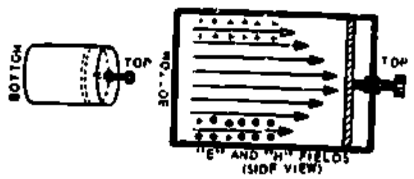
a. ____________________



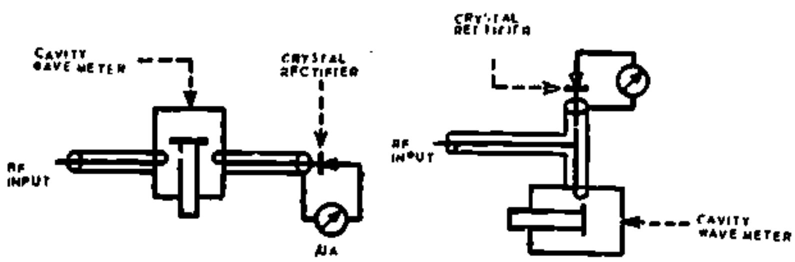
b. ____________________



c. ____________________



31. Refer to the wavemeter illustrations below to check the correct statements.



A. B.

____ a. Illustration A shows a transmission type wavemeter.

____ b. Illustration A shows an absorption type wavemeter.

____ c. Illustration B shows an absorption type wavemeter.

____ d. Only one of the wavemeters illustrated above measures the frequency in the cavity resonator.

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

MODULE SELF-CHECK

ANSWERS TO MODULE SELF-CHECK:

1. c. electromagnetic
2. a. circular b. rectangular (square)
3. b (rectangular)
4. a
5. a. A, b. B
6. A, B
7. a. H. b. b. E
6. c
9. a. E, b. H
10. a
11. b
12. a
13. c
14. a
15. b
16. (a) H (b) H (c) E (d) E
17. b
18. a. flexible, b. gradual H bend, c. twisted waveguide
19. a
20. c
21. b
22. b
23. a. (2) b. (1) c. (3)
24. c
25. c
26. e
27. a, b, e, f
28. a, c
29. a. iris, b. probe. c. loop
30. a. capacitive, b. inductive, c. volume
31. a, c

HAVE YOU ANSWERED ALL OF THE QUESTIONS CORRECTLY? IF NOT, REVIEW THE MATERIAL OR STUDY ANOTHER RESOURCE UNTIL YOU CAN ANSWER ALL QUESTIONS CORRECTLY. IF YOU HAVE, CONSULT YOUR INSTRUCTOR FOR FURTHER GUIDANCE.

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KEP-GP-75

Technical Training

Electronic Principles (Modular Self-Paced)

Module 75

MICROWAVE AMPLIFIERS AND OSCILLATORS

November 1975

AIR TRAINING COMMAND

7-14

Designed For ATC Course Use

ATC Keesler 6-2164

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Radar Principles Branch
Keesler Air Force Base, Mississippi

ATC GP 3AQR3X020-X
KEP-GP-75
November 1975

ELECTRONIC PRINCIPLES (MODULAR SELF-PACED)

MODULE 75

MICROWAVE AMPLIFIERS AND OSCILLATORS

This guidance package is designed to guide you through this module of the Electronic Principles Course. It contains specific information and references to other sources you may study that will enable you to satisfy the learning objectives.

CONTENTS

OVERVIEW

1. SCOPE: This module continues with the use and application of microwave devices, and examines the basic principles of microwave oscillators and amplifiers. It contains an introduction to the operation of special microwave tubes such as the klystron and the traveling-wave tube. A recognition of the principles and uses of the magnetron and parametric amplifier completes the unit.

2. OBJECTIVES: This module covers the following objectives:

a. Given a list of statements and a schematic diagram of a two-cavity klystron amplifier, select the statement that describes the operation.

b. Given a list of functions and a schematic diagram of a reflex klystron, match each function with its appropriate part.

c. Given a list of functions and a schematic diagram of a traveling-wave amplifier, match each function with its appropriate part.

d. Given a list of statements and a schematic diagram, select those that describe the operation of a parametric amplifier.

e. Given a list of statements and a schematic diagram, select those that describe the operation of a magnetron.

LIST OF RESOURCES

To satisfy the objectives of this module, you may choose, according to your training, experience, and preferences, any or all of the following:

READING MATERIALS:

Digest
Adjunct Guide with Student Text, Volume X

Supersedes KEP-GP-75, 1 June 1974, stock on hand will be used.

153

AUDIO VISUAL

TVK 30-913, Magnetron.

TVK 30-956, UHF and Microwave Oscillators.

AT THIS POINT, IF YOU FEEL THAT THROUGH PREVIOUS EXPERIENCE OR TRAINING YOU ARE FAMILIAR WITH THIS SUBJECT, YOU MAY TAKE THE MODULE SELF-CHECK.

CONSULT YOUR INSTRUCTOR IF YOU NEED HELP.

ADJUNCT GUIDE

INSTRUCTIONS:

Study the referenced materials as directed.

Return to this guide and answer the questions.

CONFIRM YOUR ANSWERS AT THE BACK OF THIS GUIDANCE PACKAGE.

Consult your instructor if you experience any difficulty.

Begin the program.

A. Turn to Student Text, Volume X and study paragraphs 3-1 through 3-13. This lesson covers the factors that cause poor operation of a conventional electron tube required to operate at the higher frequencies. Return to this page and answer the following questions.

Match actions listed in I with the terms in II.

I-ACTIONS

______ a. Sets the minimum limit on circuit inductance.

______ b. Influences tube oscillations and output.

______ c. Causes capacitive current that may disturb circuit operation.

______ d. Power loss caused by electromagnetic field radiation and skin effect.

II-TERMS

1. Interelectrode capacitance
2. Effect of electron transit time
3. Lead inductance
4. RF losses in external circuitry

CONFIRM YOUR ANSWERS

B. In all microwave tubes, electron transit time and its relationship to electron energy is critical.

Review paragraph 3-11. Then turn to Student Text, Volume X and study paragraphs 3-14 through 3-23. Return to this page and answer the following questions.

1. Transit time is the time required for the electrons to travel from the

______ a. cathode to the grid.

______ b. plate to cathode.

______ c. cathode to the plate.

2. At low frequencies

______ a. transit time is not a problem in electron tube oscillators.

______ b. tubes will not oscillate due to short transit times.

______ c. the actual transit time is great when compared to the time of one cycle.

3. When the transit time is longer than 1/10th of a cycle, the tube's efficiency

______ a. rises greatly.

______ b. drops greatly.

______ c. is not affected.

4. In microwave tubes, the limitation caused by transit time is solved by

______ a. using the transit time in converting the DC power to RF power by velocity modulation.

______ b. rectification of the electron energy; changing the DC power to AC power by frequency modulation.

______ c. using larger anodes.

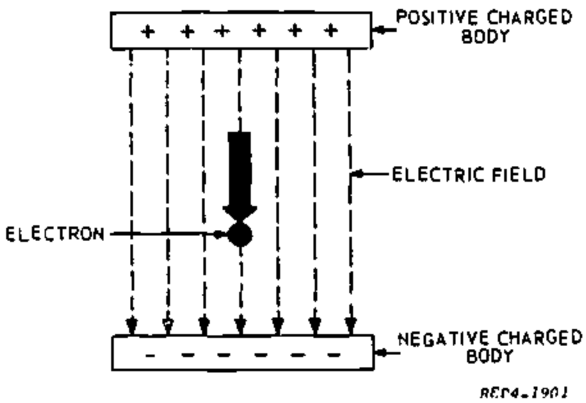


Figure 1

5. The electron in figure 1 is traveling (against)(with) the electrostatic field and (absorbs)(gives up) energy (from) (to) the electrostatic field and (accelerates) (decelerates).

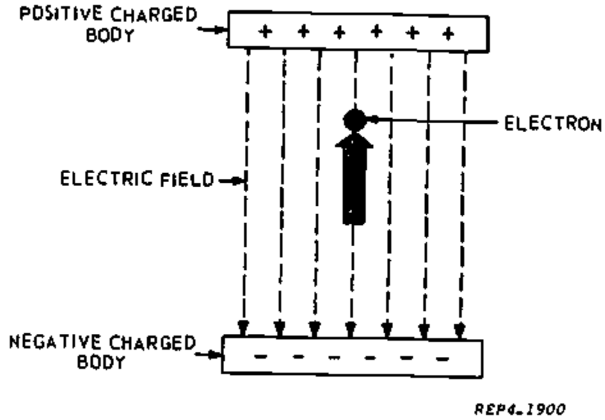


Figure 2

The electron in figure 2 is traveling (against) (with) the electrostatic field and (absorbs) (gives up) energy (from)(to) the electrostatic field and (accelerates)(decelerates).

CONFIRM YOUR ANSWERS

C. Turn to Student Text, Volume X and study paragraphs 3-25 through 3-38 for a simplified step-by-step explanation of velocity modulation. Return to this page and answer the following questions.

Refer to figure 3 and place the following statements in order as they would normally occur:

150

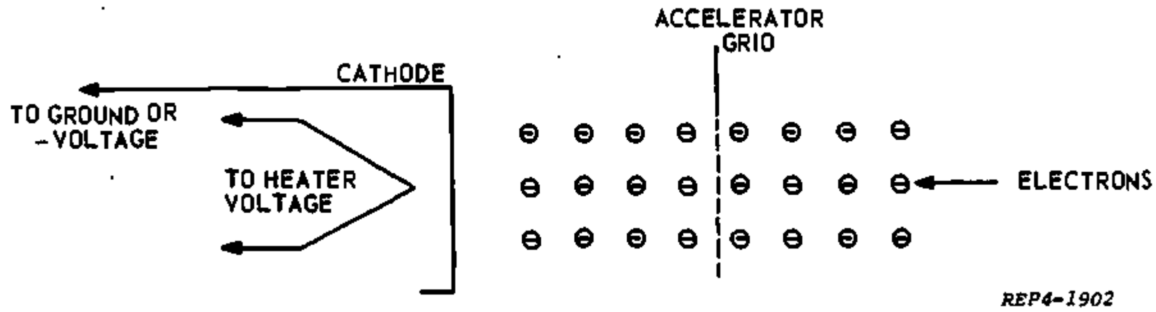


Figure 3

a. The electron beam passes through the buncher grids.

b. A constant stream of electrons is generated by the electron gun.

c. Electrons in the buncher cavity's electrostatic field are accelerated or decelerated by the rate of change of the AC field.

d. The electrons are attracted by the accelerator grid and pass through it and form a beam.

e. The velocity-modulated electrons drift into a field free area in bunches.

f. An output cavity at the point of maximum bunching induces an output RF voltage and causes cavity oscillations.

g. A periodic variation in electron beam density occurs.

h. Velocity modulation changes the DC beam into current density modulation at the same frequency as the changes occur in the buncher field cavity.

ORDER

1. ________

2. ________

3. ________

4. ________

5. ________

6. ________

7. ________

8. ________

CONFIRM YOUR ANSWERS

D. Klystrons are microwave tubes used as oscillators or amplifiers. The electron beam is velocity modulated.

Turn to Student Text, Volume X and study paragraphs 3-40 through 3-45. Return to this page and answer the following question.

1. Which of these statements describes the function of the catcher cavity in the two-cavity klystron?

_____ a. Forms electron bunches in the free field drift space.

_____ b. Controls the number of electrons in the beam.

_____ c. Collects the energy of the bunched DC electrons.

_____ d. Returns spare electrons to the cathode through an external circuit.

CONFIRM YOUR ANSWERS

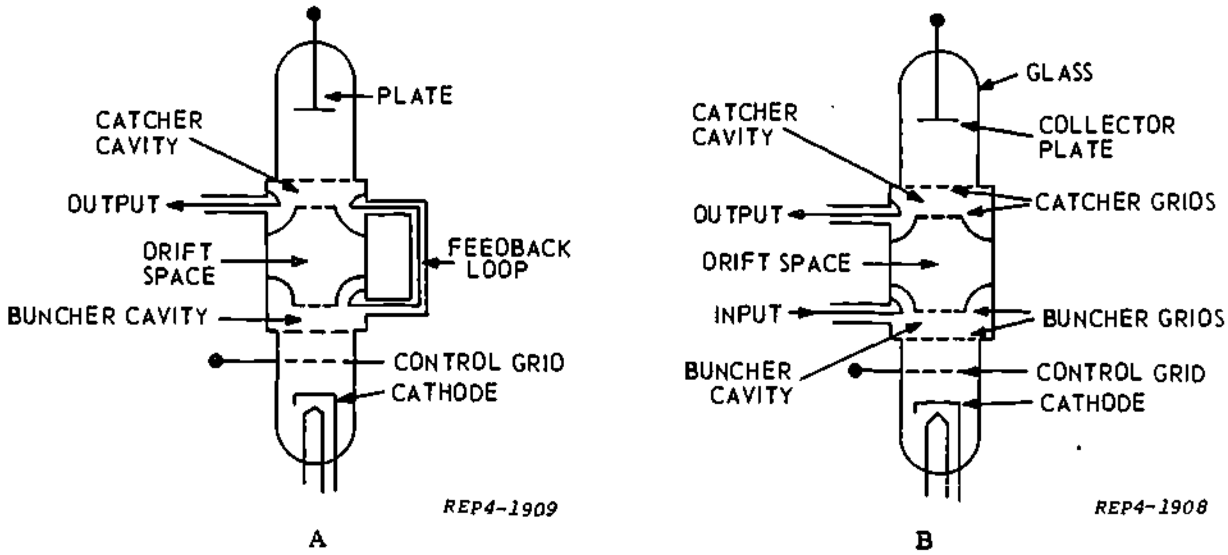


Figure 4

E. Turn to Student Text, Volume X and study paragraphs 3-46 through 3-48. Return to this page and answer the following questions.

1. Refer to the klystron drawings in figure 4 and check all statements that are TRUE.

_____ a. Klystron A is an oscillator because it has a feedback loop and no input coupling.

_____ b. Klystron A is an amplifier because it has an internal feedback path and an input coupling.

_____ c. Klystron B is an oscillator because the electrons return to the cathode externally.

_____ d. Klystron B is an amplifier because there is a maximum transfer of bunched energy to the output cavity and no feedback loop is provided.

2. Check the statement below that describes the operation of the two cavity klystron amplifier shown in figure 4B.

_____ a. A low frequency power tube that amplifies by frequency modulation using a constant velocity beam of electrons.

_____ b. An electron tube that operates in the microwave region by use of a feedback loop to provide an input to the input cavity.

_____ c. A microwave tube that takes in a low energy signal at the buncher cavity and delivers a high level output at the catcher cavity.

CONFIRM YOUR ANSWERS

F. Turn to Student Text, Volume X and study paragraphs 3-50 through 3-58. Return to this page and answer the following questions.

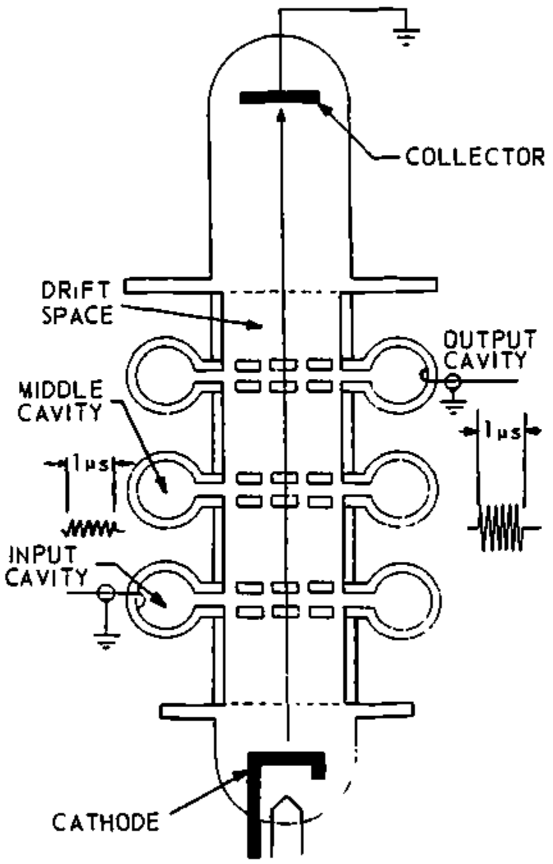


Figure 5

1. The advantages of using a klystron with more than two cavities are ____________, ____________ and ____________ ____________.

CONFIRM YOUR ANSWERS

G. Turn to Student Text, Volume X and study paragraphs 3-60 through 3-64. Return to this page and answer the following questions.

1. The reflex klystron has only one resonant cavity to bunch and collect the electrons. (True)(False)

2. The reflex klystron is used only as an amplifier. (True)(False)

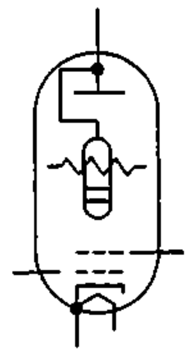
3. The feedback needed to sustain oscillations in a reflex klystron is produced by velocity modulating the accelerator grid. (True)(False)

4. The electron beam is produced by passing it through an oscillating resonant cavity. (True)(False)

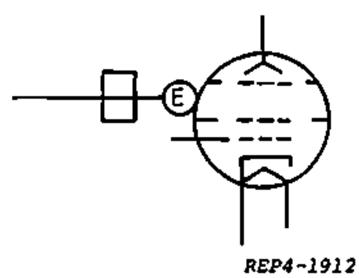
5. The reflex klystron obtains its name from the repelling action of the plate. (True)(False)

6. Reflex klystrons are used to generate high-power signals. (True)(False)

7. Which of the illustrations in figure 6 is the symbol for the reflex klystron?



A



B

Figure 6

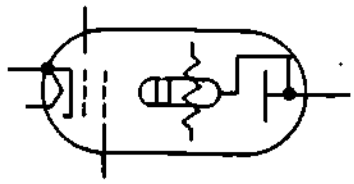
CONFIRM YOUR ANSWERS

2. Check the electronic symbol that represents the traveling wave tube.

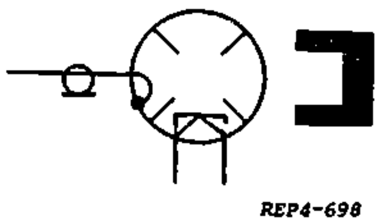
_____ a

_____ b

_____ c.



a



b

c

Figure 8

CONFIRM YOUR ANSWERS

K. Turn to Student Text, Volume X and study paragraphs 3-84 through 3-98. Return to this page and answer the following questions.

The TWT cutaway in figure 9 has numbered parts and areas along its length. Match these parts with the statement to which it relates.

STATEMENT

a. Solenoid magnet to produce magnetic focusing.

b. Where electrons are produced and accelerated.

c. The electron stream as it leaves the electron gun.

d. Adds to the electron velocity as the electrons come from the electron gun.

e. Reduces the RF signal on the helix and prevents the output signal from returning to the input coupler and causing oscillations.

f. A control axis to confine the electron stream in a narrow path, delay the RF signal and improve velocity modulation.

g. RF signal input at this point modulates the electron beam and causes bunching.

h. Removes the RF energy through a transformer coupling.

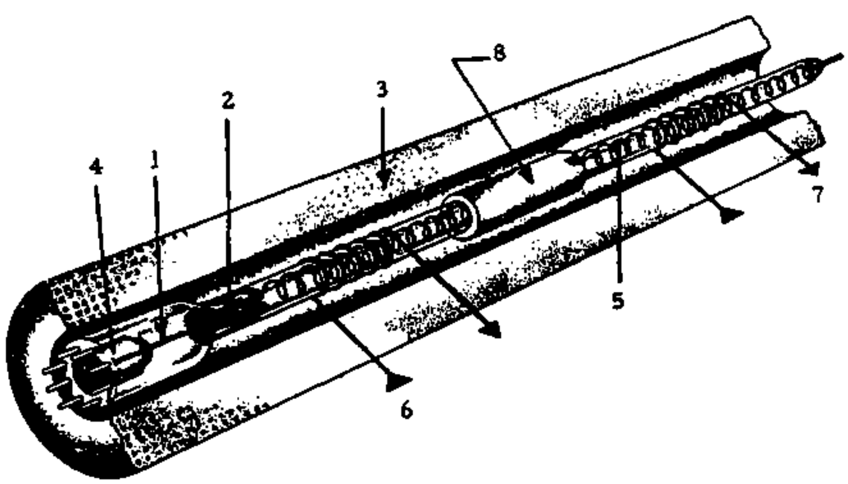


Figure 9. Cutaway View of a TWT

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____

CONFIRM YOUR ANSWERS

L. Turn to Student Text, Volume X and study paragraphs 4-1 through 4-8 to familiarize yourself with the parametric amplifier and recognize its improved qualities over the vacuum tube amplifier. Return to this page and answer the following question:

Check those statements that identify the advantages of the parametric amplifier over the vacuum tube amplifier.

______ a. Lower cost.

______ b. Simpler construction.

______ c. Improved signal-to-noise ratio.

______ d. Increased thermal circuit noise.

CONFIRM YOUR ANSWERS

M. Turn to Student Text, Volume X and study paragraphs 4-10 through 4-32 to identify those factors which cause amplification in a parametric amplifier and give it low signal-to-noise characteristic. Return to this page and answer the following questions. Indicate if each statement is True or False.

______ 1. The parametric amplifier uses a variable reactance.

______ 2. The high signal/noise ratio is achieved due to the lack of heat.

______ 3. The varactor diode is biased so that it never conducts.

______ 4. The parametric amplifier is tuned by adjusting the bias of the idler cavity.

______ 5. The pump frequency provides degenerative feedback which combines with the incoming frequency.

______ 6. The ferrite circulator isolates the input to the signal cavity from the output.

______ 7. The gain is controlled by the variable attenuator between the pump and the diode.

______ 8. The upconverter can be referred to as a mixer with gain.

______ 9. In the up-converter, the pump frequency is made as high as practical.

______ 10. The varactor diode is a nonlinear device.

11. Match the activities to their corresponding areas on the nondegenerative parametric amplifier shown in figure 10.

______ a. Difference signal recombined with pump energy signal produces antenna signal of greater amplitude than original input. Goes to ferrite circulator and to next step.

______ b. Pump energy signal input.

______ c. Antenna input through ferrite circulator to signal cavity.

______ d. Nonlinear action developes a difference (idler) frequency signal here.

______ e. Input signal developed here.

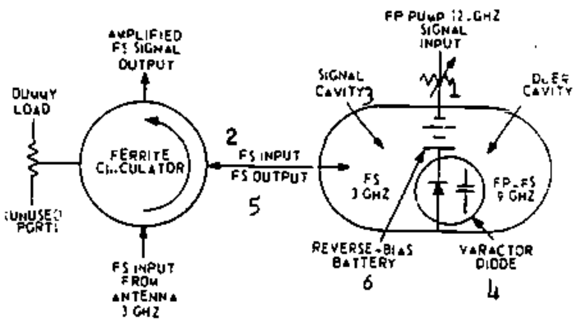


Figure 10

12. The ferrite circulator improves stability and reduces noise amplification. (True)(False)

13. The typical gain of a nondegenerative parametric amplifier is less than 10 dB. (True)(False)

14. The variable attenuator between the pump and the diode controls gain by varying the pump power to the varactor. (True) (False)

CONFIRM YOUR ANSWERS

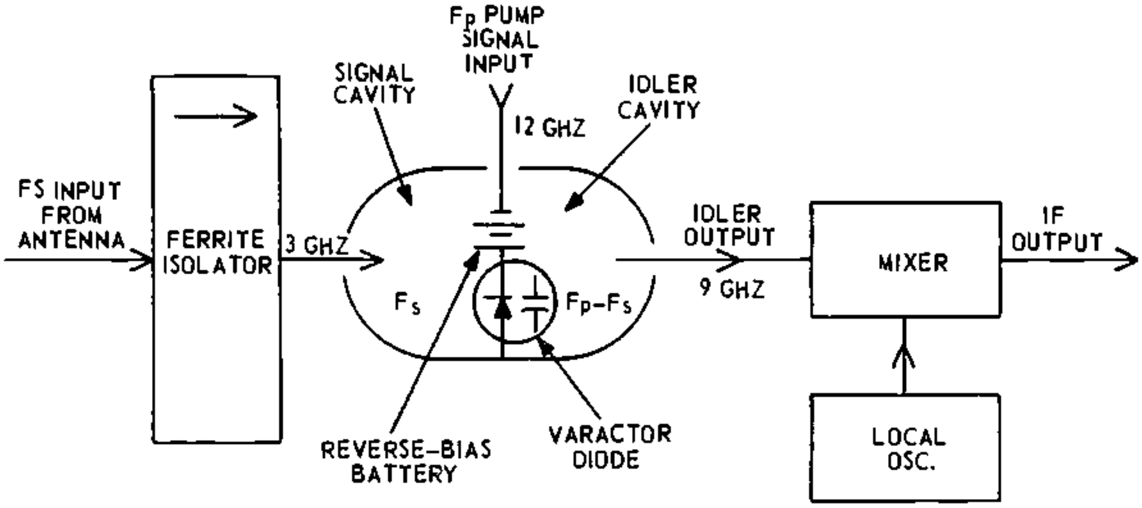


Figure 11

N. Turn to Student Text, Volume X and study paragraphs 4-34 and figure 4-6. Then return to this page and answer the following questions. Use figure 11.

1. In the up-converter parametric amplifier, the diode action results in a difference frequency only. (True)(False)

2. The pump signal and the incoming signal of the up-converter parametric amplifier are simultaneously impressed across the varactor diode. (True)(False)

3. The input frequency of the up-converter parametric amplifier is higher than the output frequency. (True)(False)

4. Identify the type of parametric amplifier in the statements that follow:

a. The pump signal and the incoming signal are applied to the varactor diode. The sum and difference frequencies are the output applied through a mixer and local oscillator. The output FS frequency is higher than the input frequency and it has been amplified. This describes the action of a/an

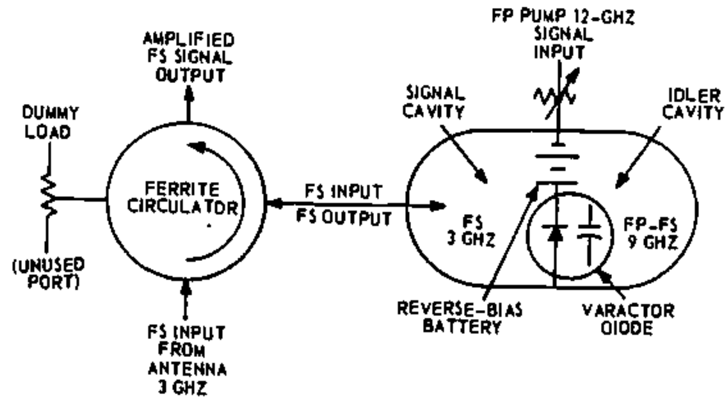
______________ parametric amplifier.

b. An input signal is developed in a signal cavity and applied across the diode. The energy content of the difference frequency is added to that of the original input signal. The output FS frequency is not changed but it is amplified. This describes the action of a/an ______________ parametric amplifier.

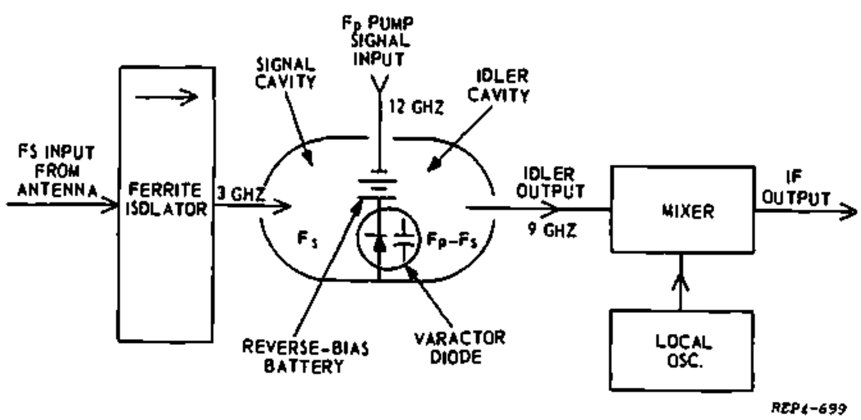
CONFIRM YOUR ANSWERS

O. From the information that you have previously learned, answer the following questions.

Label these schematics:



a. ______________________ parametric amplifier.



b. ______________________ parametric amplifier.

CONFIRM YOUR ANSWERS

162

P. Turn to Student Text, Volume X and study paragraphs 4-36 through 4-47 for a concise view of the magnetron's basic construction. Return to this page and answer the following questions.

1. Match each statement that applies to the magnetron components listed.

STATEMENT

_____ 1. A solid, cylindrical block of copper.

_____ 2. Centered on cathode axis, mounted as close as possible to cathode ends.

_____ 3. A metal sleeve.

_____ 4. Center area has space for mounting cathode.

_____ 5. Contains a heating element.

_____ 6. Has cooling fins to carry away heat.

_____ 7. Separate from anode-cathode construction.

_____ 8. Contains cavities that are resonant circuits.

_____ 9. May be directly or indirectly heated.

_____ 10. Coated with an emitting substance.

MAGNETRON COMPONENTS

a. Anode

b. Cathode

c. Magnet

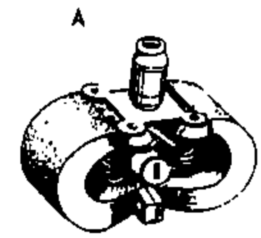
11. Select the packaged Magnetrons:

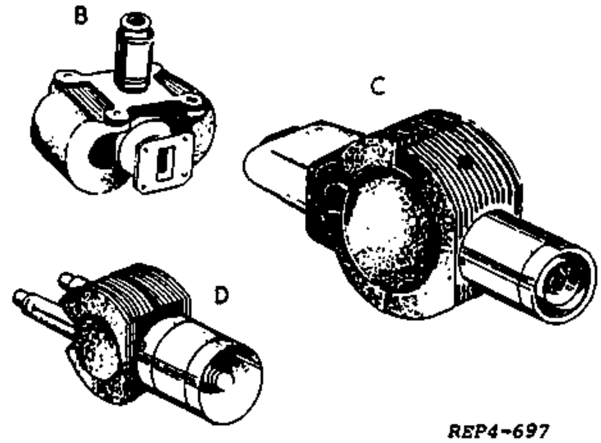
_____ a

_____ b.

_____ c.

_____ d.





REP4-697

Figure 13

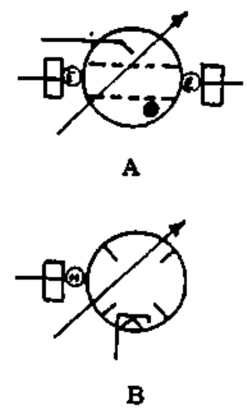
12. Select the schematic symbol for a magnetron equipped with permanent magnet.

_____ a.

_____ b.

_____ c.

_____ d.



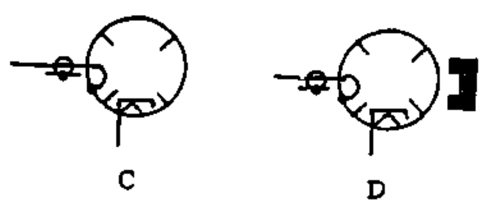


Figure 14

CONFIRM YOUR ANSWERS

Q. Turn to Student Text, Volume X and study paragraphs 4-48 through 4-53 to recognize how the permanent magnetic field influences an electron moving through it. Then return to this page and answer the following question.

Select the illustration that is correct with regard to electron path curvature and permanent magnetic field strength.

_____ a.

_____ b.

_____ c.

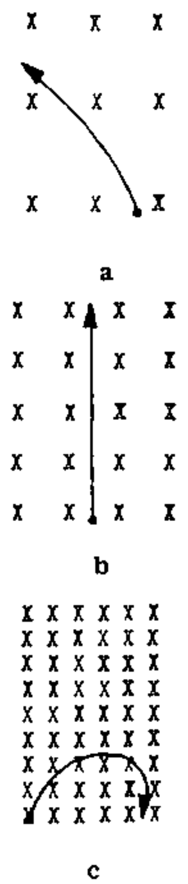


Figure 15

CONFIRM YOUR ANSWER

R. Turn to Student Text, Volume X and study paragraphs 4-54 through 4-58 to identify the DC electric field and the movement of an electron through it. Return to this page and answer the following questions.

Check the True statements concerning electron movement in the magnetron.

_____ a. The cathode is positive and the anode is negative.

_____ b. Electrons follow a straight path from anode to cathode.

_____ c. The anode is positive and the cathode is negative.

_____ d. The electron follows a straight path from cathode to anode.

_____ e. The strength of the DC electric field and the permanent magnetic field determine the number of cycloids.

_____ f. The DC electric field exists between the cathode and the anode.

_____ g. The magnetron's interaction space exists between the anode and the permanent magnet.

_____ h. The electron follows a cycloidal path between the cathode and the anode.

_____ i. Each cavity in the anode acts as an LC tank circuit.

CONFIRM YOUR ANSWERS

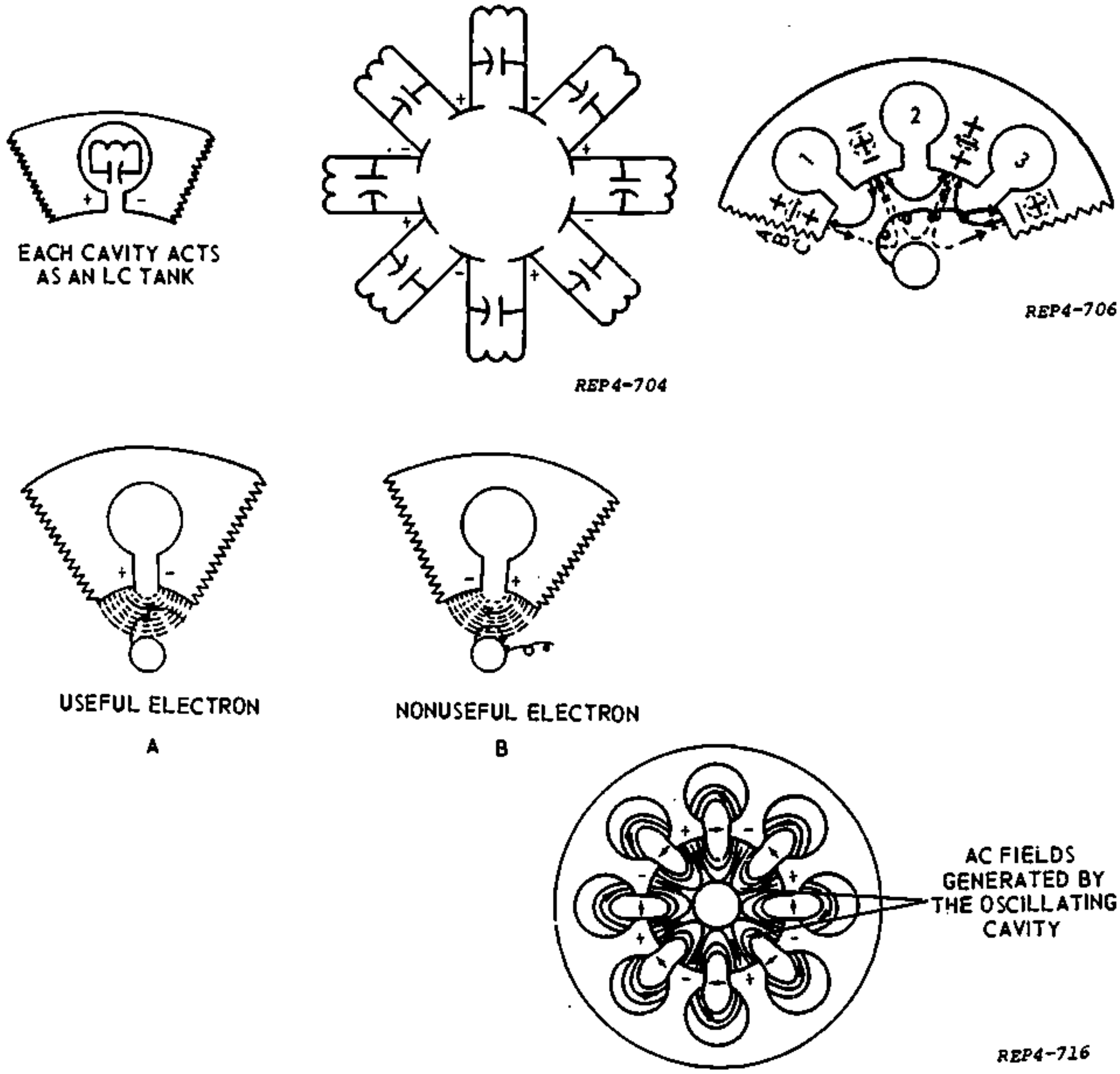

EACH CAVITY ACTS
AS AN LC TANK
REP4-704
1
2
3
REP4-706
USEFUL ELECTRON
A
NONUSEFUL ELECTRON
B
AC FIELDS
GENERATED BY
THE OSCILLATING
CAVITY
REP4-716

Figure 16

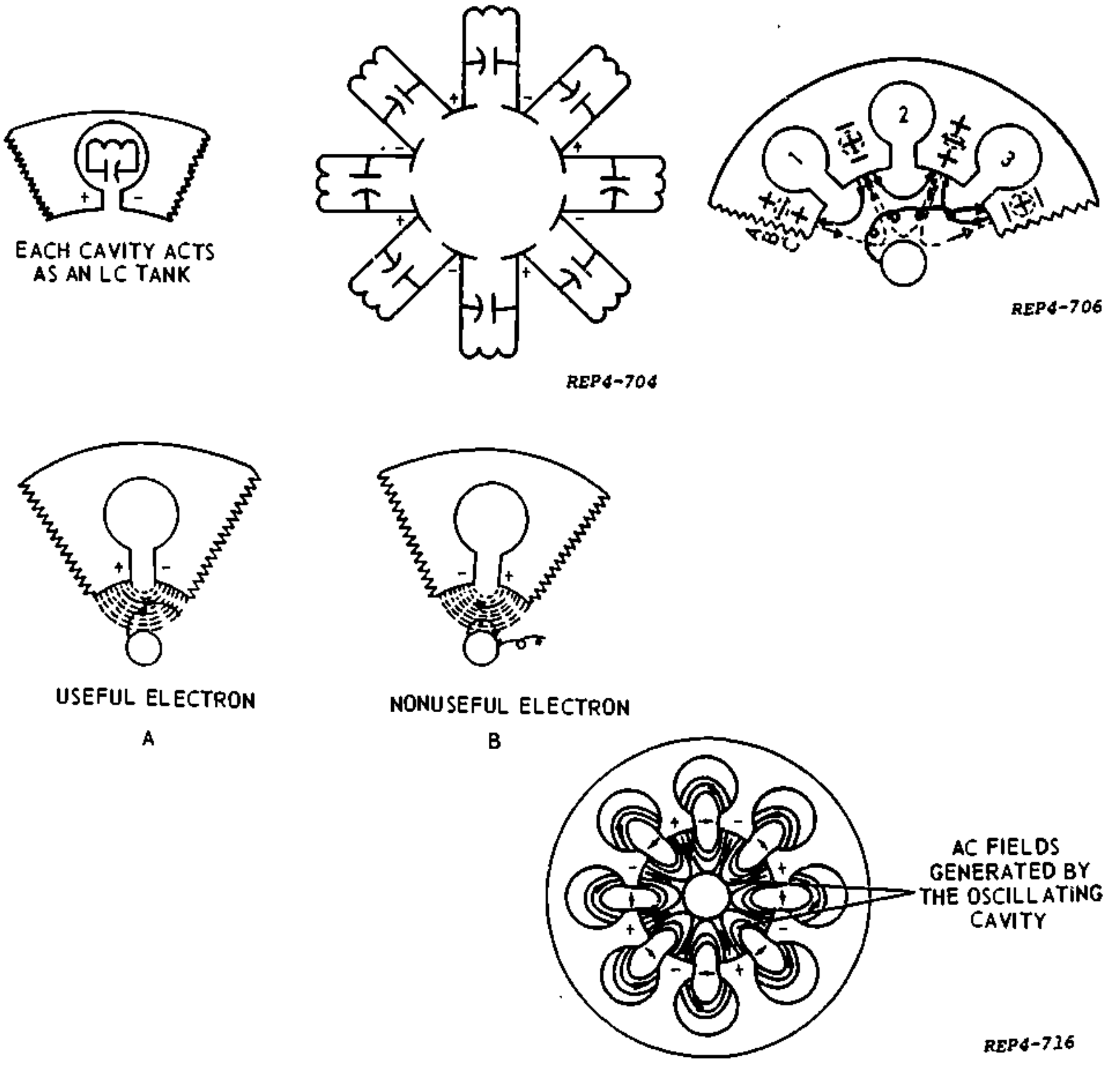

EACH CAVITY ACTS AS AN LC TANK
REP4-704
1
2
3
REP4-706
USEFUL ELECTRON
A
NONUSEFUL ELECTRON
B
AC FIELDS GENERATED BY THE OSCILLATING CAVITY
REP4-716

Figure 16

S. Turn to Student Text, Volume X and study paragraphs 4-59 through 4-62. Return to this page and answer the following questions.

Match the statements in Column A with the terms in Column B. Refer to the diagrams on page 14 if necessary.

COLUMN A

_____ a. Receives energy from a "useful" electron.

_____ b. Anode segments are of opposite polarity.

_____ c. Results in greater electron emission from cathode.

_____ d. Produces an RF voltage.

_____ e. Gives up energy to a "nonuseful" electron.

_____ f. Reverse direction every half-cycle.

_____ g. Retards electron velocity; sustains cavity oscillations.

_____ h. Nonuseful electrons return to the cathode.

_____ i. Shocked into oscillation by potential difference between cathode and anode.

_____ j. In-phase with useful electron's cycloidal path.

_____ k. Allows electron to deliver energy to several oscillating cavities.

_____ l. Extend as closed loops into cavities and interaction space.

COLUMN B

1. Oscillating cavity

2. AC field

3. Back bombardment

4. Transit time control

CONFIRM YOUR ANSWERS

T. Turn to Student Text, Volume X and study the grouping action of the electrons which is covered in paragraphs 4-63 through 4-65. Return to this page and answer the following questions.

Select the one or more statements that describe the operation of a magnetron.

_____ a. Electrons emitted by the cathode are put into a cycloidal path, bunched into groups, and release their energy to the AC field of each cavity.

_____ b. The desired mode of operation is the one in which there is a 90-degree difference between the anode segments.

_____ c. Magnetrons can oscillate in several different modes. This is desirable.

_____ d. If the mode of operation changes in the magnetron, the frequency remains in same.

CONFIRM YOUR ANSWERS

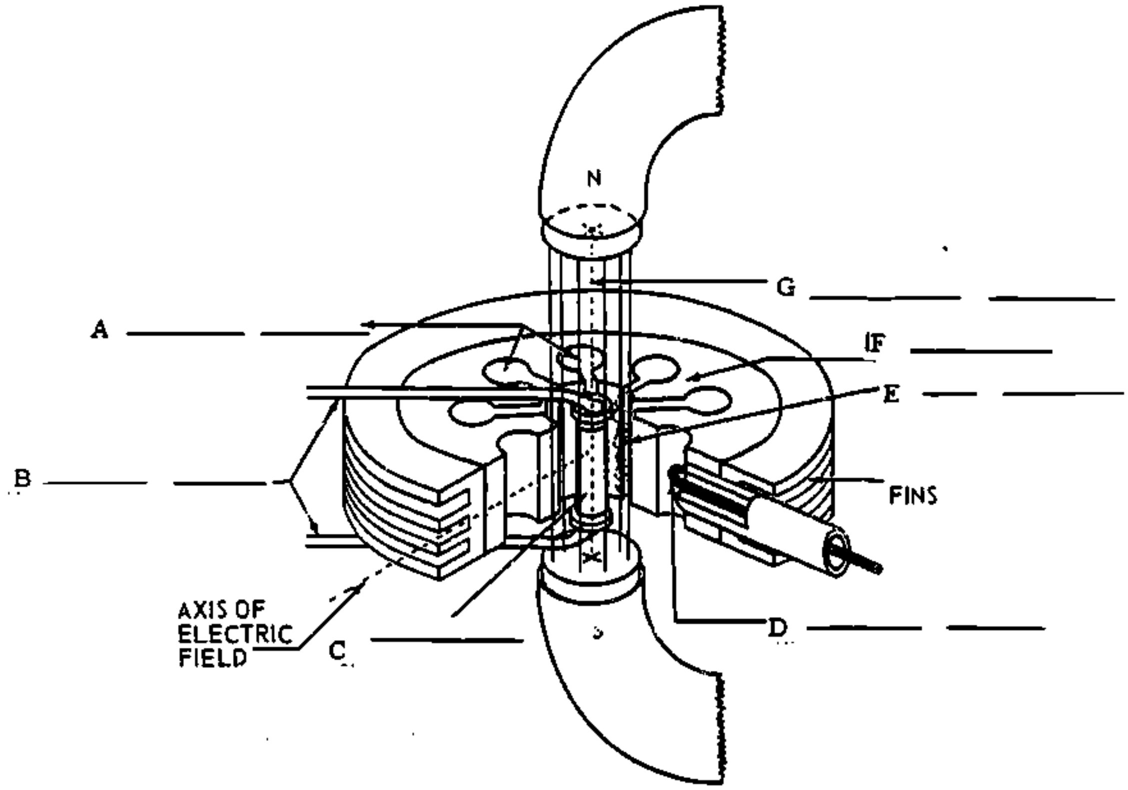


Figure 17

U. Turn to Student Text, Volume X and read paragraphs 4-66 through 4-79. Return to this page and answer the following questions.

1. Refer to figure 17 and fill in the blank spaces with one or the following terms:

- Coupling Loop
- Magnetic Field
- Heater Leads
- Resonant Cavities
- AC Field
- Cathode

2. The permanent magnetic field strength is critical in the control of transit time, output power, and the magnetron's frequency. Circle the action that will result if the magnetic flux density decreases from normal.

a. Electron transit time (Increases) (Decreases)

b. Magnetron frequency (Changes) (Remains Stable)

c. Output power (Increases) (Decreases)

CONFIRM YOUR ANSWERS

MODULE SELF-CHECK

QUESTIONS:

1. Identify the factor that does NOT cause poor operation of conventional electron tubes at the higher frequencies.

_____ a. Interelectrode capacitance.

_____ b. Electron transit time.

_____ c. Transconductance.

_____ d. Lead inductance.

_____ e. RF loss in external circultry.

2. Which illustration shows the electron decelerating and giving up energy to the electrostatic field?

_____ a

_____ b

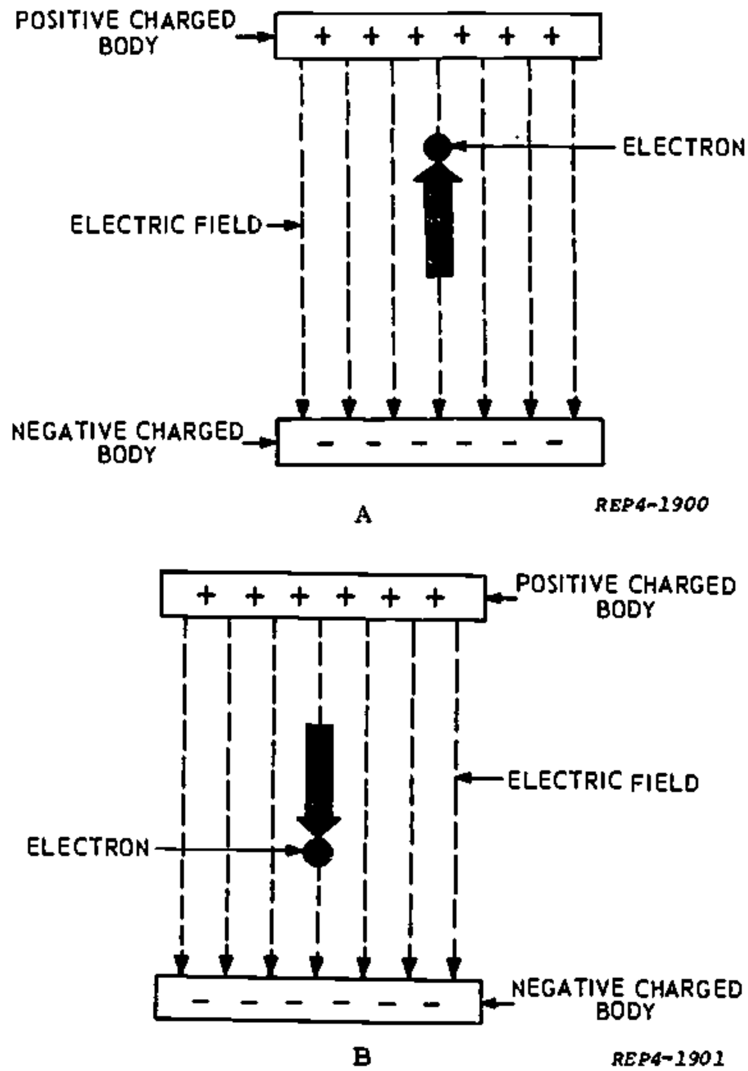


Figure 1

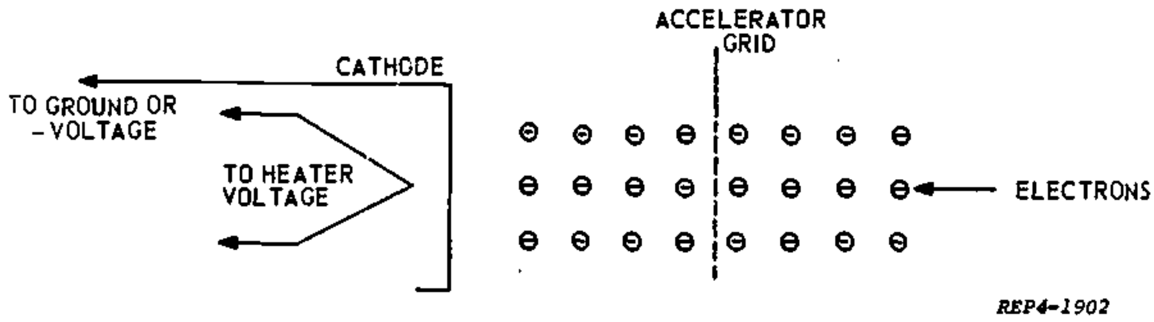


Figure 2

3. Refer to figure 2 above and identify each statement on velocity modulation as true or false.

_____ a. The electrons are repelled by the accelerator grid, pass around it and form a beam.

_____ b. Velocity-modulated electrons drift into a field-free area and bunch.

_____ c. The output cavity at the point of maximum electron bunching induces an RF voltage in the grid gap and causes the cavity to oscillate.

_____ d. Velocity modulation changes the DC beam into a current-modulated beam at a different frequency than the changes in the buncher field cavity.

4. The catcher grids in a two-cavity klystron:

_____ a. Return spare electrons to the cathode through an external circuit.

_____ b. Absorb the energy of the bunched DC electrons.

_____ c. Control the number of beam electrons.

_____ d. Form electron bunches in the free-field drift space.

5. Select the true statement for this klystron.

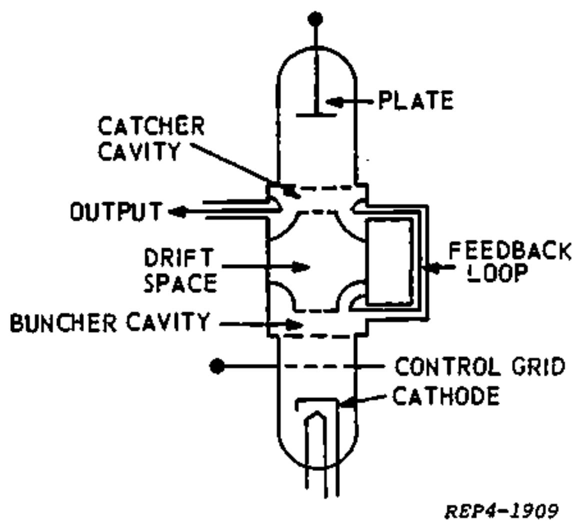


Figure 3

_____ a. This klystron is an oscillator because it has a feedback loop and no input coupling.

_____ b. This klystron is an amplifier because there is a maximum transfer of electron-bunched energy to the output cavity and no feedback loop to the input cavity.

170

6. Which statement describes the operation of the two-cavity klystron amplifier shown below?

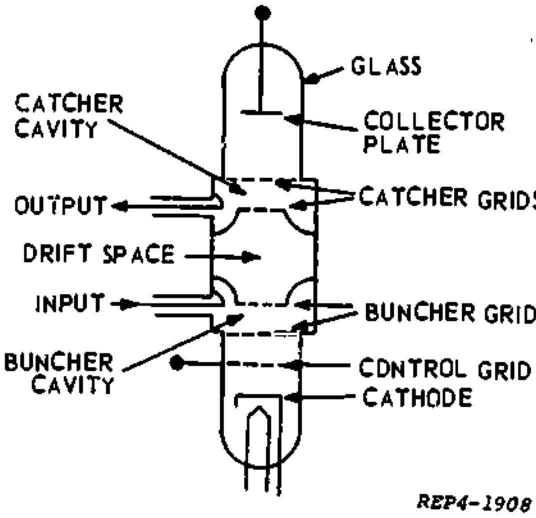


Figure 4

______ a. This electron tube operates in the microwave region by using a feedback loop to excite the input cavity.

______ b. This power tube amplifies by frequency modulating a constant velocity beam of electrons.

______ c. This microwave tube has a low energy signal applied to the buncher cavity and delivers a high energy signal from the catcher cavity.

7. The reflex klystron obtains its name from

______ a. the repelling action of the repeller plate.

______ b. the reflex action of its multiple resonant cavities.

______ c. the negative feedback which causes acceleration of the electron beam.

______ d. the method used to tune the single cavity.

8. Match the numbered part of the cutaway illustration below with the statement that applies.

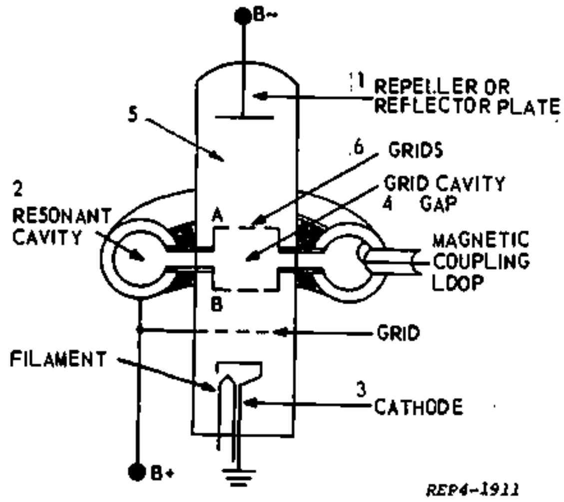


Figure 5

______ a. Electrons passing this point either accelerate, decelerate or do not change their velocity.

______ b. The electrons velocity and momentum determines the distance they will travel into this space.

______ c. Boils off electrons, forms an electron beam and directs the beam of electrons toward the repeller plate.

______ d. Causes electrons to be repelled back to the grid gap so they can contact grid A when it is at maximum positive with respect to grid B.

______ e. The electron beam is modulated in this area; controls the electron beam as it passes through.

______ f. Produces oscillations with an alternating voltage as its grid potential.

9. Write FINE or COARSE in the space provided to identify the type of reflex klystron tuning described.

_____ a. An electrical process.

_____ b. Adjustment of a tuning strut to alter grid distances of the resonant cavity which changes cavity capacitance.

_____ c. A mechanical process.

_____ d. Changes repeller plate voltage to alter the time of the electron return to the cavity grid.

10. True or False:

A traveling wave tube has a wide bandwidth because it/its:

_____ a. lacks a lumped input capacity.

_____ b. has two resonant circuits.

_____ c. has no resonant circuits.

_____ d. has negative attenuation in the forward direction.

_____ e. input and output transducers are designed to cover a bandwidth greater than one octave.

11. Which symbol represents the traveling wave tube?

_____ a.

_____ b.

_____ c.

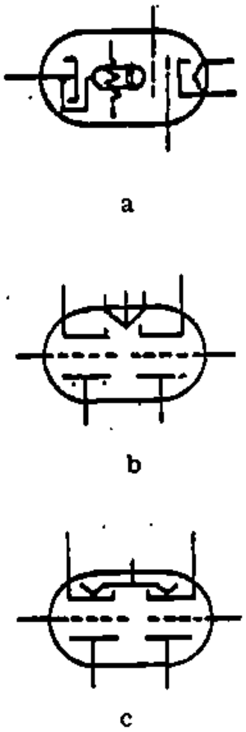


Figure 6

172

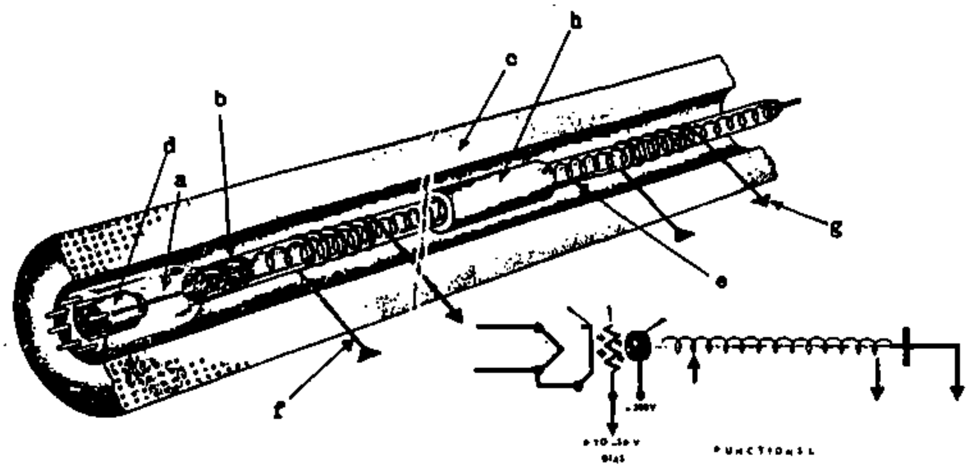


Figure 7

12. Match each function listed below with the appropriate lettered part on the traveling wave amplifier.

FUNCTION

_____ (1) Solenoid magnet to produce magnetic focusing.

_____ (2) Where electrons are produced and accelerated.

_____ (3) The electron stream as it leaves the electron gun.

_____ (4) Adds to the electron velocity as the electrons come from the electron gun.

_____ (5) Reduces the RF signal on the helix and prevents the output signal from returning to the input coupler and cause oscillations.

_____ (6) A control axis to confine the electron stream in a narrow path, delay the RF signal and improve velocity modulation.

_____ (7) RF signal input to alter the electron velocities and cause bunching.

_____ (8) Removes the RF energy through a transformer coupling.

13. The advantage of a parametric amplifier over a vacuum tube amplifier is

_____ a. increased signal-to-noise ratio.

_____ b. decreased signal-to-noise ratio.

_____ c. unlimited gain.

_____ d. unlimited bandwidth.

14. Match the activities below with the areas to which they corresponds on the non-degenerative parametric amplifier schematic:

______ (1) Difference signal recombined with pump energy signal produces signal of greater amplitude than original input. Goes to ferrite circulator and to next step.

______ (2) Pump energy signal input.

______ (3) Antenna input through ferrite circulator to signal cavity.

______ (4) Nonlinear action developes a difference (idler) frequency signal here.

______ (5) Input signal developed in this cavity.

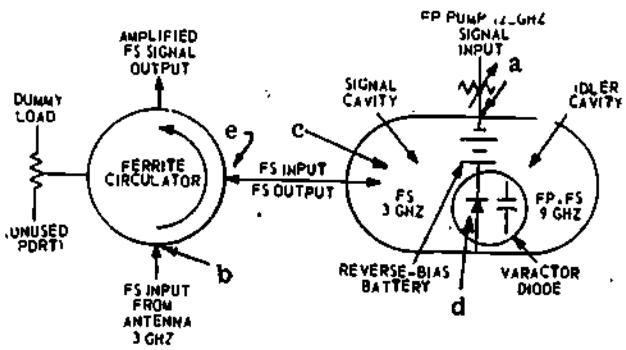


Figure 8

15. Select the true statement with regard to the operation of the up-converter amplifier shown in figure 9.

______ a. In the up-converter parametric amplifier, the diode action results in a difference frequency only.

______ b. The pump signal and the incoming signal of the up-converter parametric amplifier are simultaneously impressed across the varactor diode.

______ c. The input frequency of the up-converter parametric amplifier is higher than the output frequency.

16. Identify the type of parametric amplifier described in each statement below:

a. The pump signal and the incoming signal are applied to the varactor diode. The sum and difference frequencies are the output applied through a mixer and local oscillator. The output FS frequency is higher than the input frequency and it has been amplified. This describes the action of a (an) ________________ parametric amplifier.

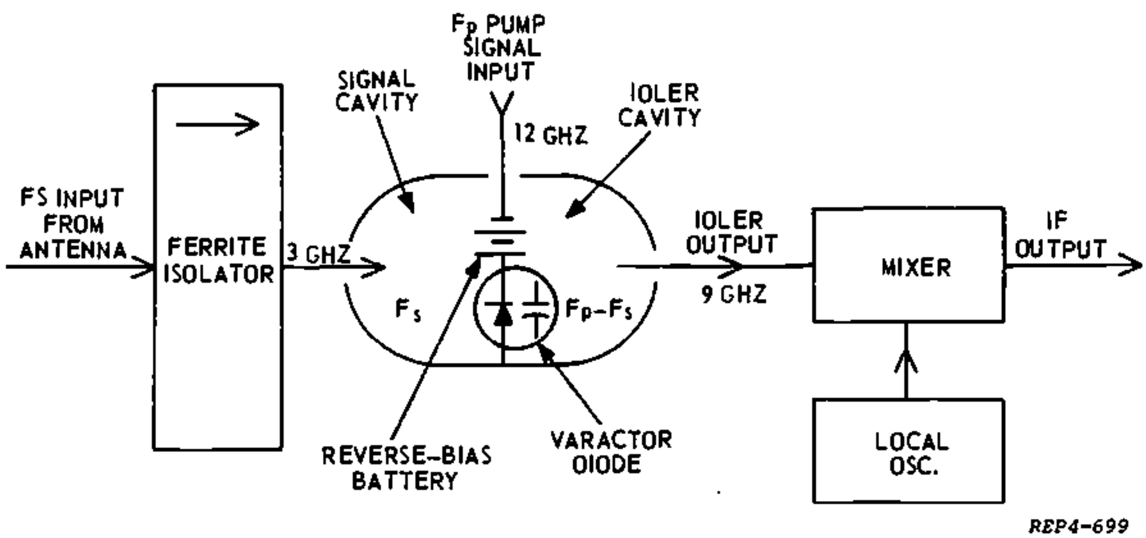


Figure 9

b. An input signal is developed in a signal cavity and applied across the diode. The energy content of the difference frequency is added to that of the original input signal. The output FS frequency is not changed but it is amplified. This describes the action

of a (an) ____________________ parametric amplifier.

17. Which of these statements describe the anode of a magnetron.

_____ a. A thin metal sleeve around the cathode.

_____ b. Contains cavities that are resonant circuits.

_____ c. A high positive voltage is applied.

_____ d. Does not require cooling.

18. Which of these statements describe the cathode of a magnetron?

_____ a. Contains cavities that are resonant circuits.

_____ b. Must be directly heated.

_____ c. Is a small current device.

_____ d. Coated with an emitting substance.

_____ e. Is mounted at right angles to the anode.

19. Which of these statements describe the magnet of a magnetron?

_____ a. Centers on the cathode axis and mounted as close as possible to the cathode ends.

_____ b. Has cooling fins.

_____ c. Is an electromagnet.

_____ d. Mounted so that the magnetic lines of force are parallel with the DC field.

20. Which symbol represents a magnetron equipped with a permanent magnet?

_____ a.

_____ b.

_____ c.

_____ d.

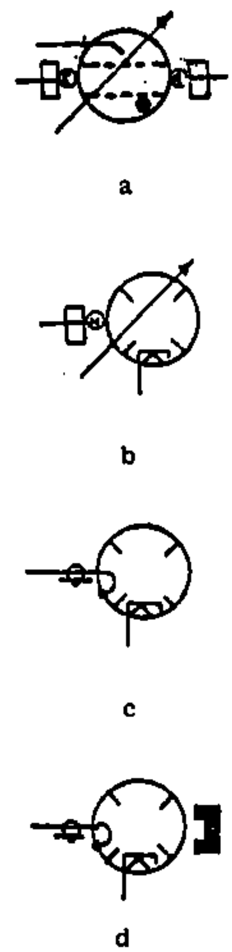


Figure 10

21. Which statement is NOT true concerning electron movement in the magnetron?

_____ a. The anode is positive and the cathode is negative.

_____ b. The strength of the DC electric field and the permanent magnetic field determines the number of cycloids.

______ c. The magnetron's interaction space exists between the anode and the permanent magnet.

______ d. Each cavity in the anode acts as an LC tank circuit.

22. Which statement describes the operation of a magnetron?

______ a. The desired mode of operation is one in which there is a 90-degree difference between the anode segments.

______ b. Magnetrons normally oscillate in several different modes, depending on the number of anode cavities.

______ c. If the mode of operation changes in the magnetron, the frequency remains the same.

______ d. Electrons emitted by the cathode are put into a cycloidal path by the magnetic field, bunch into groups, and release their energy to the AC field of each cavity.

23. Complete the blank spaces on the illustration below, using the correct number from the list of terms that follows.

TERMS

(1) AC Field
(2) Permanent Magnetic Field
(3) Coupling Loop
(4) Heater Leads
(5) Anode
(6) Cathode
(7) Oscillating Cavities

ILLUSTRATION

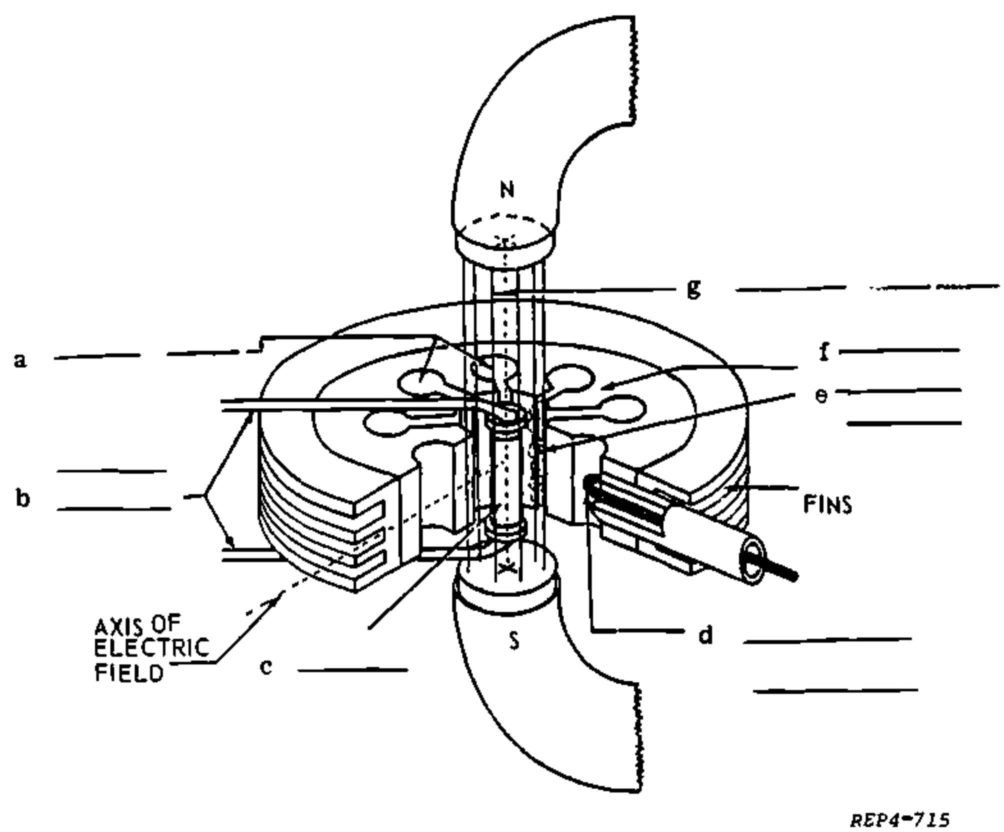


Figure 11

24. Write CHANGES or DECREASES in the blank after each action below to identify what will result in a magnetron when the magnetic flux density decreases from normal.

a. Electron transit time. ______________

b. Magnetron frequency. ______________

c. Output power. ______________

CONFIRM YOUR ANSWERS

ANSWERS TO A - ADJUNCT GUIDE

a. 3
b. 1, 2, 3, 4
c. 1
d. 4

If you missed ANY questions, review the material before you continue.

ANSWERS TO B - ADJUNCT GUIDE

1. c
2. a
3. b
4. a
5. A. with, gives up, decelerates
   B. against, absorbs, accelerates

If you missed ANY questions, review the material before you continue.

ANSWERS TO C - ADJUNCT GUIDE

1. b
2. d
3. a
4. c
5. e
6. g
7. h
8. f

If you missed ANY questions, review the material before you continue.

ANSWERS TO D - ADJUNCT GUIDE

1. c

If you missed ANY questions, review the material before you continue.

ANSWERS TO E - ADJUNCT GUIDE

1. a, d
2. c

If you missed ANY questions, review the material before you continue.

ANSWERS TO F - ADJUNCT GUIDE

1. higher gain, greater efficiency

If you missed ANY questions, review the material before you continue.

ANSWERS TO G - ADJUNCT GUIDE

1. True
2. False
3. False
4. False
5. True
6. False
7. B

If you missed ANY questions, review the material before you continue.

ANSWERS TO H - ADJUNCT GUIDE

1. d
2. f
3. c
4. e
5. b
6. a

If you missed ANY questions, review the material before you continue.

ANSWERS TO I - ADJUNCT GUIDE

1. b
2. a
3. a
4. b

If you missed ANY questions, review the material before you continue.

ANSWERS TO J - ADJUNCT GUIDE

1. a
   c
   e
2. a

If you missed ANY questions, review the material before you continue.

ANSWERS TO K - ADJUNCT GUIDE

1. c
2. d
3. a
4. b
5. f
6. g
7. h
8. e

If you missed ANY questions, review the material before you continue.

ANSWERS TO L - ADJUNCT GUIDE

a
b
c

If you missed ANY questions, review the material before you continue.

ANSWERS TO M - ADJUNCT GUIDE

1. True
2. True
3. True
4. False
5. False
6. False
7. True
8. True
9. True
10. True
11. a. 5
    b. 1
    c. 2
    d. 4
    e. 3
12. True
13. False
14. True

If you missed ANY questions, review the material before you continue.

ANSWERS TO N - ADJUNCT GUIDE

1. False
2. True
3. False
4. Up-converter
   b. Nondegenerative

If you missed ANY questions, review the material before you continue.

ANSWERS TO O - ADJUNCT GUIDE

a. Nondegenerative
b. Up-converter

If you missed ANY questions, review the material before you continue.

ANSWERS TO P - ADJUNCT GUIDE

1. a
2. c
3. b
4. a
5. b
6. a
7. c
8. a
9. b
10. b
11. A, B
12. d

If you missed ANY questions, review the material before you continue.

ANSWER TO Q - ADJUNCT GUIDE

c.

If you missed ANY questions, review the material before you continue.

ANSWERS TO R - ADJUNCT GUIDE

c
e
f
h
i

If you missed ANY questions, review the material before you continue.

ANSWERS TO S - ADJUNCT GUIDE

a. 2
b. 1
c. 3
d. 1
e. 2
f. 2
g. 4
h. 3
i. 1
j. 1
k. 4
l. 2

If you missed any questions, review the material before you continue.

ANSWERS TO T - ADJUNCT GUIDE

a.

If you missed ANY questions, review the material before you continue.

ANSWERS TO U - ADJUNCT GUIDE

1. A. Resonant Cavities
   B. Heater Leads
   C. Cathode
   D. Coupling Loop
   E. AC Field
   F. Anode
   G. Magnetic Field
2. A. Decreases
   B. Changes
   C. Decreases

If you missed ANY questions, review the material before you continue.

ANSWERS TO MODULE SELF-CHECK

1. c
2. b
3. a. False
   b. True
   c. True
   d. False
4. b
5. a
6. c
7. a
8. (6) a
   (5) b
   (3) c
   (1) d
   (4) e
   (2) f
9. fine a
   coarse b
   coarse c
   fine d
10. true a
    false b
    true c
    false d
    true e
11. a
12. c (1)
    d (2)
    a (3)
    b (4)
    h (5)
    e (6)
    f (7)
    g (8)
13. a
14. e (1)
    a (2)
    b (3)
    d (4)
    c (5)

15. b
16. a. up-converter
    b. nondegenerative
17. b
18. d
19. a
20. d
21. c
22. d

23. a. (7)
    b. (4)
    c. (6)
    d. (3)
    e. (1)
    f. (5)
    g. (2)
24. a. Decreases
    b. Changes
    c. Decreases

176

PREPARE THE MAN

ATC GP 3AQR3X020-X
Prepared by Keesler TTC
KEP-GP-76

Technical Training

ELECTRONIC PRINCIPLES (MODULAR SELF-PACED)

MODULE 76

SOLDERING TOOLS AND MATERIALS

1 June 1974

AIR TRAINING COMMAND

7-14

Designed For ATC Course Use

DO NOT USE ON THE JOB

177

Electronic Principles Department
Keesler Air Force Base, Mississippi

ATC GP 3AQR3X020-X
KEP-GP-76
1 June 1974

ELECTRONC PRINCIPLES

MODULE 76

This Guidance Package is designed to guide you through this module of the Electronic Principles Course. It contains specific information and references to other sources you may study, that will enable you to satisfy the learning objectives.

CONTENTS

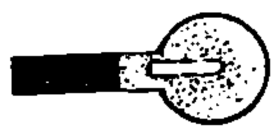
Errata 1 for Guidance Package, KEP-GP-76, 1 June 1974

1 January 1975

PAGE	LINE	CORRECTION
4	3	Change "lead" to "tin" and "tin" to "lead"
20	3	Replace illustrations with the following:

a. ____________

b. ____________



c. ____________

d. ____________

e. ____________

f. ____________

Supersedes Guidance Package KEP-GP-76, 1 January 1974, which will be used until exhausted.

183

SOLDERING TOOLS AND MATERIALS

1. SCOPE: This module will introduce you to the theory of soldering and the safety procedures to be followed when making repairs on electronic circuitry. It will show you the proper use of tools and materials you will use in the laboratory phase of your soldering training. This module outlines the accepted procedures to be used in soldering and desoldering components and conductors on circuit boards and will prepare you with the skills which will enable you to build an operational circuit.

2. OBJECTIVES: Upon completion of this module you should be able to satisfy the following objectives:

a. Given a list of applications pertaining to the soldering process, match them with pictures of the following tools and list of materials:

(1) Tools

(a) Soldering iron

(b) Bending tools

(c) File

(d) Heat sink

(e) Wire strippers

(f) Diagonal cutting pliers

(2) Materials

(a) Emery cloth

(b) Erasers

(c) Brushes

(d) Cloth, paper tissues, or sponge

b. Given a printed circuit board with examples of soldered connections, indicate those with the correct amount of solder:

(1) Single turret connection

(2) Single bifurcated connection

(3) Pads

c. Given a printed circuit board with examples of soldered connections, indicate those with the correct insulation clearance:

(1) Single turret connection

(2) Single bifurcated connection

OVERVIEW

d. Given a list of statements covering soldering principles, select the correct statement(s) that describe(s):

(1) Results of improper heat

(2) Type of solder used in electronics

(3) Proper alloy ratios and melting points

(4) Correct mechanical and electrical characteristics of a properly soldered connection.

(5) Proper type and use of flux

(6) Correct type and use of solvent

AT THIS POINT YOU MAY TAKE THE MODULE SELF CHECK. IF YOU DECIDE NOT TO TAKE THE MODULE SELF CHECK, TURN TO THE NEXT PAGE AND PREVIEW THE LIST OF RESOURCES. DO NOT HESITATE TO CONSULT YOUR INSTRUCTOR IF YOU HAVE ANY QUESTIONS.

LIST OF RESOURCES

SOLDERING TOOLS AND MATERIALS

To satisfy the objectives of this module, you may choose, according to your training, experience, and preferences, any or all of the following:

READING MATERIALS:

Adjunct Guide with Student Text

Programmed Text

AUDIO VISUALS:

TV Lesson, Soldering Techniques, TVK-30-401-B

SELECT ONE OF THE RESOURCES AND BEGIN YOUR STUDY OR TAKE THE MODULE SELF-CHECK.

CONSULT YOUR INSTRUCTOR IF YOU REQUIRE ASSISTANCE.

DIGEST

SOLDERING TOOLS AND MATERIALS

Soldering is the action of bonding two or more metal surfaces together with a metal alloy. The alloy is melted as the surfaces are heated. The heat is removed and the alloy is allowed to cool. The alloy used for bonding in electronic maintenance is 60% lead and 40% tin and has a melting point of 361°. The most common of the 60/40 solder is the wire type with a rosin core.

There are two types of soldering flux, corrosive and non-corrosive. Rosin flux is non-corrosive and the type used in electronic maintenance. Corrosive types such as acid flux is never used on electronic equipment. The rosin flux is used to coat the metal surfaces prior to applying the heat to prevent oxidation of the metal. This oxidation would prevent a good bond between the metal surfaces and the solder.

All metal surfaces must be properly cleaned before soldering. There are several cleaning agents available for this purpose. They remove the oil, wax and flux from the metal surfaces. These solvents are dangerous and must be handled carefully.

During the soldering process, safety must be observed constantly. Some of the hazards to be aware of are electric shock, burns, and the fumes from cleaning agents. As in all electronic work, safety must be a habit. Good safety habits prevent accidents.

The common tools used in soldering are the soldering iron, wire strippers, bending tools, heat sinks, file, and wire cutting pliers. Many types of soldering irons are available and it is very important that you select the correct iron for the job to prevent overheating. When soldering to heat sensitive components, it is best to use a temperature controlled soldering iron. The calibrated wire strippers are the only type that should be used because they will prevent nicking and scraping the conductors as the insulation is removed. The bending tools are used to shape wires and leads prior to soldering. The heat sink is used to absorb heat and protect heat sensitive devices such as transistors and diodes. When using a soldering iron with a copper tip, it is often necessary to reshape the tip. This is the purpose of the file. Never use a file on a tip with a permanent coating. Although there are several types of cutting tools available, the most common are the diagonal cutting pliers. These are used to trim wire and component leads. Each of thse tools has a specific purpose and must be properly used.

When making solder connections to turret or bifurcated (slotted) terminals, the wire must be pre-tinned. This prevents the spreading of the strands when the wire is bent around the terminal. Care should be taken to insure that the correct amount of solder is used on the terminals and that they are properly cleaned after being soldered.

When soldering to a printed circuit board, all surfaces must be clean and the component leads correctly bent. Also, the proper amount of solder must be used with sufficient heat applied. Too little heat results in a cold solder joint and too much heat will damage the board and components. Finally, the board and connections must be thoroughly cleaned after soldering to remove the flux.

In maintenance work, desoldering of defective components is the first order of business. Care must be taken in removing the solder to insure the board and pads are not damaged. Once the components are removed, the area must be cleaned before new components are mounted.

YOU MAY STUDY ANOTHER RESOURCE OR TAKE THE MODULE SELF-CHECK.

SOLDERING TOOLS AND MATERIALS

INSTRUCTIONS:

Study the referenced material as directed.

Return to this guide and answer the questions.

Check your answers against the answers at the top of the next even numbered page following the questions.

If you experience any difficulty, contact your instructor.

Begin the program.

A. As an introduction to soldering turn to the Student Text Volume X, and study paragraphs 5-1 through 5-3. There are no exercises for this part.

B. Safety is always a very important factor. Turn to the Student Text Volume X and read paragraphs 5-4 through 5-5. Return to this page and indicate which of the following statements are true or false:

1. ______ Your work area must always be neat and clean.

2. ______ The soldering iron should be placed where you do not have to reach over it.

3. ______ It is not necessary to disconnect power from circuits you are working with.

4. ______ Place the open side of the wire cutters away from your body when cutting wires.

5. ______ When using cleaning solvents, it is safe to work in an unvented room.

6. ______ Never unsolder a wire that has tension on it.

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

ADJUNCT GUIDE

ANSWERS TO B:

1. T
2. T
3. F
4. T
5. F
6. T

If you missed ANY questions, review the material before you continue.

C. Turn to the Student Text Volume X and study paragraph 5-6 through 5-14. Return to this page and match Column A with Column B.

COLUMN A	COLUMN B
1. _______ Classification of solder	a. Conditions during the soldering process.
2. _______ Used for most electronic soldering	b. Not used in electronics
3. _______ Direct contact of parts to be soldered	c. 60% tin 40% lead.
4. _______ Soft Solder	d. Lead/tin alloy
5. _______ Bar type solder	e. Good electrical connection
6. _______ Solid plastic and liquid	f. Hard and soft

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

D. During the soldering process, it is necessary to use flux and cleaning solvents. Turn to the Student Text Volume and study paragraphs 5-15 through 5-21. Return to this page and answer the following questions:

1. _______ (True/False) Flux is used to prevent the metal to be soldered from developing an oxide coating when heat is applied.

2. _______ type flux should never be used when soldering electronics equipment.

3. ______ (True/False) Rosin type flux is noncorrosive.

4. Zinc Chloride, Hydrochloric Acid, and Sal Ammoniac are forms of ______________ type flux.

5. ______ (True/False) Dry Cleaning solvent, Isopropyl Alcohol, and Aliphatic Naptha are forms of approved solvents.

6. ______ (True/False) Solvents are used to remove wax, oil, and flux before and after the soldering process.

7. ______ (True/False) Solvents are dangerous and must be used with caution.

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

E. In order to produce a properly soldered connection, the correct tools and materials must be used. Turn to the Student Text Volume X and study paragraphs 5-22 through 5-50. Return to this page and complete the following exercise. Match the correct tools and materials with the statement that describes its proper use:

1. ______ Wire Stripper
2. ______ Heat Sink
3. ______ Bending Tool
4. ______ Cutting Tool
5. ______ File
6. ______ Soldering Iron
7. ______ Emery Cloth
8. ______ Erasers
9. ______ Brush
10. ______ Cloth, Paper tissue, or Sponge

a. Cleans surface by removing unwanted material.
b. Prevents overheating of heat sensitive components.
c. Cuts wires to desired length.
d. Bends wires and component leads.
e. Removes insulation without nicking wires.
f. Shapes soldering iron tips.
g. Supplies heat for soldering.
h. Removes loose particles after cleaning.
i. Removes excess solder from iron tip.
j. Places fine polish on newly filed tip.

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

ADJUNCT GUIDE

ANSWERS TO C:

1. f
2. c
3. e
4. d
5. b
6. a

If you missed ANY questions, review the material before you continue.

ANSWERS TO D:

1. True
2. Corrosive
3. True
4. Corrosive
5. True
6. True
7. True

If you missed ANY questions, review the material before you continue.

ANSWERS TO E:

1.	e	6.	g
2.	b	7.	j
3.	d	8.	a
4.	c	9.	h
5.	f	10.	i

If you missed ANY questions, review the material before you continue.

F. Prior to soldering, the conductors, leads and wires must be prepared correctly. Turn to the Student Text Volume X and study paragraphs 5-51 through 5-57. Return to this page and complete the following exercises.

Check the following statements as True or False:

_______1. All surfaces to be soldered must be clean.

_______2. There must be no wax, grease, or oxidation on the surfaces to be soldered.

_______3. A knife may be used to strip insulation from a conductor.

_______4. The leads on components directly from the factory need not be cleaned.

_______5. Stripped wires must not be nicked, scraped, or broken.

_______6. Wetting means the ability of solder to adhere to the surface of the conductor.

_______7. When stranded wire is tinned, the strands must be covered with a very thick coat of solder.

_______8. When the wire is tinned, the solder should run up under the insulation.

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

G. When soldering stranded wire to a turret terminal, certain standards must be met. Turn to the Student Text Volume X and study paragraphs 5-58 through 5-66. Return to this page and complete the following exercises.

1. Match the statements in Colmun B with the terms in Column A.

_______1. 180°

_______2. Cold solder joint

_______3. 270°

_______4. Burnt insulation

_______5. Heat Bridge

_______6. Fillet

a. Results from insufficient heat

b. A slight buildup of solder where the wire and terminal surfaces make contact

c. Too much heat

d. Maximum wrap on a turret

e. Application of solder to form a pool between the iron tip and conductor

f. Minimum wrap on a turret.

ANSWERS TO F:

1. T
2. T
3. F
4. F
5. T
6. T
7. F
8. F

If you missed ANY questions, review the material before you continue.

2. Check the correct statements that indicate a correctly soldered turret terminal.

_______a. The wire forms a good mechanical bond with the terminal.

_______b. Wire tip covered with solder.

_______c. Solder run down over the lip of the turret.

_______d. Solder joint clean, shiny, and smooth.

_______e. Wire wrapped 360° around the terminal.

_______f. A slight fillet between the terminal base and conductor.

CONFIRM YOUR ANSWES ON THE NEXT EVEN NUMBERED PAGE.

H. When soldering stranded wire to a bifurcated terminal, certain standards must be met. Turn to the Student Text Volume X, and study paragraphs 5-67 through 5-70. Return to this page and complete the following exercise:

Indicate which of the following statements are true and false.

_______1. The conductor should lie flat on the base.

_______2. Form a slight fillet between the conductor and insulation.

_______3. The insulation should be no further from the terminal base than the diameter of the insulated portion of the wire.

_______4. The iron should be held at a 45° angle.

_______5. The stranded wire should be bent at a 90° angle.

_______6. The tip of the stranded wire should not be covered.

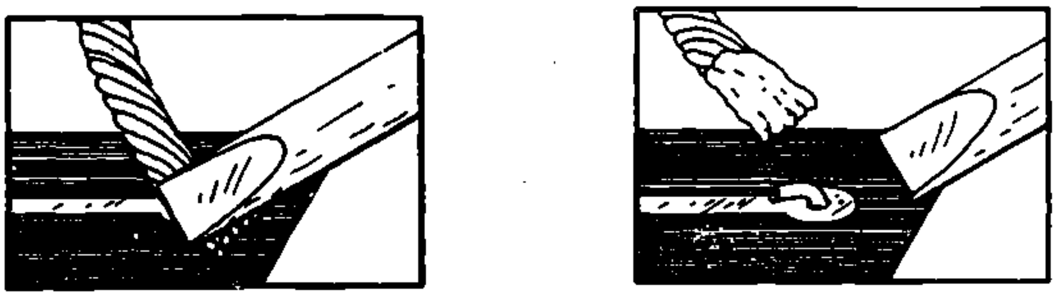
_______7. The completed connection should be bright and shiny.

_______8. If two wires are to be soldered to the same terminal they should be bent in the same direction.

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

I. Soldering and desoldering printed circuit boards must be done very carefully and requires practice. Turn to the Student Text Volume X and study paragraphs 5-71 through 5-92. Return to this page and complete the following exercise.

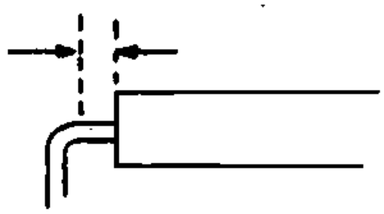
1. The process shown in the figure below is called _______________.



REP4-24

a b

2. The minimum distance from a component body to the bend on a component lead below is _______________ inch.



REP4-32

3. When components are properly mounted, the printed identification must be _______________.

4. When mounting components on a printed circuit board, the clinched leads should not exceed the _______________ of the pad.

ANSWERS TO G:

1.	1.	f	2. a.	X
	2.	a	b.	X
	3.	d	d.	X
	4.	c	f.	X
	5.	e		
	6.	b		

If you missed ANY questions, review the material before you continue.

ANSWERS TO H:

1. T
2. F
3. T
4. T
5. T
6. F
7. T
8. F

If you missed ANY questions, review the material before continuing.

5. Printed circuit boards are made of fiber and therefore are sensitive to __________ .

6. One way to prevent overheating a printed circuit board is to use ______________/ ______________ rosin core solder.

7. Heavy leads that cannot be bent or clinched should be allowed to protrude __________ of an inch beyond the pad.

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

J. All soldered connections must be carefully inspected and evaluated to insure that it meets the proper standards. Turn to the Student Text Volume X and study paragraphs 5-93 through 5-96. Return to this page and complete the following exercises:

Label the following statements concerning soldering connections as Satisfactory (S) or Unsatisfactory (U).

_____ 1. Bare copper showing

_____ 2. Solder on adjacent areas

_____ 3. Clean smooth undisturbed surface condition

_____ 4. Labeling of parts not visible

_____ 5. Dewetting

_____ 6. Complete wetting

_____ 7. Conductor contour visible

_____ 8. Pitted surface

_____ 9. Concave fillet between conductor and the terminal

_____ 10. Dirty connections.

CONFIRM YOUR ANSWERS ON THE NEXT EVEN NUMBERED PAGE.

YOU MAY STUDY ANOTHER RESOURCE OR TAKE THE MODULE SELF-CHECK.

ADJUNCT GUIDE

ANSWERS TO I:

1. Wicking
2. 1/16 inch
3. Visible
4. Diameter
5. Heat
6. 60/40
7. 1/32 inch

If you missed ANY questions, review the material before you continue.

ANSWERS TO J:

1. U
2. U
3. S
4. U
5. U
6. S
7. S
8. U
9. S
10. U

If you missed ANY questions, review the material before you continue.

YOU MAY STUDY ANOTHER RESOURCE OR TAKE THE MODULE SELF-CHECK.

SOLDERING TOOLS AND THEIR APPLICATIONS

QUESTIONS:

From the following list, match the proper application to the correct tool or material by placing the appropriate letter in the space provided.

a. Absorbs heat of soldering and diverts high temperature away from component.

b. Shapes and smoothes copper soldering iron tips.

c. Cuts light wires to proper length.

d. Removes insulation without nicking wire.

e. Shapes leads and wires in preparation for soldering.

f. Provides heat to make the soldering bond.

g. Polishes a newly filed soldering iron tip.

h. Removes loosened fragments from area to be soldered.

i. Loosens unwanted materials to prepare and clean surfaces to be soldered.

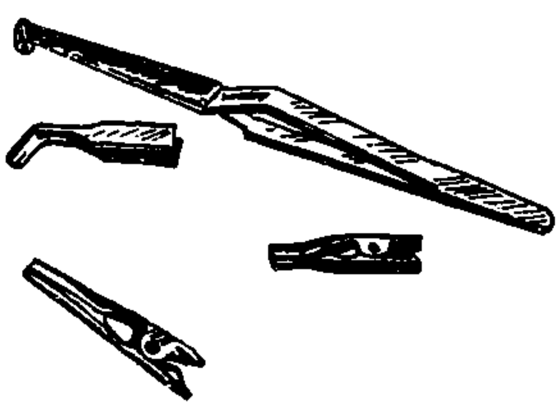
j. Used to wipe off and clean soldered connections.

_______ 1. Cloth, paper tissues, or sponge

_______ 2. Emery cloth

_______ 3. Erasers

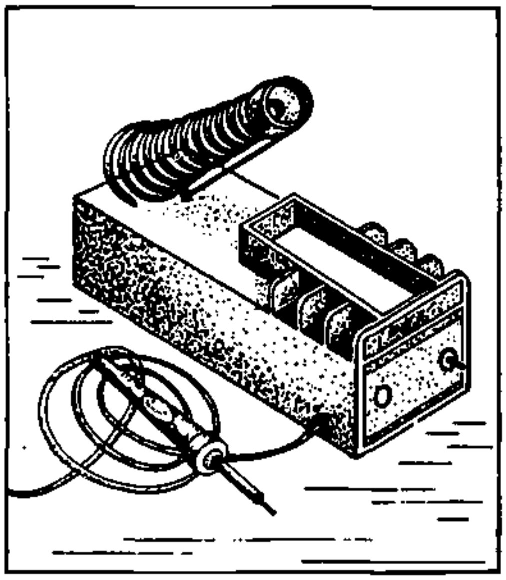
_______ 4. Brushes



REP4-19

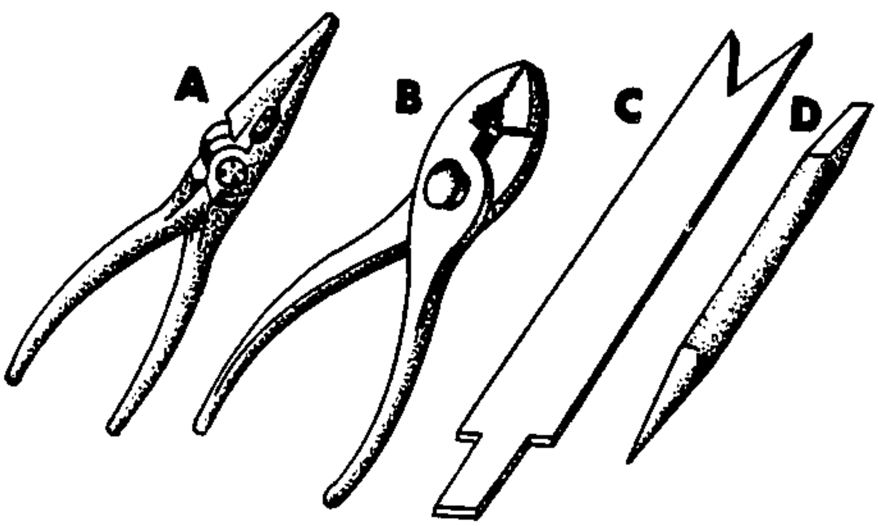
_______ 5. Heat Sinks

MODULE SELF-CHECK



REP4-26

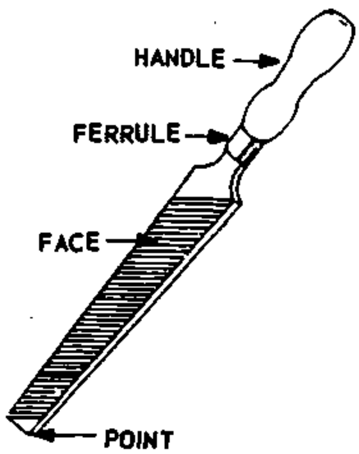
______ 6. Soldering Iron



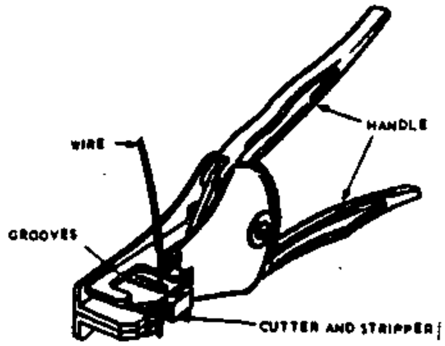
REP4-29

______ 7. Bending Tools

8. Diagonal Cutting Pliers



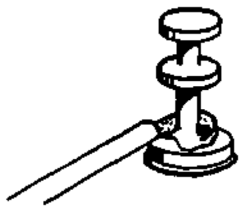
9. Single-Cut Flat File



10. Wire Strippers

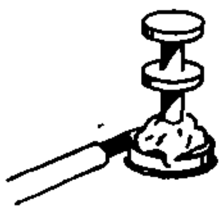
MODULE SELF-CHECK

11. Select the picture that depicts a properly soldered turret connection, by placing a check-mark in the space provided.



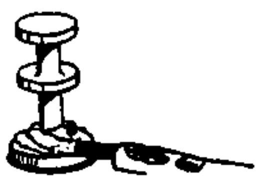
a. ______

b. ______

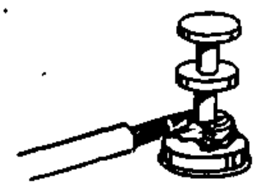


c. ______

d. ______



e. ______



f. ______

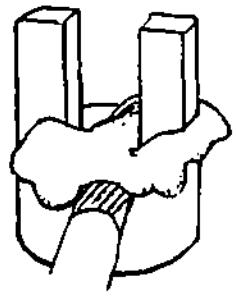
12. Using the pictures of turret terminals select the ones that have improper insulation clearance by placing an X in the space provided.

13. From the following pictures select the one that depicts a properly soldered bifurcated terminal by placing a checkmark in the space provided.

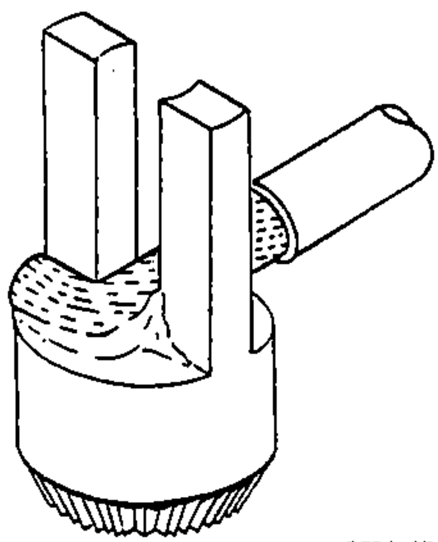
a. ______

b. ______

c. ______



d. ______



REP4-27

e. ______

14. Using the above pictures of bifurcated terminals select the ones with proper insulation clearance by placing an X in the space provided.

MODULE SELF-CHECK

15. From the following pictures of printed circuit pad connections select the one that is properly soldered by placing a checkmark in the space provided.

a. ______

b. ______

c. ______

d. ______

e. ______

f. ______

16. Check the true statements that apply to soldering techniques used in electronic repair work.

______ a. Since circuit connections are made on metal, overheating is not a problem in soldering operations.

______ b. When soldering on a printed circuit board, too much heat can cause the pad to separate from the board.

______ c. Bar solder is the most common type of solder used in electronic circuit repair work.

______ d. The most commonly used solder for electronic circuit repair work has a tin-to-lead ratio of 60/40.

______ e. A good mechanical connection helps to insure a good electrical connection.

______ f. Corrosive flux is not used for electronic repair work.

______ g. Liquid flux may be used for electronic circuit repair as long as it is non-corrosive flux.

______ h. Cleaning solvents are used in soldering to disolve wax, flux, and oil from the connection.

______ i. When using cleaning solvents it is extremely important to provide adequate ventilation.

______ j. Solder with a tin-to-lead ratio of 60/40 goes from the liquid to solid state very quickly, this lessens the chance for fracture.

NOTES

MODULE SELF-CHECK

ANSWERS TO MODULE SELF-CHECK

1. j
2. g
3. i
4. h
5. a
6. f
7. e
8. c
9. b
10. d
11. f
12. a, b
13. e
14. c, d, e
15. f
16. b, d, e, f, g, b, i, j

HAVE YOU ANSWERED ALL OF THE QUESTIONS CORRECTLY? IF NOT, REVIEW THE MATERIAL OR STUDY ANOTHER RESOURCE UNTIL YOU CAN ANSWER ALL QUESTIONS CORRECTLY. IF YOU HAVE, CONSULT YOUR INSTRUCTOR FOR FURTHER INSTRUCTION.

CONSULT YOUR INSTRUCTOR FOR THE PROGRESS CHECK.

200

PREPARE THE MAN

ATC ST 3AQR3X020-X
Prepared by Keesler TTC
KEP-GP-77

Technical Training

ELECTRONIC PRINCIPLES (MODULAR SELF-PACED)

MODULE 77

SOLDERING AND DESOLDERING PROCEDURES

1 May 1975

AIR TRAINING COMMAND

7-14

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Basic and Applied Electronics Department
Kees'er AFB, Mississippi

ATC GP 3AQR3X020-X
KEP-GP-77
1 May 1975

ELECTRONIC PRINCIPLES

MODULE 77

This Guidance Package is designed to guide you through this module of the Electronic Principles Course. It contains specific information and references to other sources you may study, that will enable you to satisfy the learning objectives.

CONTENTS

OVERVIEW

SOLDERING AND DESOLDERING PROCEDURES

1. SCOPE: The purpose of this module is to teach you to solder and desolder wires and components on printed circuit boards and terminals. The proficiency you develop while accomplishing these objectives will aid you in making repairs to printed circuit boards.

2. OBJECTIVES: Upon completion of this module you should be able to satisfy the following objectives:

a. Given the required tools, materials, and conductors, solder connections on slotted terminals in accordance with TO 00-25-234.

b. Given the required tools, materials, and conductors, solder connections on turret terminals in accordance with TO 00-25-234.

c. Given the required tools and materials, desolder leads from terminal connections in accordance with TO 00-25-234.

d. Given the required tools, materials, and conductors, solder connections in accordance with TO 00-25-234 on printed circuit boards:

(1) passive components (resistor or capacitor).

(2) active components (solid state diode or transistor).

e. Given soldering tools and materials, desolder components from printed circuit boards in accordance with TO 00-25-234.

Supersedes Guidance Package, KEP-GP-77, 1 December 1974.

SOLDERING AND DESOLDERING PROCEDURES

OBJECTIVE

Given the proper tools and materials, solder and desolder connections on a printed circuit board in accordance with T.O. 00-25-234 to include:

a. stranded wire to slotted (bifurcated) terminals.

b. stranded wire to turret terminals.

c. passive components (resistors and capacitors).

d. active components (solid state diodes and/or transistors)

e. desolder and remove wires from terminals

f. desolder and remove components from printed circuit board.

EQUIPMENT

Controlled Soldering Station

PC Board Holder

Long Nose Pliers

Nonmetallic Bending Tool

Diagonal Cutting Pliers

Heat Sinks

Typewriter Eraser

Alcohol

Cellulose Tissue

Solder

Brush (Bristle)

Flux

Multivibrator Kit

Transformer (28 V AC or VARIAC- one per classroom)

Stranded Wire

LABORATORY EXERCISE

REFERENCE

Student Text, Volume X, Chapter 5

CAUTION: Soldering iron burns are painful and slow to heal. Place your soldering iron in a location that will not require you to reach around or across it. When not in use, place it in its holder at the upper corner of your work area.

PROCEDURE:

Inventory the M.V. Kit. Place a check mark on this checklist to indicate the part was supplied.

PC Board - DD 5700	( )
Capacitor - 100 μf (2 ea)	( )
Capacitor - 50 μf	( )
Diode	( )
Resistor - 56 Ohm, 1 watt	( )
Resistor - 10 k Ohm, 1/2 watt	( )
Resistor - 15 k Ohm, 1/2 watt	( )
Resistor - 22 k Ohm, 1/2 watt	( )
Lamp - GE 1820	( )
Transistor - 2N1304 (2 ea)	( )
Stranded Wire - 20 ga, 2 ft	( )
Solder	( )

Inspect the printed circuit board for possible defects. Observe the board carefully to determine:

1. Each pad has a hole drilled completely through the board.
2. The copper pads and runs are not damaged.
3. Board is not cracked or otherwise damaged.

NOTE: If defects are found, check with your instructor for a replacement board.

A. Preparation of the Soldering Iron

1. Remove retaining nut at the base of soldering iron barrel.

2. Remove barrel.

3. Remove the soldering tip from retainer.

4. Wipe the round portion of tip thoroughly.

5. Place soldering tip back into retainer.

6. Replace barrel.

7. Tighten retainer nut with fingers.

8. Plug the soldering station into 110 volt AC outlet.

9. Turn on/off switch to ON position (if equipped with switch).

10. Allow approximately one minute for soldering iron to reach operating temperature and then apply solder to the two faces of soldering tip.

11. Wipe all solder from the faces of soldering tip with the tissue provided. (CAUTION: The iron tip is hot.)

12. If the faces of soldering tip are not clean and tinned, use a piece of wire to apply a small amount of flux to the soldering tip faces.

13. Immediately wipe tip clean.

14. Apply a small amount of solder to each face of tip.

15. Report any equipment discrepancy to your instructor.

PREVENTIVE MAINTENANCE: THE FACES OF THE SOLDERING IRON TIP MUST REMAIN COATED WITH SOLDER. THIS PREVENTS OXIDATION OF THE TIP FACES. THE TIPS USED ARE PLATED AND MUST NOT BE FILED OR CLEANED WITH ANY ABRASIVF MATERIAL.

B. Preparation of Stranded Conductors.

1. Use the diagonal cutting pliers to cut the 3-foot section of stranded wire into eight pieces. Each should be approximately 4 inches long.

2. Place a piece of wire in the wire stripper jaws, in the notch labeled for the size of wire being used. Allow approximately 3/4 inch wire to extend beyond the cutting jaws of the wire strippers.

3. Squeeze the handles of the wire stripper to cut the insulation and slide the insulation off the wire.

LABORATORY EXERCISE

CAUTION: Do not disturb the individual strands of the wire. If any wires are disturbed, twist the wire in the original direction of the strands.

Repeat this process on one end of the other pieces of wire.

4. Check with your instructor and have your work inspected. It must meet the following standards:

a. The individual wires are not cut, nicked, or scraped.

b. The individual wires retained their natural twist.

c. Sufficient length of stripped wire.

Accepted ________

When your work is accepted, continue with the next step.

C. Tinning Stranded Conductors

1. Apply a very small amount of flux to the portion of the wire to be tinned.

2. Place the soldering iron on the holder so one face of the tip is horizontal (face-up).

3. Apply a very small amount of solder to the face of the soldering iron tip.

4. Hold the wire in one hand and a piece of solder in the other.

5. Position bare wire on face of soldering iron tip and apply solder to wire near soldering tip.

6. Roll the wire across the face of the iron, feeding solder to the wire as it moves.

CAUTION: Do not allow too much solder to be deposited on the wire, but make sure the exposed surface has been tinned.

7. Remove the solder, then the wire, from the iron.

8. Allow the wire to cool, then clean the tinned wire with alcohol and cellulose tissue.

9. Wipe the tip of the iron to remove excess solder.

10. Repeat this process on one end of the other pieces of wire.

11. Check with your instructor and have your work inspected. It must meet the following standards:

a. The contours of the individual strands are visible under the solder coating.

b. The wire is completely covered with solder.

c. The tinned coating is uniform in coverage.

d. Solder has not run under the insulation.

Accepted ________

When your work is accepted, continue with the next step.

D. Slotted (Bifurcated) Terminal Solder Connections

1. Plug soldering station into 110 volt AC outlet, and turn on/off switch to ON.

2. Using a tinned piece of wire and the long nose pliers, make a connection to SLOTTED TERMINAL 1 (See figure 1).

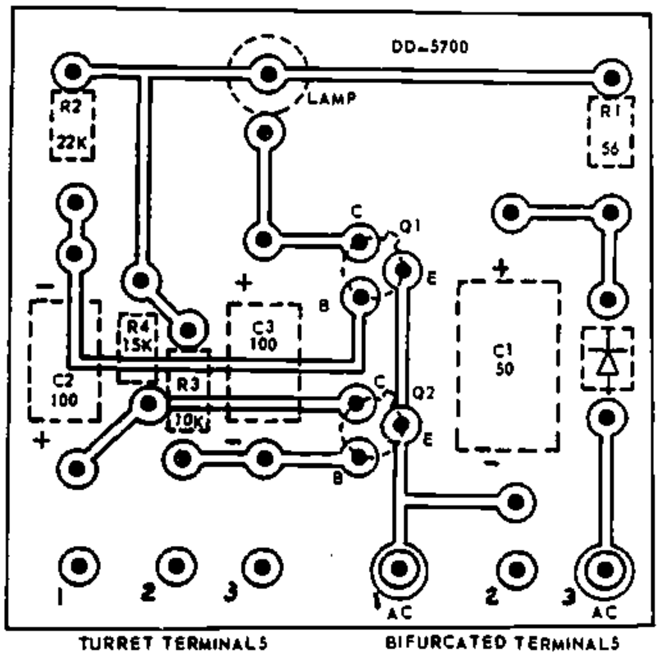

Figure 1. Printed Circuit Board REP4-2400

3. Place the wire between the posts of the terminal and bend the wire 90° in a clockwise direction. Make sure the insulation is no closer than 1/32 inch or not more than the diameter of the insulated wire, from the terminal base.

4. Position the wire so it is flush with the post and lies flat on the terminal. Cut off the excess length (trim the wire flush with the post) using diagonal cutting pliers.

5. Place a tinned and heated soldering iron at a 45° angle to the base of the terminal post, touching the wire.

6. Form a heat bridge and wipe solder along the conductor and across the end of the wire.

LABORATORY EXERCISE

7. Remove the solder and then the iron.

8. Allow the terminal to cool.

9. Clean the connection with brush and alcohol and dry with the cellulose tissue.

10. Check with your instructor and have your work inspected. It must meet the following standards:

a. Wire lies flat on the terminal base.

b. Wire is bent correctly around the terminal.

c. The correct amount of solder is used.

d. Terminal is properly cleaned.

e. Insulation clearance is a minimum of 1/32 inch and not more than the diameter of the insulated wire.

Accepted ____________________

When your work is accepted, continue with the next step.

11. Make a double connection to SLOTTED TERMINAL 2. Bend one wire clockwise and the other counterclockwise.

12. After cleaning the completed connection check with your instructor and have your work inspected. It must meet the same standards as before.

Accepted ____________________

When your work has been accepted, continue with the next step.

NOTE: Step 13 constitutes a progress check and must be checked by your instructor.

13. Solder a single connection to bifurcated terminal Nr. 3.

E. Turret Terminal Solder Connections

1. Position the printed circuit board so that the TURRET TERMINALS are near you.

2. Using a tinned piece of stranded wire and the long nose pliers, make a connection to TURRET TERMINAL 1.

3. Place the wire on top of the center ferrule and bend the wire in a clockwise direction around the terminal. The bend must be at least 180° but not to exceed 270°. The insulation should not be closer than 1/32 inch nor more than the diameter of the insulated wire from the terminal.

4. Position the wire flush with the post and flat on the ferrule. Then trim the wire with diagonal cutting pliers.

5. Place a tinned and heated iron at a 45° angle to the ferrule, touching the ferrule and wire.

6. Form a heat bridge and wipe solder along the conductor and across the end of the wire.

7. Remove the solder and the iron.

8. Clean the terminals thoroughly with brush, alcohol, and cellulose tissue.

9. Check with your instructor and have your work inspected. It must meet the following standards:

a. Wire lies flat on the terminal.

b. Wire is wrapped around the terminal at least 180° and not more than 270 °.

c. Insulation clearance is not less than 1/32 inch and not more than the diameter of the insulated wire.

d. Correct amount of solder. (See T.O. 00-25-234 and classroom example).

e. Terminal is properly cleaned, and flux residue removed.

Accepted ____________________

When your work is accepted, continue with the next step.

10. Make a double connection to TURRET TERMINAL 2 by repeating steps 3 through 8. Bend both wires in the same direction.

11. Check with your instructor and have your work inspected. It must meet the same standards as before.

NOTE: Step 12 constitutes a progress check and must be checked by your instructor.

12. Make a single solder connection to turret terminal Nr. 3.

F. Desoldering Terminal Connections

1. To remove wires from turret and slotted terminals, place the circuit board in a printed circuit board holder so that the terminals are face up.

2. On the soldering console, turn on/off switch to ON position (if equipped with switch).

3. Allow time for soldering iron to reach operating temperature (approximately one minute) and then apply solder to both faces of soldering tip. (Always keep solder on faces of iron tip when not in immediate use and wipe clean just prior to use.

4. Place the tip of the soldering iron on slotted terminal number 2 where the wire and terminal join.

5. Remove the wire from the connection as solder begins to melt.

LABORATORY EXERCISE

6. Remove excess solder from hot terminal with brush.

7. Put a small amount of solder on iron tip before placing in holder.

8. Repeat the above procedures on the three turret terminals on the board.

9. Check with your instructor to inspect your work. The complete work must meet the following standards:

a. The terminal is clean.

b. Excess solder has been removed.

c. The terminal has not been damaged.

Accepted ______________________

When your work is accepted, continue with the next step.

NOTE: Step 10 constitutes a progress check and must be checked by your instructor.

10. Desolder a terminal connection as directed by your instructor.

G. Multivibrator Construction

Refer to figure 2 for component location and polarities.

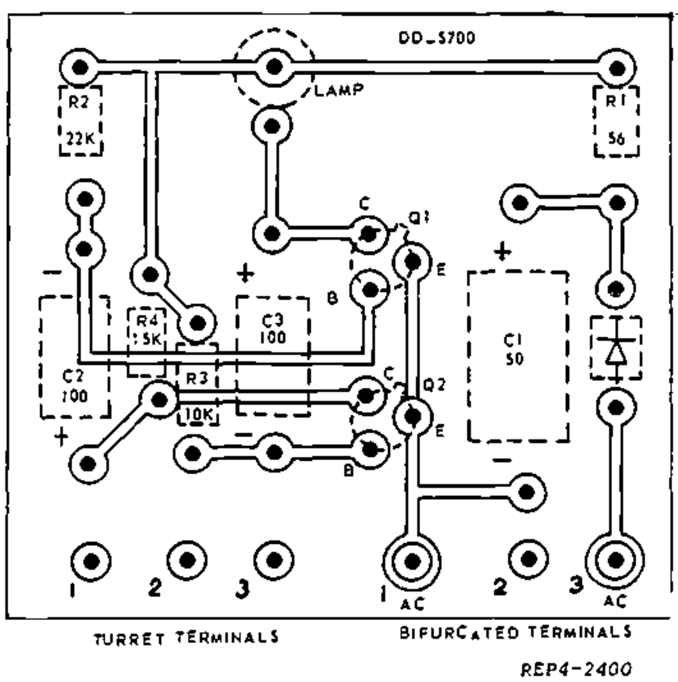

Figure 2. Multivibrator Printed Circuit Board

NOTE: Clean all component leads and solder pads with an eraser.

Mount all components on the fiber side of the PC board with the component leads extending through the conductor (printed) side of the board. Insure that you observe polarities as shown on figure 2. All printing and color codes on the components should read in the same direction.

1. Select R1, the 56 ohm resistor (green, blue, black). Using the metal forming jig or long nose pliers, bend the resistor leads to fit the mounting holes for R1.

2. Insert R1 into the proper holes in the PC board.

3. Bend the leads at a 45° angle in the direction of the run on the conductor side of the board.

4. Select CR1 diode, bend and shape the leads to match the proper hole in the PC board.

NOTE: Insure the leads are bent in such a fashion to permit the lettering on the diode to be visible after it is mounted.

5. Insert CR1 into the proper holes in the PC board.

6. Bend the leads of the diode to a 45° angle to hold it in place.

7. Select C1, 50 μf capacitor, bend and shape the leads, and mount in the proper holes on the PC board. CAUTION: Observe polarity of the capacitor.

8. Bend the leads to a 45° angle to hold the capacitor in place.

9. Using the diagonal cutting pliers, cut all component leads so the minimum length is equal to the radius of the pad and the maximum length does not exceed the diameter of the pad when clinched.

10. Using the nonmetallic bending tool, clinch all component leads against the pads in the direction of the runs.

11. Check with your instructor and have your work inspected. It must meet the following standards:

a. Diode and Capacitor C1 mounted with the proper polarities.

b. Components mounted with color code in proper direction.

c. All components mounted in proper holes.

d. All leads properly clinched with the lead length a minimum of the radius of the pad and a maximum of the diameter of the pad.

Accepted ____________________

When your work has been accepted, continue with the next step.

LABORATORY EXERCISE

NOTE: Use the heat sink on the diode leads when soldering.

12. Solder all connections. Note, wipe your soldering iron tip with a wet sponge before soldering each connection.

13. Clean all connections with brush and alcohol to remove all residue. Wipe the connections dry with the cellulose tissue to prevent a film from developing.

14. Check with your instructor to inspect your work. It must meet the following standards.

a. Proper amount of solder.

b. Pads and board not damaged.

c. Connections not pitted.

d. Solder is even with no stress lines or cracks.

e. All solder connections are clean. (See T.O. 00-25-234 and classroom examples.)

Accepted ____________________________

When your work is accepted, continue with the next step.

NOTE: Steps 15 through 19 constitute a progress check and must be checked by your instructor.

15. Mount R2, 22 k ohm resistor (red, red, orange) in the proper position, clip the leads, and clinch them to the pads in the direction of runs.

16. Mount transistor Q1 on the PC board a minimum of 3/8 inch and a maximum of 1/2 inch above the board.

NOTE: When mounting the transistors, the emitter lead is the first lead clockwise from the tab (looking at the bottom of the transistor), the next lead clockwise is the base, and the third lead clockwise is the collector.

17. Hold the transistor in place, bend, clip and clinch the leads to the pads.

18. Repeat steps 16 and 17 for transistor Q2.

NOTE: Insure a heat sink is connected to each lead on the transistors as they are soldered to prevent heat damage.

19. Solder the connections for R2, Q1, and Q2.

20. Select two pieces of solid wire or leads clipped from previously used components and solder them to the lamp. Refer to figure 3. One lead is connected to the outer shell of the base and the other is inserted into the solder at the bottom of the lamp.

Figure 3. Lamp

21. Insert the lamp leads into the proper mounting holes and bend them 45° on the conductor side of the board to hold them in place.

22. Cut the lamp leads to the proper length and clinch them to the pads.

23. Solder the lamp leads to the pads.

24. Clean the connections made to the lamp, R2, Q1, and Q2, with a brush and alcohol to remove the residue and wipe the connections clean with a tissue.

25. Check with your instructor to inspect your work. These connections must meet the following standards:

a. Each connection has the proper amount of solder.

b. The components are properly mounted.

c. All leads are properly clinched with the length a minimum of the radius of the pad and a maximum of the diameter of the pad.

d. The pads and board not damaged.

e. The solder connections are not pitted.

f. The solder is even with no stress lines or cracks.

g. All connections are clean.

Accepted ______________________

When your work is accepted, continue with the next step.

26. Prepare and mount C2, 100 μf capacitor; C3, 100 μf capacitor; R3 10 k ohm (brown, black, orange) resistor; and R4, 15 k ohm (brown, green, orange) resistor onto the PC board in the proper position.

LABORATORY EXERCISE

NOTE: Observe the polarity of the capacitors. The lettering on one will not be in the same direction as the other components.

27. Solder the connections.

28. Clean the connections thoroughly.

29. Check with your instructor to have your work inspected.

Accepted ________________________

When the PC board has been accepted, connect the two AC leads to the output of the 28 V AC transformer. Turn the transformer ON. The multivibrator lamp should flash ON and OFF. If the light does not flash on and off, consult your instructor. If the light flashes on and off, continue with the next step.

H. Desolder and Remove Components from Printed Circuit Boards

1. Place printed circuit board into holder with runs facing upward and use the following procedure for removing components.

2. Strip about one inch of insulation from a piece of stranded wire and untwist it slightly.

3. Dip the bare strands of wire into the flux and place them on the top of pad connection to be unsoldered (wicked). The wire should be placed at a 90° angle to the direction of the run.

4. Position the soldering iron tip on top of the stranded wire.

5. While holding soldering iron in place, gradually pull the wire from between the soldering iron and the pad. Remove the iron from the pad.

6. Care should be taken not to drag solder out onto the run.

7. Cut off the section of stranded wire that is saturated with solder. Then strip another one inch section and repeat wicking procedure until as much of the solder as possible has been removed.

CAUTION: Too much heat will damage the board.

8. Position soldering iron tip to lead of component and as remaining solder melts, use long nose pliers to remove component lead from pad. (This may require straightening of lead).

9. Apply a little heat to each pad and brush away any remaining solder with tissue or a brush. Only a slight tinning of the pad should remain.

10. Clean the board with alcohol to remove the flux.

11. Wipe the board clean with a tissue.

12. Check with your instructor and have your work inspected. It should meet the following standards.

a. Excess solder removed from the pads.

b. Pad and board not damaged.

c. Mounting hole not clogged.

Accepted ____________________

NOTE: Step 13 constitutes a progress check and must be checked by your instructor.

13. Wick, desolder and remove a component from your printed circuit board as directed by your instructor.

When your work has been accepted, resolder the component that was removed and continue with the next module.

ATC GP 3AQR3X020-X
Prepared by Keesler TTC
KEP-GP-78

Technical Training

ELECTRONIC PRINCIPLES (MODULAR SELF-PACED)

MODULE 78

MULTILEAD AND COAXIAL CABLE FABRICATION

1 March 1975

AIR TRAINING COMMAND

Designed For ATC Course Use

DO NOT USE ON THE JOB

216

Basic and Applied Electronics Department
Keesler Air Force Base, Mississippi

Guidance Package 3AQR3X020-X
KEP-GP-78
1 March 1975

ELECTRONIC PRINCIPLES (MODULAR SELF-PACED)

MODULE 78

MULTILEAD AND COAXIAL CABLE FABRICATION

This guidance package (GP) is designed to guide you through this module of the Electronic Principles Course. It contains specific information, including references, to other resources you may study, enabling you to satisfy the learning objectives.

CONTENTS

OVERVIEW

1. SCOPE: The purpose of this module is to teach you how to construct a multilead cable and coaxial cables which will be used with the equipment you will be using when you arrive in the field.

2. OBJECTIVES: Upon completion of this module you should be able to satisfy the following objective. Given the required tools, materials, and multimeter, fabricate a multiconductor cable in accordance with technical order (TO) 1-1A-14 to include:

   a. Multipin plug
   b. Terminal lugs
   c. Tiedown straps

LIST OF RESOURCES

To satisfy the objectives of this module, you may choose according to your training, experience, and preference, any or all of the following:

1. LABORATORY EXERCISE:

78-1 Multilead Cable Fabrication
78-2 Coaxial Cable Fabrication

2. AUDIO VISUAL:

TV Lesson, Coaxial Cable Fabrication, TVK-30-9

Supersedes Guidance Package, KEP-GP-78, 1 January 1974.

217

MICROWAVE AND SOLDERING

MULTICONDUCTOR CABLE FABRICATION

OBJECTIVE

Given the required tools, materials, and multimeter, fabricate a multiconductor cable in accordance with TO 1-1A-14 to include:

Multiconductor plug
Terminal lugs
Tiedown straps

EQUIPMENT

Soldering station
Multimeter
Diagonal cutting pliers
Holding jig, multiconductor plug
Crimper
Long nose pliers
Wire strippers, calibrated

REFERENCES

1. Student Text, Volume X, Chapter 5, KEP-ST-X

2. TO 1-1A-14

CAUTION: Soldering iron burns are painful and slow to heal. Place your soldering iron in a location that will not require you to reach across or around it. When not in use, place it in its holder at the upper corner of your work area.

PROCEDURES

1. Check your tools against the list located on the bench. If there are items missing, call the instructor.

2. Cut four pieces of 18-gauge stranded wire approximately 1-foot long.

3. Place the body assembly in the holding device so that pins A and J are at the top.

4. Using the wire strippers and the following procedure, strip approximately 1/4 inch of insulation from one end of each wire.

a. Insert the wire into the exact center of the correct cutting slot for the size wire to be stripped. (Each slot is marked with the wire size.)

b. Close the handles together as far as they will go.

c. Release the handles allowing the wire holder to return to the open position.

d. Remove the stripped wire.

5. Clean and prepare the soldering station.

6. Tin the ends of the stripped wires and consult the instructor to inspect your work. The wires should meet the following standards:

a. The strands remain tightly wound in the natural twist of the wire.
b. The solder did not run under the insulation.
c. The contours of the strands can be seen under the tinned surface.

LABORATORY EXERCISE 78-1

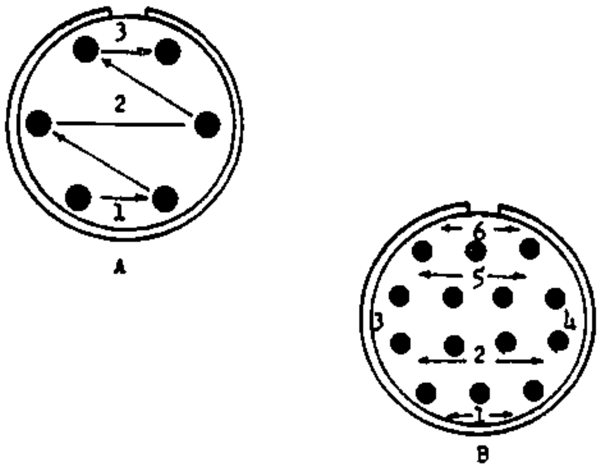

Figure 1. Connector Soldering Sequence

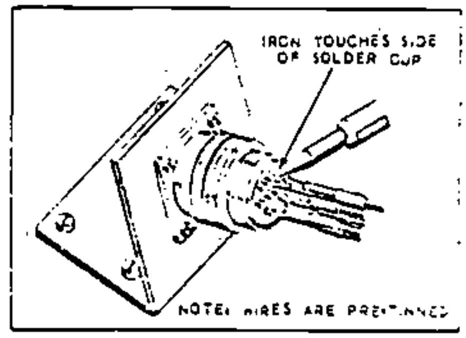

Figure 2. Soldering Small-Size Contacts

INSTRUCTION

Figure 1 shows two sequences which may be used in soldering wires to a multiconductor plug. Figure 2 shows the method to use with the soldering iron. Whether you work from left to right or right to left is your option. However, you should start at the bottom and work toward the top.

If you are using a new plug, you will find the manufacturer has filled the cups with solder. IF YOU ARE USING AN OLD PLUG, THE CUPS WILL HAVE TO BE FILLED WITH SOLDER PRIOR TO INSERTING THE WIRE.

CAUTION: Do not burn or unsolder other wires during the soldering process.

7. Solder four short wires to the four center cups. Remember to work from the bottom toward the top as the wires are installed.

8. Consult your instructor and have your work inspected. It should meet the following requirements.

a. No excessive solder on the outside of the cups
b. No burned insulation
c. No cold solder joints (Connections should be bright and shiny.)
d. Good mechanical serviceability (Pull firmly on the wire.)

CONSULT YOUR INSTRUCTOR FOR THE PROGRESS CHECK.

Accepted ________

9. Using the wire strippers, remove approximately 1/4 inch of insulation from the four wires using the same procedure as in step 4. See example III on the Exploded View Panel.

10. Insert a wire into the terminal lug and crimp the lug to the wire using the crimping tool. See example VIII on the Exploded View Panel.

NOTE: The stripped wire should extend slightly beyond the neck of the terminal.

11. Install terminal lugs on the remaining three wires. The installation should meet the following standards:

a. A firm mechanical connection will not come loose when the terminal is pulled on.
b. Stripped end of the wire extends slightly beyond the neck of the terminal.

CONSULT YOUR INSTRUCTOR FOR THE PROGRESS CHECK.

Accepted ________

12. Using a multimeter, check for electrical serviceability as follows:

a. Insert one lead of the multimeter into a hole on the connector and locate the lug on the other end by measuring zero resistance. There should be infinite resistance (open) between all other lugs.

b. Repeat this procedure for each hole in the connector until all connections have been checked.

INSTRUCTION

Wire groups or bundles are laced or tied to provide ease of installation, maintenance, and inspection. This is accomplished either by lacing with cord or by the use of plastic self-clinching cable straps. In completing this exercise, a plastic strap will be used to tie your cable together.

13. Place a self-clinching plastic strap around the wires approximately 2 inches behind the body assembly with the ribbed side in.

14. Thread the tip of the strap through the eye in the strap boss and pull the strap tight around the bundle. The long-nose pliers may be used to tighten the strap around the bundle. See example IX of the Exploded View Panel.

15. Use the diagonal wire cutters and cut off the excess strap close to the point where it extends from the strap boss.

16. When the strap is in place, consult your instructor and bave your work inspected. It should meet the following standards:

a. The strap should be tight around the bundle.
b. All excess strap should be cut off where it extends beyond the strap boss.

CONSULT YOUR INSTRUCTOR FOR THE PROGRESS CHECK.

Accepted ________

17. Unsolder the wires from the plug and cut off all lugs and tinned leads.

18. Using the brush and alcohol, remove all dirt and flux from the plug.

19. Return the wires to the instructor and have him inspect the plug.

NOTE: See TVK 30-9 before proceeding to the next exercise.

Proceed with Laboratory Exercise 78-2, Coaxial Cable Fabrication.

LABORATORY EXERCISE 78-2

MICROWAVE AND SOLDERING

COAXIAL CABLE FABRICATION

OBJECTIVE

Given the required tools, materials, and multimeters, fabricate a coaxial cable in accordance with TO 1-1A-14.

EQUIPMENT

Soldering station
Multimeter
Diagonal cutting pliers
Scissors
Long nose pliers
Pocket knife
Open end wrenches
Scribe

REFERENCES

1. Student Text, Volume X, Chapter 5, KEP-ST-X-5

2. TO 1-1A-14

PROCEDURES

1. Check your tools with the list located on the bench. If any items are missing, call your instructor.

2. Lay your parts out in the order of assembly as shown in the example on the Exploded View Panel.

3. Wrap several layers of tape around the center of the cable to prevent components from slipping down the cable. See example II of the Exploded View Panel.

4. Place the cable nut, washer, and gasket (with the "V" groove toward the front) on the cable as shown in example II on the Exploded View Panel.

5. Using the pocket knife, make a cut carefully around the circumference of the outer jacket of the cable 1/2 inch from the end. See example III on the Exploded View Panel.

CAUTION: Do not cut or nick the shield strands.

6. Make a lengthwise cut toward the end of the cable and strip off the outer jacket.

7. Insert the braid clamp over the copper shield with the sharp beveled edge toward the nut. See example IV on the Exploded View Panel.

CAUTION: BE SURE THIS CLAMP IS NOT UPSIDE DOWN.

8. Comb out the braid using your fingers or the point scribe.

9. Press the combed out braided wires back over and against the clamp as tight as possible with your fingers. See example V on the Exploded View Panel.

10. Use the scissors to trim the excess wire shield to the shoulder of the braid clamp. See example V on the Exploded View Panel.

11. Carefully cut the dielectric approximately 1/8 inch from the braid with a knife and remove the dielectric from the inner conductor.

CAUTION: Do not nick or cut the inner conductor.

12. Slide the pin onto the inner conductor. The pin should butt against the dielectric. If it does not, it may require cutting to allow the pin to fit flush against the dielectric.

13. Clean and prepare the soldering station.

14. Tin the inner conductor and the inside of the pin.

15. Hold the pin with the long nose pliers, apply heat to it, and slide it onto the inner conductor. The pin should butt against the dielectric.

16. If needed, apply more solder through the hole in the pin to secure it to the center conductor. See example VI on the Exploded View Panel.

17. Remove excess solder from the pin if necessary.

18. At this point, consult your instructor for an inspection of your work. The cable must meet the following standards:

a. Shielded strands not damaged
b. Center pin seated against the dielectric
c. No excess solder on the outside of the center pin

19. Hold the connector body against a flat surface. Insert the prepared cable into the body and press firmly. Make certain that the pin is bottomed or seated in the connector body. See example VII on the Exploded View Panel.

20. Slide the gasket, flat washer, and cable nut up into the connector body and rotate it clockwise to tighten it into the body. See example VIII on the Exploded View Panel.

21. Use the open end wrenches to tighten the cable nut until it bottoms in the connector body.

22. Check for mechanical serviceability by pulling firmly on the connector.

23. Check for electrical serviceability by making the following checks with the multimeter:

a. Measure zero resistance between the center pin on the connector and the center conductor at the opposite end of the cable.

b. Measure infinite resistance between the center pin and the outer case of the connector body.

24. When you are satisfied with your work, consult the instructor and have it inspected. The completed cable connection must meet the following requirements:

a. Good mechanical connection between the cable and body
b. Braid nut NOT CROSS THREADED.
c. Infinite resistance between inner and outer conductors.
d. Continuity between the center pin and the center conductor at the opposite end.

CONSULT YOUR INSTRUCTOR FOR THE PROGRESS CHECK.

Accepted ________

25. On completion of the progress check, clean up your work area.